

Computing Intensity Increments For Incremental Exercise Protocols

Robert A. Robergs, Ph.D., FASEP, EPC

Director: Exercise Physiology Laboratories, Exercise Science Program, Department of Health, Exercise and Sports Sciences, The University of New Mexico, Albuquerque, NM, USA. Phone: (505) 277-2658; FAX: (505) 277-9742; Email: rrobergs@unm.edu

Nutrition, Exercise and Sports Information Services (NEXSIS); www.NEXSIS.org

Overview

The program you purchased and are about to use is a LabVIEW program, or as referred to by LabVIEW users, a virtual instrument (VI). With this program you will be presented with several control variables from which you enter input. From these variables you can devise incremental protocols for treadmill walking or running, and cycle ergometry (either cadence independent or dependent).

LabVIEW programming is based on what are called the Front Panel and the Block Diagram. The Block Diagram is for the programmer for developing the program, and you will not see this programming. The Front Panel is essentially the user interface.

How to Use This Program

General Features

Figure 1 provides an image of the Front Panel for this program. This is how it appears prior to any selection of the mode-specific content bars identified as the red, yellow, light blue and light green rectangular icons. As you will read in the following material, selection of a mode-specific bar will reveal user interactive control variables in the box labeled "Mode Specific Controls". While these mode-specific controls are being used, results will be continually displayed and updated in the specific regions to the right.



Figure 0. A subject performing a treadmill incremental exercise test to $VO_2\max$. (Courtesy of Dr. Todd Astorino, Exercise Physiologist and Associate Professor, California State University-San Marcos)

The bottom panel of smaller rectangular icons can be used any time to access their clearly stated features. The specific features of these icons are explained below.

Universal Control Variables

Figure 2 presents the universal control variables for all exercise modes of the program.

Test Duration

I recommend using a test duration of 10 min for subjects. As you get more experienced with this program, you may want to decrease this down to 8 min for trained subjects with moderate to high cardiorespiratory and muscular endurance, as tests closer to 8 min are more conducive to inducing a true (highest) VO_2max for these subjects.

Stage Duration

Even though it is not yet common-place in exercise physiology to use short stage durations, I recommend that stage durations of 1 min or less be used rather than 2 or 3 min. Of course, using ramp functions for cycle ergometry protocols is preferable to 1 min or even 30 s stage durations. If you are developing a protocol for treadmill exercise, I would even argue that a 30 s stage duration is best as my work shows that shorter stage durations have less of an oxygen deficit with each new stage, which in turn means that the protocol induces a VO_2 response closer to estimated steady state VO_2 per stage. This in turn will make the protocol development closer in time to the anticipated protocol time. The end result is a more valid protocol for measuring VO_2max and/or other true maximal physiological responses.

Stage 1

For stage 1 I often use a duration at least twice the length of the remaining stages to allow added time to increase VO_2 closer to steady state. This is more important to do than you might think, for to keep protocol

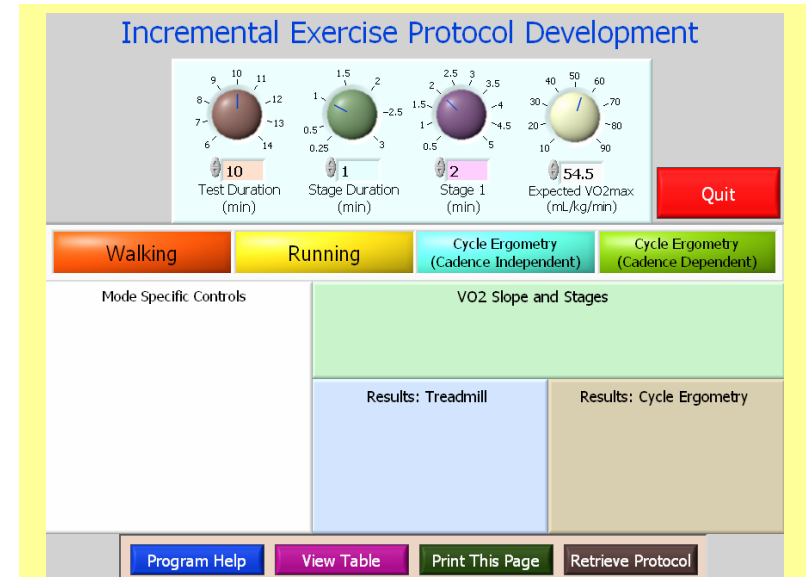


Figure 1. The front panel image of the program, revealing the main control icons prior to any feature selection.

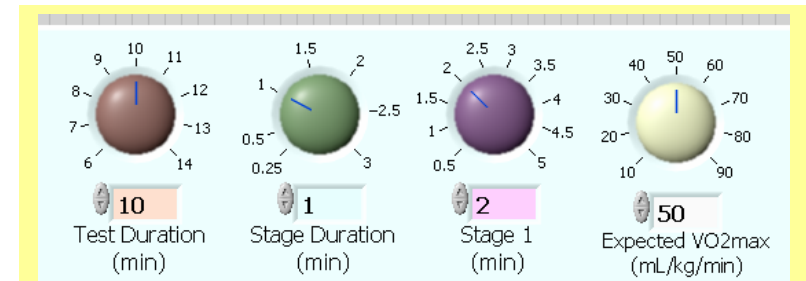


Figure 2. The universal control icons that apply to all exercise modes.

durations short and VO_2 demand increments per stage low, it is imperative to commence stage 1 at a higher intensity than you might be accustomed to do.

Expected VO_2max

Now this is the most important control variable to get right. However, this variable entry is estimated for most subjects, as you will only have a true VO_2max value if the subject was recently tested.

The reason why this estimate is important is that it largely determines the protocol VO_2 stage increment and total time. Any errors will change each of these two protocol features, and for the total time this would mean that an underestimation would prolong the protocol. A longer than desired protocol has potential to lower the measured VO_2max value, which as previously explained, is more concerning for moderate to highly endurance trained subjects. Protocol durations less than 8 min will also lower the VO_2max . You may choose to use one of the several non-exercise VO_2max estimation procedures for new subjects. I do not do this, as I find a few pertinent questions about training, recent race performance results, and perceived strengths and weaknesses gets me close to the true VO_2max .

If the subsequent test duration is < 8 min or > 11 min and the subject is a trained athlete, then I redo the test on another day if the test was part of research, or when it suits the client's schedule if it is a community test. For untrained subjects, I am less particular and aim somewhere between 10 and 14 min for the protocol duration.

An important question concerns when the protocol duration becomes too short or long. I think it comes down to two issues; the purpose (research vs. other) and the VO_2max value. I am more meticulous for research, and any test I do for VO_2max measurement for subjects with an expected $\text{VO}_2\text{max} > 50$ ml/kg/min, I need the protocol duration to be < 8 min and > 11 min. For less fit non-research subjects, I discuss the issue of protocol duration with them and offer to repeat the test if the duration exceeds 14 min.

Mode Specific Control Variables

Figure 3 presents the four mode-specific control bars, and the blank mode-specific added control box and results boxes. The content within the mode-specific control box is identical for walking and running protocols, but different for each cycle ergometry protocol. Thus, discussion of the walking mode-specific added control variables presented in Figure 4 also pertains to running protocols.

Walking and Running

Figure 4 presents the added control variables for walking protocols, which as stated previously, are identical to those of the running protocols option. However, the user needs to be aware that most subjects will transition between walking and jogging between 4 and 4.6 miles/hr (6.7 and 7.7 km/hr), so the treadmill speed should not increase beyond a value within this range, with the exact transition speed being very individual specific.

In this example, and when assessing the universal control variable settings of Figure 2, I couldn't keep these settings as the VO_2 max value was too high to conduct a walking protocol. Note the unrealistically high top treadmill speed of 13 mi/hr! Consequently, I reset the universal control values as shown in Figure 5, with the only change being that I decreased VO_2 max from 50 to 30 mL/kg/min. To keep the maximal treadmill speed to a realistic walking pace, I had to decrease the time of the protocol that only had a speed increment to 3 min (Speed Duration), and the start speed to 3.5 mi/hr. Alternatively, if desiring to use a walking protocol on a subject that has this anticipated value for VO_2 max, you would need to constrain the speed component of the protocol to a short duration so that %grade induced almost all of the intensity increment.

When looking at the results, these protocol conditions produced a walking protocol that has 9 stages and an average VO_2 -time slope of 2.14 ml/kg/min. The protocol started at 3.5 mi/hr for 2 min, and then increased by

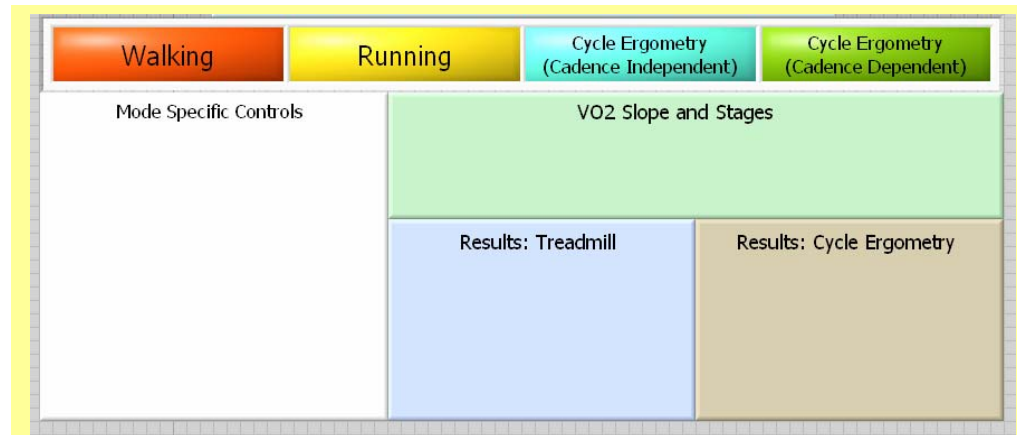


Figure 3. The icons for mode selection prior to any icon activation.

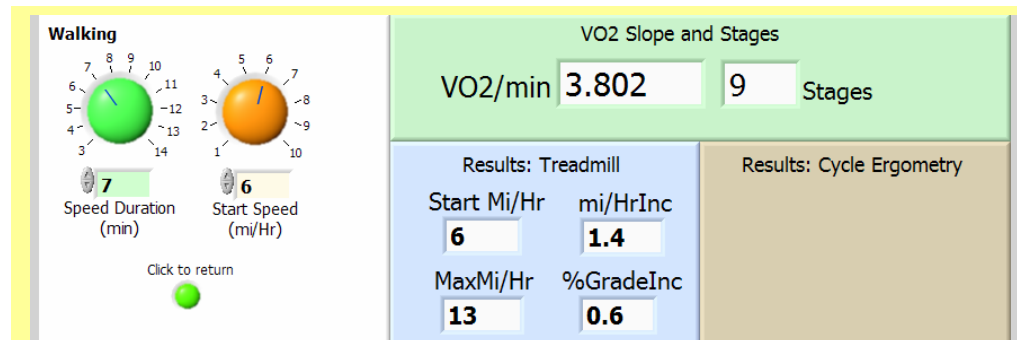


Figure 4. When the user selects “Walking”, the added controls for “Walking” protocol development appear. As explained in the text, these controls are the same for “Running” protocols. Results automatically appear in the right colored regions of the display.

0.81 mi/hr until min 3. Thereafter, treadmill %grade increased 1% each min for the remaining 7 min, which should induce voluntary exhaustion at test termination. However, if the subject was still able to exercise, 1% grade increments would continue each min until fatigue.

At the end of the protocol development routine, the user clicks on the “Click to return” button the make the four exercise mode bars reappear. Added protocol development could then occur with the same or another exercise mode. Clicking the “Quit” icon ends the program.

Cycle Ergometry

While most cycle ergometers used in exercise physiology laboratories today are electronic, have cadence independent capabilities and allow for ramp functions, there is still a need to know what will be a suitable protocol Watts-time ramp increment to end the test within 8 to 10 min. This program can help with this by revealing the Watts/min ramp function needed.

Cadence Independent

Figure 6 shows the universal control and mode-specific added controls and results for cadence independent cycle ergometry. This data is for a male of 78 kg and an expected VO_2max of 65 mL/kg/min. I would not accept this protocol, as the Watts/min increment and subsequent $\text{VO}_2\text{/min}$ slope function are too high at 52 Watts/min and 6.575 mL/kg/min/min, respectively. When dealing with trained individuals, there is really no need to start a protocol at a low intensity. To do this increases the intensity range of the protocol, which as revealed in this example, results in a large Watts increment per stage. This decreases the time sensitivity for detecting threshold changes in metabolism, and the likelihood for a VO_2 plateau at the end of the test.

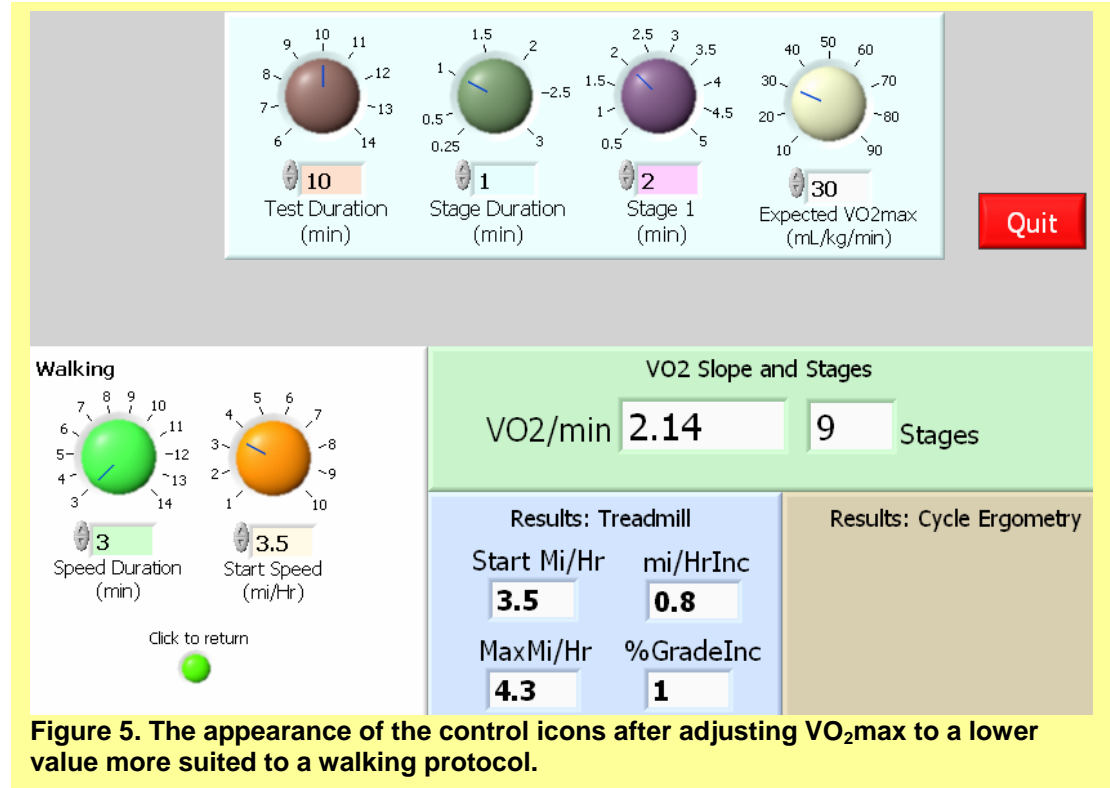


Figure 5. The appearance of the control icons after adjusting VO_2max to a lower value more suited to a walking protocol.

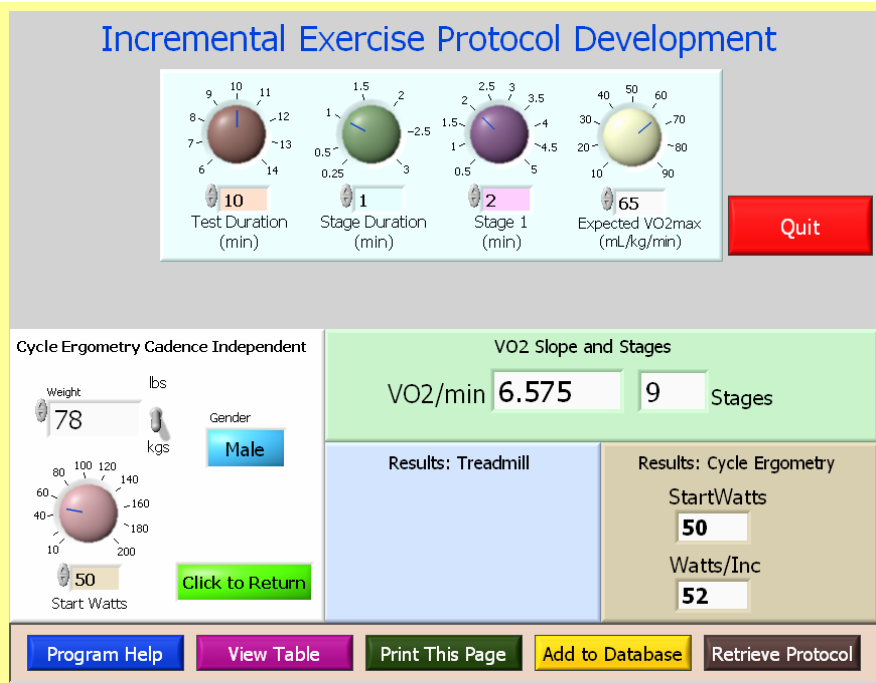


Figure 6. The universal and mode specific controls for cadence independent cycle ergometry.

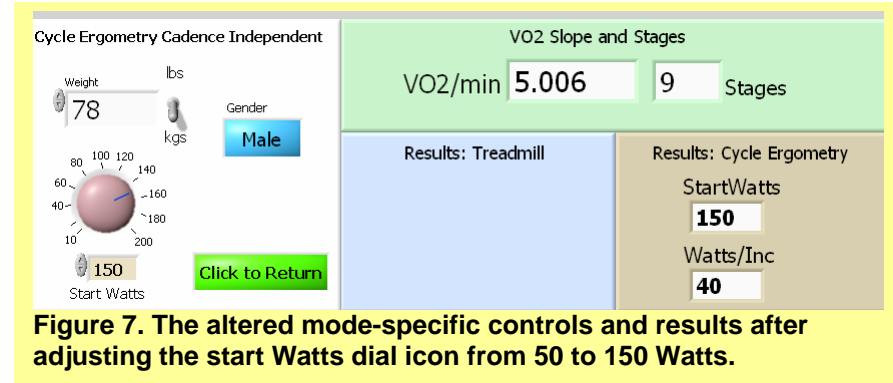


Figure 7. The altered mode-specific controls and results after adjusting the start Watts dial icon from 50 to 150 Watts.

Figure 7 presents the altered control variables for this subject and the revised protocol results. I simply increased the start Watts from 50 to 150 Watts, which lowered the Watts/min increment from 52 to 40, and decreased the VO₂/min slope function from 6.575 to 5.066 mL/kg/min/min. Although I have no experimental data to verify this yet, I like to keep the VO₂ slope number < 5 mL/kg/min/min to prevent excessive and rapid fatigue during the non-steady state phase of the protocol. This requirement also makes the subject more likely to be close to a steady state VO₂ for each stage, which in turn makes the time estimation for the protocol more valid.

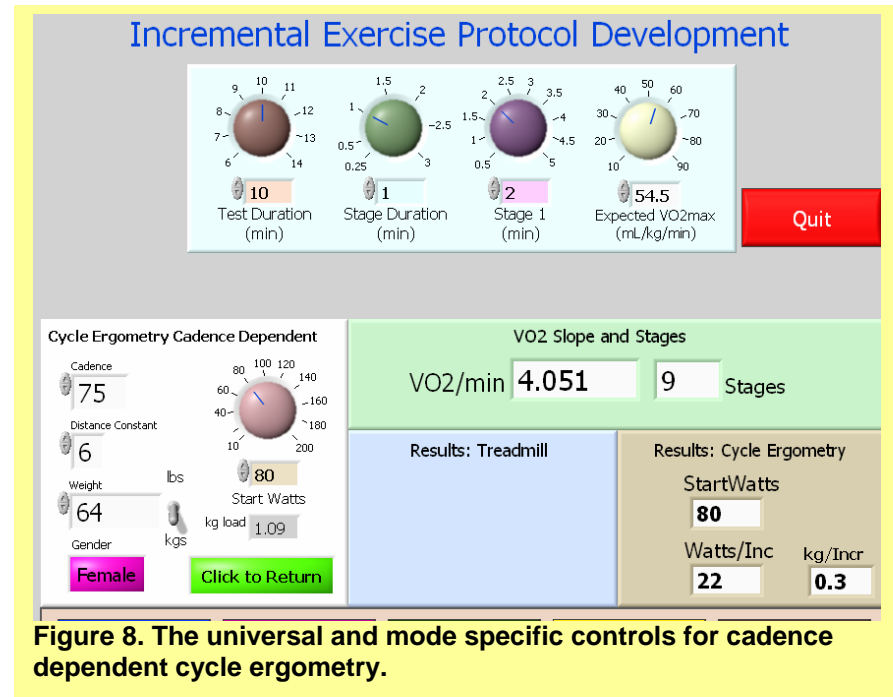


Figure 8. The universal and mode specific controls for cadence dependent cycle ergometry.

Cadence Dependent

Figure 8 shows the universal control and mode-specific added controls and results for cadence dependent cycle ergometry. This data is for a female of 64 kg and an expected VO_2max of 54.5 mL/kg/min. The protocol requires a cadence of 75 rev/min, and an initial kg load of approximately 1.09 kg equating to 80 Watts. The protocol requires an initial 2 min at 80 Watts, followed by 0.3 kg increments (22 Watts) in load every 1 min to fatigue.

Bottom Icon Features

The bottom icon features as revealed in Figure 9 provide links to “Program Help”, “View Table”, “Print This Page” and “Retrieve Protocol”.

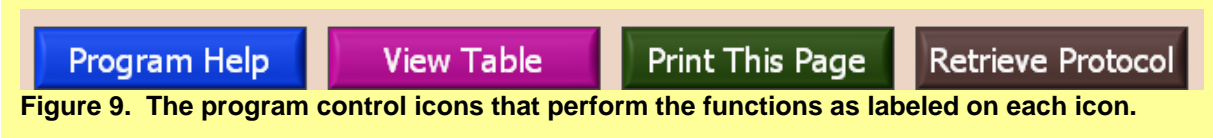


Figure 9. The program control icons that perform the functions as labeled on each icon.

Program Help

Allows you to interactively view figures and read the explanations of the program, as you are doing now.

View Table

Figure 10 provides an image of a protocol table that is produced in a new window when you use this link. You can either print this protocol table, or add it to the database.

Print

Use the “Print” icon to print this table (see below), or add this protocol to the database (see below).

Add to Database

This option is for you if you want to save some or all of your protocols. This is a good idea so that you can retrieve past protocols for a given subject, or to get a place to start for a new subject based on past protocols you have used for a similar subject. This feature is automatic and does not produce a new window. You will be prompted to replace the old array with this new one that has been updated by one new entry. Click “Replace” for this. If you click “Cancel”, a program default “Error” dialogue box will appear. Click

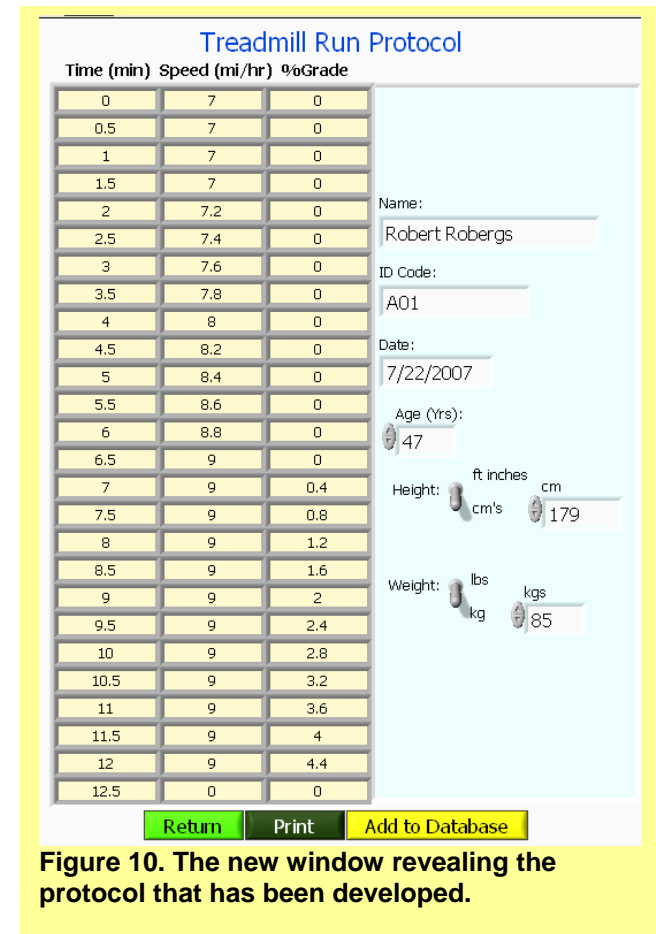


Figure 10. The new window revealing the protocol that has been developed.

‘Continue’ to get back to the base program, or “Stop” to end the program.

Print This Page

This will automatically print a 1 page image of the panel to your default printer.

Retrieve Protocol

This option allows you to get a prior protocol saved to the database. This might be helpful to develop a new protocol for another subject of similar fitness, or another test on the same subject.

Figure 11 presents the control and display features for retrieving a protocol from the database. You can search the database by Name, ID Code, Date and protocol mode. The example of Figure 11 reveals the Name selection. The contents of this initial table reveal all header names for the saved variables. Toggle the row and column increment markers to scroll through the table. Note that protocols differ in their header and data content once the data variables (after demographic data) are revealed. Note the codes used for the protocol types and genders.

Figure 11. The control and display features of the “Retrieve Protocol” selection. See Figure 12 for the added features.

Figure 12 shows the protocol mode search selection, for which the run protocol was selected. After the “Start” icon is clicked, a second table appears containing all protocols in the database that adhere to the selection criteria. The pertinent data are saved, and then protocols are re-computed by selecting the row that contains the protocol you want to retrieve, and then clicking the “Get Protocol” button. Either write down the key features of the protocol, or print the protocol table, and use this information to devise a new protocol, or repeat this protocol by going back to the initial front panel display (Figure 1).

Retrieve Protocol

Search
Protocol Mode
Start

Protocol Mode

Run

Go

Row Header Codes

0	Headers	Gender Codes						
0		Male=0	Female=1					
0	Mode Codes							
	CECI = 1	Mode Code	Date	Name	ID Code	Age yrs	Ht inches	Ht cm
	CECD = 2	Mode Code	Date	Name	ID Code	Age yrs	Ht inches	Ht cm
	Run = 3	Mode Code	Date	Name	ID Code	Age yrs	Ht inches	Ht cm
	Walk = 4	Mode Code	Date	Name	ID Code	Age yrs	Ht inches	Ht cm

Row Procotols

0		3	7/22/2007	Robert Robergs	A01	47	69.8	179
0		3	7/22/2007	Robert Robergs	A01	47	69.8	179
0								
0								
0								

Select Protocol Row

0

Get Protocol

Go

Return

Figure 12. The added display features after protocols adhering to selection criteria are retrieved.