

Experiment EP-1: Cardiac Recovery after Exercise

Background

During exercise, there is an increased demand for oxygen in muscles and an increased need to move carbon dioxide away from those muscles. People with higher levels of physical fitness usually have higher stroke volumes and can deliver more oxygen in a single cardiac cycle than people with lower levels of fitness. More fit persons can usually sustain a greater work level before reaching maximum heart rate. Less fit subjects of the same age and gender will reach about the same maximum heart rate, in a shorter period of time; and, they are usually unable to sustain the same level of work. However, the time from resting to maximum heart rate is not a good indicator of fitness; this time is a reflection of the effort put into exercise by the subject.

As soon as exercise stops and the demand for oxygen and the transport of carbon dioxide decreases, heart rate decreases. The heart rate of a more fit person usually returns to the resting rate more quickly than it does in a less fit subject. Recovery rate, which is the drop in heart rate between the end of exercise and the 1-minute mark of the recovery period, is an excellent measure of fitness. Studies have shown that a drop of 50 beats in the first minute indicates excellent fitness, and a drop of less than 30 beats in the first minute indicates poor fitness. The time to recover to the resting level is also a good indicator of fitness, though less used than recovery rate. More fit subjects take shorter times to reach complete recovery.

Cardiorespiratory fitness levels can be determined through many types of aerobic assessment: the 2-minute, positional step test; the 3-minute step test; the 1-mile walk test; and more. In this experiment, the heart rates of human subjects will be measured as they recover from a three minute period of stepping. The heart rate at a minute into recovery, and the time it takes the subject's heart rate to return to the resting level, will be used as measures of the subject's level of the physical fitness.

Equipment Required

PC or Macintosh computer

IX-ELVIS

USB cable

Power supply

PTN-104 Pulse plethysmograph

Step (30cm (12in) in height)

Metronome (electronic or mechanical)

Stopwatch

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.
2. Connect the IX-ELVIS to the computer with the supplied USB cable.
3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.
2. On the Main window, pull down the Settings menu and select Load Group.
3. Locate the folder that contains the settings group, ELVISNI.iwxgrp. Select this group and click Open.
4. Pull down the Settings menu again. Select the CardiacRecovery-Exercise-LS2 settings file.
5. After a short time, LabScribe will appear on the computer screen as configured by the CardiacRecovery-Exercise-LS2 settings.
6. The settings used to configure the LabScribe software and the IX-ELVIS for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

Pulse Sensor Setup

1. Locate the PTN-104 pulse plethysmograph ([Figure EP-1-S1](#)).
2. Plug the mini-DIN connector to the PT-104 into the Channel 3 input of the IX-ELVIS ([Figure EP-1-S2](#)).



Figure EP-1-S1: The PTN-104 pulse plethysmograph.

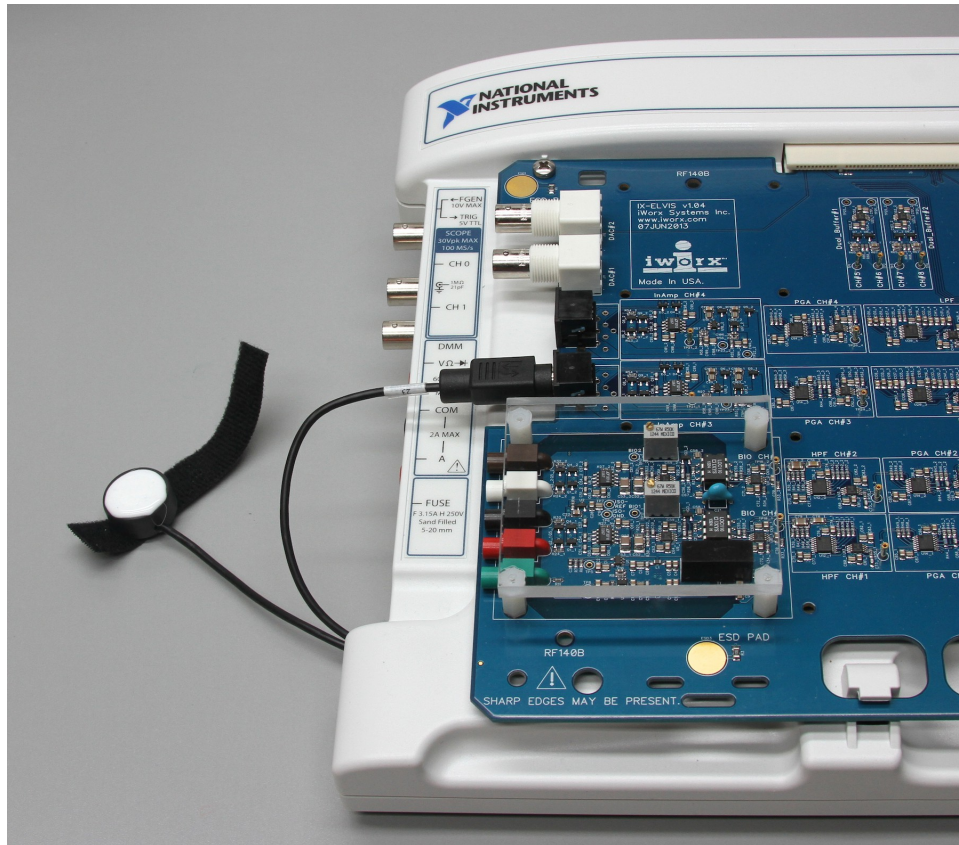


Figure EP-1-S2: The PTN-104 pulse plethysmograph connected to an IX-ELVIS.

3. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of the subject's middle finger or thumb, and wrap the Velcro strap around the end of the finger to attach the unit firmly in place.

Preparation before Exercise Begins

1. Each subject will perform a three minute period of stepping. There will be a 5-minute rest period before the three minute exercise period, and a recovery period after stepping that will be as long as it takes the subject's heart rate to return to the resting value. Lab partners should keep time for the rest, exercise, and recovery periods.

Warning: *The Step Test should not be attempted by individuals with a very poor level of physical fitness, or individuals taking a beta blocker medication or any medication affecting heart rate.*

2. The step rate will be 24 steps per minute.
3. Each step is a four-beat cadence, so the metronome will be set to 96 beats per minute.
4. The movements for each of the four beats in a step are:
 - 1st beat: Right foot up on step.
 - 2nd beat: Use the right leg to lift body, and place left foot on step
 - 3rd beat: Lower the right foot to the ground.

- 4th beat: Lower the left foot to the ground.
5. It is important to secure the step against the side of a lab bench or up against a wall to prevent it from slipping from under the feet of the subject.

Exercise 1: Heart Rate at Rest

Aim: To measure the heart rate of a resting subject.

Procedure

1. Instruct the subject to sit quietly and rest with his or her hands in the lap for five minutes.
2. Type “<Subject’s Name> Sitting at Rest” in the Mark box that is to the right of the Mark button.
3. At the end of the five minute rest period, click on the Record button, located on the upper right side of the LabScribe Main window. The signal should begin scrolling across the screen.

Note: If the user clicks the Record button and there is no communication between the IX-ELVIS and computer, an error window will appear in the center of the Main window. Make sure the IX-ELVIS is turned on and connected to the USB port of the computer. Click OK and select the Find Hardware function from the LabScribe Tools menu.

4. Click on the AutoScale buttons at the upper margins of the Pulse and Heart Rate channels. The pulse signals and heart rate histogram should expand to fill the channel windows ([Figure EP-1-L1](#)).
 - If the signal on the Pulse channel is upside down when compared to trace in figure, click on the downward arrow to the left of the channel title and select the Invert function. the trace should now look similar to the one in the figure.
 - If the pulse signal is small or noisy, adjust the tension on the strap holding the pulse plethysmograph to the finger.
5. Record the subject’s resting heart rate for one minute. Then, click Stop to halt the recording.
6. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file. Designate the file type as *.iwxdata. Click on the Save button to save the data file.
7. Remove the pulse plethysmograph from the subject’s finger.

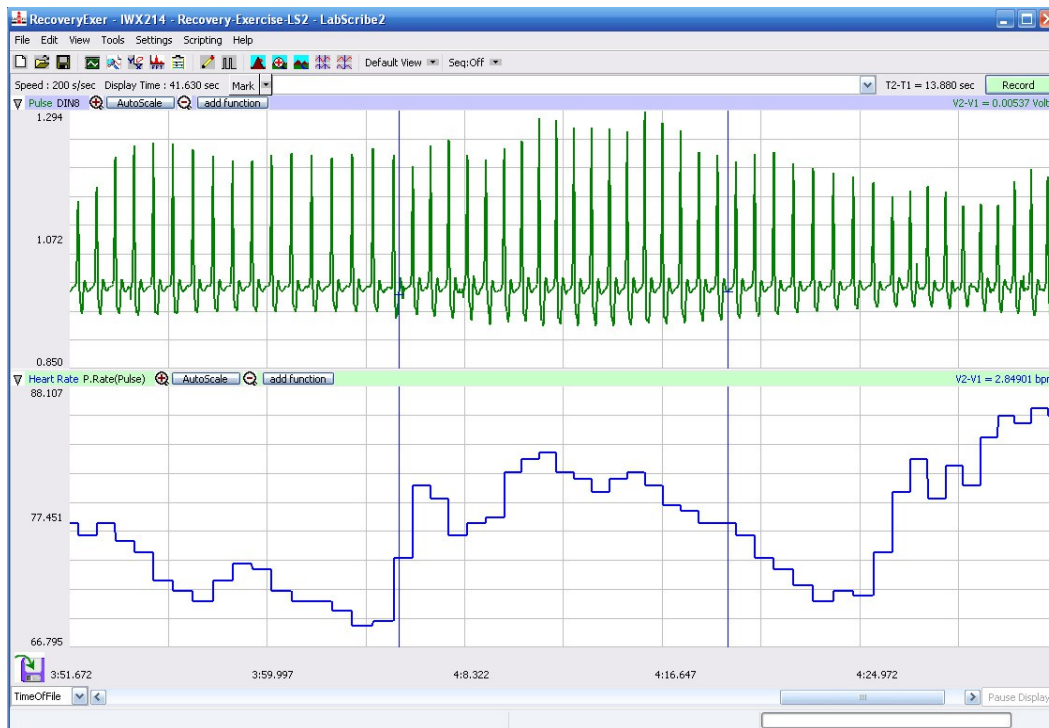


Figure EP-1-L1: Pulse and heart rate from a resting subject displayed in the Main window.

Data Analysis

1. Scroll to the beginning of the recording of the subject's heart rate while at rest. Display a ten second section of data that is free of artifacts in the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show ten seconds of data on the Main window. The ten second section of data can also be selected by:
 - Placing the cursors on either side of the ten seconds of data; and
 - Clicking the Zoom between Cursors button on the LabScribe toolbar ([Figure EP-1-L2](#)) to expand the ten seconds of data to the width of the Main window.

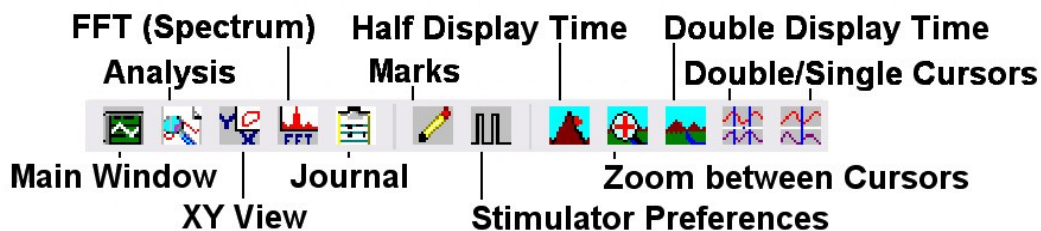


Figure EP-1-L2: The LabScribe toolbar.

3. Click on the Analysis window icon in the toolbar ([Figure EP-1-L2](#)) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window ([Figure EP-1-L3](#)).
4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical function, Mean, should appear in this table. The value for the mean heart rate should appear across the top margin of the Heart Rate channel.

5. Place a cursor near the beginning of the data displayed on the Analysis window, and place the other cursor near the end of the data displayed on the window. The cursors are in the correct positions for determining the mean resting heart rate of the subject from the ten seconds of data on the window.
6. Record the mean resting heart rate of the subject in the on-line notebook of LabScribe by typing the name and value of the parameter directly into the Journal. You can open and close the Journal by clicking on its icon on the LabScribe toolbar ([Figure EP-1-L2](#)).

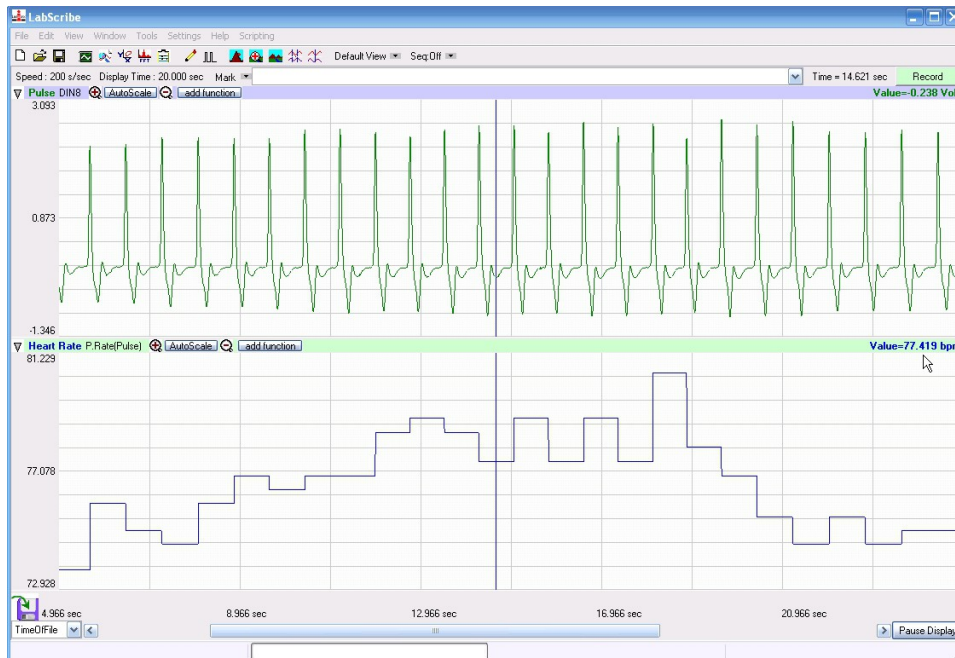


Figure EP-1-L3: Pulse and heart rate from a resting subject displayed in the Analysis window.

7. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of parameters from the recording to the Journal. To use these functions:
 - Transfer the names of the mathematical functions used to determine the volumes and rates to the Journal using the Add Title to Journal function in the Heart Rate Channel pull-down menu.
 - Transfer the values for the volumes and rates to the Journal using the Add All Data to Journal function in the Heart Rate Channel pull-down menu.
8. Record the mean resting heart rate for in [Table EP-1-L4](#).

Exercise 2: Heart Rate During Recovery

Aim: To measure the changes in the heart rate of the subject while he or she recovers from exercise.

Procedure

1. After the subject's resting heart rate is recorded, the subject should stand in front of the step and await the signal of the timekeeper.
2. Once the timekeeper calls "Start!", the subject should begin stepping at the rate of 24

steps/minute for 3 minutes.

3. While the subjects are stepping, the lab partners can enter pertinent data into the Journal.
4. Thirty seconds before the end of the stepping exercise, the timekeeper should alert the subject and other lab partners to be ready attach the pulse plethysmograph. Type “Recovery from Exercise” in the Mark box that is to the right of the Mark button.
5. The timekeeper should give the subjects and the lab partners a 10 second countdown before calling “Stop!”. At the end of the 3-minute stepping exercise, each subject should immediately sit in a chair and attach the pulse plethysmograph to the same finger with about the same tension used earlier.
6. As soon as the subject is seated and the pulse plethysmograph is in place, click on the Record button. Click on the AutoScale buttons on both channels.
7. Continue to record the subject’s pulse until his or her heart rate returns to the resting level. Click on the Stop button.
8. Select Save in the File menu.

Data Analysis

1. Scroll to the beginning of the recording of the subject’s heart rate during the recovery period. Display a ten second section of data that is free of artifacts in the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show ten seconds of data on the Main window. The ten second section of data can also be selected by:
 - Placing the cursors on either side of the ten seconds of data; and
 - Clicking the Zoom between Cursors button on the LabScribe toolbar ([Figure EP-1-L2](#)) to expand the ten seconds of data to the width of the Main window.
3. Click on the Analysis window icon in the toolbar ([Figure EP-1-L2](#)) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window.
4. Position a cursor on either side of the five pulses on the Pulse channel. The value for Mean in the table across the upper margin of the Heart Rate channel is the subject’s mean heart rate at the start of the recovery period.
5. Record this value in the Journal using one of the two techniques described in Exercise 1. Enter the value for this mean heart rate in [Table EP-1-L3](#).
6. Use the same techniques described earlier to measure the mean heart rate at one minute intervals from the beginning of the recovery period. Record these values in the Journal and on [Table EP-1-L3](#).

Fitness Ratings

1. For each subject, use the measurements made in the Data Analysis section to fill in [Table EP-1-L3](#).
2. From the data in [Table EP-1-L3](#), determine:
 - The difference between the subject’s resting and maximum heart rates.
 - The difference between the subject’s maximum and one-minute recovery heart rates.

- The time for the subject to recover from maximum heart rate to a heart rate equal to the resting rate.
3. Compare the subject's one minute recovery heart rate to the first table of fitness ratings ([Table EP-1-L1](#)).
 4. Compare the subject's time to recover to his or her resting heart rate to the ratings in a second fitness table ([Table EP-1-L2](#)).
 5. Enter measurements and ratings into the Journal by typing them directly into the Journal window.

Table EP-1-L1: Fitness Rating based on Heart Rate at 1-Minute into Recovery after a 3-Minute Aerobic Step Test.

Fitness Rating	Gender	Heart Rate (BPM)
Excellent	Male	<71
	Female	<97
Good	Male	71-102
	Female	97-127
Fair	Male	103-117
	Female	128-142
Poor	Male	118-147
	Female	143-171
Very Poor	Male	148+
	Female	172+

Table EP-1-L2: Fitness Rating based on the Time to Recover to Resting Heart Rate.

Time to Recover to Resting Heart Rate	Rating
0-30 secs	Excellent
31-60 secs	Good
61-90 secs	Fair
91-120 secs	Poor
121+ secs	Very Poor

Questions

1. How does the difference between the resting and maximum heart rate of a subject relate to his or her fitness?
2. How do the resting and maximum heart rates of all the subjects compare? Do the subjects' levels of fitness correlate to the resting heart rates, the maximum heart rates, and/or the differences between the two heart rates?
3. How does the difference between the maximum and recovery heart rate of a subject relate to his or her fitness?
4. How do the maximum and recovery heart rates of all the subjects compare? Do the subjects' levels of fitness correlate to the maximum heart rates, the recovery heart rates, and/or the differences between the two heart rates?
5. How does the time taken to recover to resting heart rate relate to the fitness of each subject? How do the times to recovery for all the subjects compare?
6. How do the two techniques of determining fitness (one minute recovery and time to recovery) compare to each other? Are they consistent?
7. Do you agree with the fitness ratings obtained from this experiment? Explain.
8. Examine the data of a fit subject. Predict what his or her maximum heart rate might be, if he or she exercised for five minutes instead of three minutes.
9. Examine the data from a less fit subject. Predict what his or her maximum heart rate might be, if he or she exercised for five minutes instead of three minutes.

Table EP-1-L3: Heart Rates at 1-Minute Intervals into Recovery

	Rest	Max										
Time (mins)		0	1	2	3	4	5	6	7	8	9	10
HR (BPM)												