How to use 1-lead ECG recorders to obtain 12-lead resting ECGs and exercise ("stress") ECGs

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Introduction

Although 1-lead ECG (EKG) recorders are normally used primarily for basic heart monitoring, checking for various arrhythmias, or simple educational or research purposes, they can also be used for looking at the effects of exercise on the ECG. One-lead recorders can also be used to accomplish full 12-lead recordings in a sequential manner.

New, low-priced, 1-lead handheld ECG recorders have become available for personal, home, and sports use, much as with home blood-pressure/pulse recorders or glucose testers for diabetics. They also are suitable in some emergency situations but only when used by medical or emergency personnel. Otherwise, they can be used by the general public for personal recording of information, such as for baseline information, routine monitoring, or during uncommon events, like with cardiac event recorders. The recordings can then be shown to the person's cardiologist or electrophysiologist or, for non-emergency or simple monitoring purposes, used by the person himself or herself if he or she is able to interpret them. (ECGs are complex and have a fairly steep learning curve. For a basic introduction, click here.)

One-lead ECG recorders may also be used for monitoring the heart in association with regular exercise, workouts, and sports activities. The actual recordings need to be done while the body is not moving, to avoid artifacts from the muscles. However, "resting" measurements can nonetheless be done during exercise and while the heart is responding to the exercise by briefly interrupting the activity long enough to obtain a recording or immediately after finishing the activity. Recordings can also be made while resting during the recovery period following exercise. The use of any ECG recorder for exercise, however, is somewhat akin to stress tests done in a clinic or hospital under medical supervision and should not be done at home if cardiac problems are suspected or might occur or if clear emergency or urgent situations exist (see disclaimer section below). Please consult a cardiologist if in doubt.

The purpose of this article is to explain how to use 1-lead (2 to 3 electrode contact) recorders in both exercise and 12-lead contexts. When using the recorder for exercise purposes, one might want to focus on a particular lead of the various 12 that are available, such as lead II or one of the chest leads (V1-V6). Thus, I will explain how to obtain the different 12 leads first and then one can choose which of them to use for measuring the ECG during exercise.

Important disclaimer: This information is provided for educational, sports-associated (by healthy persons), research, and non-emergency monitoring use only, not diagnostic or emergency uses by untrained persons. In the event of an emergency or suspected-emergency situation, appropriate medical help and facilities should be sought as quickly as possible. The only time that personal ECG recorders should be even considered in urgent, emergency situations would be if problems were to occur in remote locations to obtain useful information and/or while waiting for transportation and help, that is, when the use of the recorders would not delay possible help and might permit the collection of useful information for later use.
**Source of 1-lead ECG recorders:** The descriptions and information in this web page are based on handheld recorders from Favoriteplus.com, a medical equipment division of Favorite Imports LLC and a worldwide distributor of pulse oximeters, handheld ECG-EKG, & fetal dopplers. They are "an international distributor and global provider of medical devices for the hospital, emergency, home and specialist environments. Established in 1998, ... grown to be one of the most reliable worldwide distributors of new and innovative health products, medical devices and accessories." They have three models of handheld ECG recorders currently available, the FP-RMH, FP-ICH, and FP180 (PC-80). For further company information about the units and ordering, [click here](#). For general comparisons and a review that I conducted of the three units, [click here](#). I thank Favoriteplus for providing two of these recorders to me for purposes of comparison.

The following figure shows the three 1-lead handheld recorders used for this article, from left to right: ReadMyHeart (FP-RMH, hereafter referred to as RMH), InstantCheck (FP-ICH, referred as IC in the remainder of the article) and PC-80 (FP180). Top row closed, bottom row open.

![Three handheld ECG recorders](image)

All three of these can be used with thumb and hand electrode contacts with simple touch, without adhesive electrodes attached to the skin. However, they also have cables with snap ends so adhesive electrodes can be used if desired. The cables and adhesive electrodes are much less vulnerable to artifacts and variability, provide much cleaner and more stable ECG recordings, and are highly recommended. Compared to a normal 12-lead ECG system which uses 10 wires (four on the legs and arms and six on the chest), the two or three electrodes used with these handheld units are much simpler and not a hassle. The cables and adhesive snap electrodes were used in all of the recordings done for this article.

The next figure shows an example of a standard 12-lead resting ECG printout. If you are not already familiar with resting 12-lead ECG recording and would like a basic introduction, [click here](#). The example in the figure was produced with a Nasiff 12-lead PC-based system. (For a link to the Nasiff company, [click here](#).) For additional 12-lead comparisons in this article, as another example of a standard 12-lead system, I also used a CardioPerfect recorder, the systems of which are currently available from Welch Allyn.
Procedures for obtaining **12-lead recordings** with 1-lead recorders

For connecting to the skin surface at the various locations for the different leads, it is best (or even necessary) to use the electrode cables and adhesive electrodes. Even though it's possible to run some of the leads using the thumb/hand contacts on these handheld units, much better results are achieved with the cables and adhesive electrodes. RMH and IC have only two wires. PC-80 uses three, including a ground (on the right leg).

The three recorders with cables are shown below, along with a sample of the adhesive electrodes.
To determine which wire should be designated as negative and which as positive, the standard for negative is the right arm and the positive is the left arm. In the case of RMH and IC, the red (RA) is negative and the blue (LA) is positive. For the PC-80, the markings on the contact ends are confusing. After trial and error, I discovered the white end ("RA") to be negative, as expected, but the black ("LA") end is the ground and the red end ("LL") is the positive. In all cases, I recommend using a marking pen to mark the -'s and +'s on the contact ends as appropriate (except the black for the PC-80 which can be considered the ground).

All three recorders were used to obtain 12-lead recordings. The RMH unit, with only two wires, is used to illustrate the procedures, below. The IC unit would be connected as shown for the RMH. For the PC-80, which has three wires, the ground would be attached to the right leg and the remaining neg and pos wires would be attached as with the two wires of the other units.

Photos below:

(Note: Resting ECGs are normally made on subjects in a horizontal, reclined position, not sitting up. For demonstration and learning situations, however, sitting quietly also usually works well. ECG results are virtually the same for many people whether they are reclining or sitting, whereas they will be different for other individuals.)

**Left picture** -- RMH being used with the electrodes as recommended for the cable, with red on the right and blue on the left. This amounts to a **standard Lead I**.

**Middle picture** -- Adhesive electrodes positioned on the body for obtaining 12-lead recordings, with either a standard 12-lead system (as in the right photo) or with 1-lead systems, as in the subsequent photos.

**Right picture** -- Running a standard 12-lead recording using the Nasiff recorder, with all of the electrode contacts connected simultaneously.
To obtain the remaining leads, the negative and positive recorder wires of a 1-lead system can be sequentially moved to the different electrode positions on the body, as demonstrated in the next series of photos.

**Lead II** (left photo) with the negative on the RA and the positive on the LL.

**Lead III** (right photo) with the negative moved to the LA.

The augmented leads (aVR, aVL, and aVF) require an additional step. The negative connection for the augmented leads is combined for two of the limb leads rather than one. To accomplish that, a wire is needed to connect between two of the electrodes.

The connecting wire can be constructed simply by using a length of wire, two alligator clips, and a small connector that the recorder's negative contact can snap onto. Strip the insulation from both ends of the wire and at a short section half way between the ends of the wire (see arrow in the photo below). Bend the wire where exposed in the middle so it projects outward; push it into the connector; and solder in place. (Alternatively, one could take two wires of equal length, expose both ends of each, and twist an end of each together to form the middle section.) Then solder the alligator clips onto the remaining ends. The finished connecting wire is shown on the right side of the picture below.
For **Lead aVR** (left photo below), the connecting wire is clipped to the electrodes on the left arm and left leg, negative wire is attached to the connector in the middle of the connecting wire (shown held in the left hand in the picture), and the positive wire is attached to the electrode on the right arm. **Lead aVL** (not pictured) is similar to aVR except that the arm connections are switched, that is, the connecting wire for the negative end is moved to the right arm and the positive end moved to the left arm.

**Lead aVF** (right photo) is obtained by attaching the alligator clips and negative recorder wire to the two arm electrodes and the positive wire to the LL.

**Leads V1 through V6**, the chest leads, use the negative wire connected to the right leg and the positive placed at the appropriate chest electrodes. Note: the limb leads can be placed essentially anywhere on the limb, as long as they are at least 4 inches (10 cm) from the heart. Because the wires for the RMH (and IC) are not long enough to reach between the lower leg (the traditional position for the leg electrodes) and the chest, the right leg electrode was moved to the upper leg, as can be seen in the photos below.

Examples: V1 connections are shown in left photo, V3 in the right photo. (For the PC-80, which has three wires, leave the ground on the RL, the neg on the RA, and move the pos to the various V positions.)
RESULTS: The outputs from each of the systems were uploaded to a computer for analysis, display, and printing. The tracings for the following figures were all taken from the computer screen monitor for each system. (The computer screen backgrounds, grid, and line colors are different from their respective hardcopy printouts.) The two standard 12-lead traces are shown in the two left columns, with the three 1-lead handheld outcomes shown in the three right columns.

The resulting ECG traces are similar and consistent for all five systems, except that the PC-80 seems to accentuate the QRS component and often shows the P and T waves differently, particularly in amplitude, than in the standard 12-lead systems or the other two 1-lead systems. For 12-lead purposes, the PC-80 works but not as well as the other two 1-lead systems.

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<th>Instant Check</th>
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Printouts can be obtained from each of the systems, with the full 12-lead systems producing the standard printout (see example at the start of this article). The 1-lead systems obviously display and print only one lead at a time. To see all 12 leads, you can either simply have a collection of all of the printouts, or else cut/copy-paste a segment from each lead into one page. Below is an example of one that I assembled for a set of RMH outputs.
Procedures for obtaining exercise ECG recordings with 1-lead recorders

Using 1-lead ECG recorders for exercise ("stress") purposes is relatively simple and straightforward. The only requirement is that when actually recording, the subject must not be moving or else the
body muscles will create a lot of artifact and background noise. Thus, to record ECGs during the exercise, one must stop briefly, long enough to make a recording, and then resume the activity. Similarly, at the end of the activity one can record immediately following the activity. To do the recording with a minimum of stopped time during exercise, keep the electrodes connected and be ready to press the buttons to start the recording. In the case of the InstantCheck unit, you can monitor the output for an extended period and it saves the last 30 seconds, so you can have it running during actual exercise (and getting lots of artifact and noise) and then simply stop and stand still for 30 seconds, at which point you can stop the recording and it will save that 30 seconds.

**Example:**

I used the InstantCheck recorder set up for lead II and, at the same time, put on a Holter ECG unit (which is used for extended ECG recording during activity). (The Holter system subtracts out the muscle noise with complex computer functions and a different placement of electrodes, using outputs that are referred to as "channels" rather than "leads"). I recorded a period of rest prior to exercise, exercised for 25 minutes (including 5 minute warm up and cool down periods) on a stationary bicycle, then continued recording ECGs while subsequently resting.

For comparison, I also looked at the output from an earlier clinical stress test, performed in a clinic/hospital setting with standard 12-lead stress-testing equipment on a treadmill, with nurse technicians running the equipment, monitors, and recording, plus a cardiologist supervising.

Here is a sample of the printed output from the clinic results for two of the 12 leads while at a comparable heart rate (133-136 BPM) followed by samples of the printouts for the Holter and 1-lead recorders. For all practical purposes, the outcomes are all the same, demonstrating that 1-lead systems can be used to produce good exercise/stress-test results.

Finally, here is a sample from the full sequence for the 1-lead system, from resting prior to the workout, a sample taken in the middle of the exercise (by stopping briefly to obtain the recording), and two samples during the recovery period.
Comments and Conclusions

Single-lead ECG systems not only work, but they work remarkably well for conducting both 12-lead and exercise ECGs. It must be noted, however, that the 12-lead results from 1-lead systems are sequential, not simultaneous as are the ones recorded with most standard 12-lead systems. Similarly, exercise recordings cannot be done continuously during the actual activity as with Holter units or standard stress-testing equipment. Instead, quick recordings must be made during brief interruptions of the activity, while the heart is still responding to the activity.

Of the three 1-lead handheld systems discussed in this article, the PC-80 produced the least satisfactory 12-lead outcomes. It does, however, detect beats against other muscle noise better than the other two during actual activity. Trying to make recordings during active movement, nonetheless, is noisy and messy with these simple systems regardless of which of the three is used. The PC-80 appears most suitable for its intended purpose of being able to quickly record arrhythmias (see the comparative review of these three 1-lead recorders).

If one is really serious (and has the equipment, or finances to obtain full, standard 12-lead or Holter equipment), the standard equipment still produces better results and the kinds of outputs that cardiologists and electrophysiologists are more accustomed to reading. Nonetheless, particularly for persons on a limited budget, wanting a simple home personal system, or wanting something very portable and handy, including for traveling, the small, handheld, 1-lead systems will do the job.

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