Comparison of a Derived ECG from a CardioWare Harness to a Standard 12-Lead ECG During Rest and Exercise

Nickole R. Lay M.Ed¹ (n.lay@csuohio.edu), Kenneth E. Sparks Ph.D¹, David Dashevsky²
¹ Cleveland State University, Cleveland, Ohio
² Orbital Research Inc., Cleveland, Ohio

Introduction:
The number one leading cause of death in both men and women is heart disease, with more than 600,000 deaths per year. Many Americans suffer from coronary heart disease. Heart disease may also lead to arrhythmias such as atrial fibrillation also known as AFib. AFib can be detected by a common diagnostic test, an electrocardiogram (ECG).

A standard 12-lead ECG using 10 gel electrodes (Figure 1) is commonly used in both clinical and ambulatory settings to record heart rate and rhythm during everyday normal activities. This poses potential problems for the patient including aggressive skin preparation, possible dehydration of the electrode therefore causing it to fall off, and skin irritation. Inaccurate signals or interference in the ECG may also cause the clinician to misdiagnose a heart condition.

A novel dry electrode (Figure 2) has been developed by Orbital Research Incorporated (ORI, Cleveland, OH) and has been investigated to see if its signal quality is similar to that of a standard gel electrode for ECG use. The ORI dry electrode has been tested in previous studies and found to produce a similar signal to that of the standard gel electrode.

- ORI embedded the dry electrode into a wearable harness that is capable of displaying a 12-lead derived ECG from the modified EASI electrode placement as described by Dower et al.² and Field et al.² (Figure 3).
- The placement of the electrodes in the CardioWare system is modified meaning the “E” and “S” electrodes are moved off the sternum to accommodate patients who have undergone a midline sternotomy.
- Derived electrocardiogram refers to when the standard limb leads are moved away from the extremities and placed on the torso and the precordial leads are reduced to a single lead that is calculated for the unipolar precordial V lead on the horizontal plane.

Methods
Thirty healthy men (n=15) and women (n=15), ages 20-54 years, from Cleveland State University and the surrounding community participated in this study. Each subject served as their own control as they were connected to both types of ECG simultaneously (Modified EASI CardioWare and Standard Mason-Likar) (Figure 4). Data was collected from the data acquisition unit (DAQ) from both ECG placements for five minutes of rest (Trial A) and during Trial B for two intensities of exercise (Figure 5).

- The first half of Trial B included rest and ambulatory walking (Stage 1: standing rest and Stage 2: walking 1.7mph, 0% incline).
- The second half of Trial B consisted of strenuous walking and recovery (Stage 3: walking 1.7mph, 10% incline, Stage 4: walking 2.5mph, 12% incline, and Stage 5: standing recovery).

Paired samples correlations were used to determine whether ambulatory walking and strenuous walking on the treadmill correlated to harness signal quality as measured by RMSE. Paired samples t-tests were conducted between each pair of limb, augmented and precordial leads during the first half of exercise during Trial B and the second half of Trial B. Subjective evaluation of the goodness of fit overlay was also determined.

Results
There was no significant difference between the root mean square error (RMSE) of the two different types of electrode placements during either the first half or the second half of Trial B (p < .05) (Table I). All correlations were robust (r = 0.658 - 0.942) and significant (p < .0001) (Table II). The subjective goodness of fit measure based on the overlay of both types of ECGs was similar (Figure 6).

Conclusion
It can be concluded that the modified EASI derived 12-lead ECG is an acceptable alternative to the standard 12-lead ML system at rest, ambulatory, and strenuous walking.

References

Table I. Comparison of RMSE between first half and second half of Trial B

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean ± SD</th>
<th>Sig (paired)</th>
<th>Pair</th>
<th>N</th>
<th>Correlation</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead I RMSE1 vs Lead I RMSE2</td>
<td>0.0230 ± 0.017958</td>
<td>.658</td>
<td>Lead I RMSE3 vs Lead I RMSE2</td>
<td>30</td>
<td>.891</td>
<td>.0001</td>
</tr>
<tr>
<td>Lead II RMSE1 vs Lead II RMSE2</td>
<td>0.082075 ± 0.0435294</td>
<td>.330</td>
<td>Lead II RMSE3 vs Lead II RMSE2</td>
<td>30</td>
<td>.932</td>
<td>.0001</td>
</tr>
<tr>
<td>Lead III RMSE1 vs Lead III RMSE2</td>
<td>0.082053 ± 0.0396507</td>
<td>.263</td>
<td>Lead III RMSE3 vs Lead III RMSE2</td>
<td>30</td>
<td>.903</td>
<td>.0001</td>
</tr>
<tr>
<td>V1 RMSE1 vs V1 RMSE2</td>
<td>0.04576 ± 0.0368086</td>
<td>.460</td>
<td>V1 RMSE1 vs V1 RMSE2</td>
<td>30</td>
<td>.909</td>
<td>.0001</td>
</tr>
<tr>
<td>V2 RMSE1 vs V2 RMSE2</td>
<td>0.05433 ± 0.0412235</td>
<td>.474</td>
<td>V2 RMSE1 vs V2 RMSE2</td>
<td>30</td>
<td>.913</td>
<td>.0001</td>
</tr>
<tr>
<td>V3 RMSE1 vs V3 RMSE2</td>
<td>0.080174 ± 0.0361335</td>
<td>.212</td>
<td>V3 RMSE1 vs V3 RMSE2</td>
<td>30</td>
<td>.910</td>
<td>.0001</td>
</tr>
<tr>
<td>V4 RMSE1 vs V4 RMSE2</td>
<td>0.059099 ± 0.0621849</td>
<td>.390</td>
<td>V4 RMSE1 vs V4 RMSE2</td>
<td>30</td>
<td>.769</td>
<td>.0001</td>
</tr>
<tr>
<td>V5 RMSE1 vs V5 RMSE2</td>
<td>0.115229 ± 0.4457409</td>
<td>.166</td>
<td>V5 RMSE1 vs V5 RMSE2</td>
<td>30</td>
<td>.854</td>
<td>.0001</td>
</tr>
<tr>
<td>V6 RMSE1 vs V6 RMSE2</td>
<td>0.053773 ± 0.307200</td>
<td>.346</td>
<td>V6 RMSE1 vs V6 RMSE2</td>
<td>30</td>
<td>.942</td>
<td>.0001</td>
</tr>
<tr>
<td>V1 RMSE1 vs V1 RMSE2</td>
<td>0.020576 ± 0.762353</td>
<td>.882</td>
<td>V1 RMSE1 vs V1 RMSE2</td>
<td>30</td>
<td>.658</td>
<td>.0001</td>
</tr>
</tbody>
</table>

Table II. Correlations of RMSE between first half and second half of Trial B