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# Top Portable ECGs in the Status Quo

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## ABSTRACT

Electrocardiograms (ECGs) are devices that measure the heart's electrical activity. ECGs have shown to identify issues with a person's heart. It is quite well known that heart disease has been a leading cause of death. Using ECGs for those who have heart issues is crucial for preventing serious implications, but it's not always possible to have immediate access to a 12-lead ECG used in healthcare facilities. For this reason, it's important to have a portable ECG that suits the user's needs. In the status quo, there are many portable ECGs with splendid features offered. However, a deeper dive into the categories of statistical data, mechanical qualities, price, and tech features of these ECGs reveals that we can reduce the number of high-quality portable ECG options available to a select few. Over 10 devices were identified originally. However, the number was reduced to 8 as only those had statistical data. Devices that did not have information about a subcategory or category were excluded in the analysis of identifying the best ECG for their respective categories. The study concluded with identifying AliveCor Kardia Mobile SL as the "winner" of the 8 ECG lineup, with the Microlife WatchBP Home A and AliveCor Kardia Mobile 6L devices following in second and third places, respectively. In conclusion, this study allows the consumer to make an educated decision, based on their preferences, which ECG would suit best for him/her.

## Introduction

Heart disease is the leading cause of death worldwide [1], with an average of 655,000 deaths annually in the US alone [2]. Heart diseases end in death in many ways: high blood pressure (hypertension), the formation of blood clots due to plaque buildup in the arteries (coronary artery heart disease), etc. [3]. No matter the type of heart disease, the inevitable outcome when the severity is too high is the disruption of the heart's electrical wiring, leading to sudden cardiac arrest (SCA) - when the heart stops beating [4]. Those with a history of heart disease have a significantly higher chance of developing SCA. The leading cause of SCA is arrhythmias which are abnormal heart rhythms. Other conditions that can lead to SCA include coronary artery disease (CAD), heart attack, enlarged heart (cardiomegaly), valvular heart disease, and heart defect present at birth (congenital heart disease), with CAD being the most common reason for SCAs for people above 35 years old. So, identifying the major causes of SCA such as arrhythmias and CAD in people beforehand of any accidents will only better the society. Fortunately, the number of all deaths attributable to CAD decreased by roughly 10% from 2008 to 2018 because of the growing awareness of the risk factors associated with heart disease, and this number is decreasing annually.

Studies have shown that such preventive care can decrease the prevalence of SCAs and thereby increase the quality of life for individuals [5]. Our healthcare system recommends those who are healthy to not get ECG readings because some ECGs could produce false positives which can lead to unwanted invasive procedures and costs for CVD detection [6]. Although this is true, most heart defects are found after patients take ECG readings at a health care facility because that is where the gold standard of ECGs, which are the 12-lead ECGs, are used. With that being said, we must acknowledge that there are a variety of reasons that could limit the people who want to go to health care facilities. For instance, those who live in rural areas and are out of immediate reach by healthcare providers and those

who may find healthcare bills unaffordable. Stunningly, 70% of all out-of-hospital SCAs occur at a home or residence, with the rest occurring in public settings (18.8%) and nursing homes (11.2%). Additionally, around 40% of all heart attacks are recurring [7]. Moreover, a multitude of internet searches resulted in identifying the top portable ECGs in the market. Statistical and non-statistical analyses of these portable ECGs were then conducted with the statistical data portion being compared to a gold standard 12-lead ECG's results or expert's results. On a personal need basis, the user may decide which ECG is best for him/her.

## Methods

### Devices

First, studies regarding the best portable ECGs in the market were collected from searches in Google [8, 9, 10, 11, 12, 13, 14, 15]. ECGs were also collected from studies that compared one or more ECGs with each other. ECGs without statistical data were eliminated because accuracy was a main aspect of determining how useful an ECG was. Also, smartwatches and such devices were excluded. With this filtration, the search was reduced to 8 portable ECGs: AliveCor Kardia Mobile SL (single-lead), AliveCor Kardia Mobile 6L (six-lead), Omron Complete Blood Pressure Monitor + EKG, HeartCheck™ ECG Pen, Beurer ME 90 Mobile ECG Device, Zenicor-ECG, MyDiagnostick, and Microlife WatchBP Home A.

Multiple searches on PubMed, Google Scholar, and Google for studies that measured the statistical measures of these devices were performed. These searches contained the ECG's name, "specificity", and "sensitivity". Information about non-statistical measures was found in the ECG's website and/or manual. Studies without statistical data were excluded. Additionally, studies with paywalls were excluded unless they had statistical data listed in their abstract. If information about an ECG of a category or subcategory was unavailable in either the results from the searches, website, or manual, then "NA" or no input about the information was used to show that the desired information was unavailable.

### Criteria for Devices

The ideal portable ECG is one that is small in size and affordable but still offers high quality feedback. For this reason, the general user will prefer the portable ECG that has characteristics similar to those of the ideal portable ECG. This study evaluates some of the best portable ECGs in the market to identify an ECG or ECGs that is/are "ideal". The devices were evaluated based on the following categories: statistical data, mechanical qualities, price, and tech features. In the mechanical qualities category, the best ECGs, based solely on portability, were determined. In the price category, the most affordable ECG was determined based on their baseline prices. The quality of each ECG's feedback was determined by an analysis of their statistical data and technological (tech) features. The ECGs were evaluated for accuracy via the collection of multiple studies regarding their statistical measures (i.e., specificity, sensitivity). The ECGs were evaluated for their tech features by collecting information regarding significant sub-categories: internal memory, battery life, multi-purpose, sampling rate, and display. Those sub-categories were chosen as they summed up the non-statistical portion for the ECGs.

For each category, a "winner", or in other words, the most qualified device was chosen. If there were sub-categories, then the device that had the greatest number of wins in the sub-categories was named as the overall winner of that category. If a sub-category or category had two or more devices that tied in qualifications, then the ECGs that were tied were all named as winners.

## Results

**Table 1**. Statistical Data

| Device | Study | Sample Description | Sample Size | Result |
|---|---|---|---|---|
| AliveCor Kardia Mobile 6L [16] | a) Krzowski B et al [24] | A group of consecutive cardiology patients with underlying conditions. Mean Age = 69 ± 12.9 years. Location: N/A. | 98 | Sensitivity - 88.1%; Specificity - 89.7%; |
| | b) Scholten J et al [25] | Included patients had no underlying conditions. Mean age = 70 ± 10 years. Location: Amsterdam, Netherlands. | 220 | Sensitivity - 99.4%; Specificity - 91.4%; |
| AliveCor Kardia Mobile Single-Lead [17] | a) Wegner F et al [26] | A group of consecutive cardiac inpatients with underlying conditions. Mean Age = 64 ± 15 years. Location: Germany. | 99 | Sensitivity - 100%; Specificity - 94%; |
| | b) Zaprutko T et al [27] | Underlying conditions = yes. Age ≥ 65 years. Location: Poland. | 417 | Sensitivity - 66.7%; Specificity - 98.5%; Positive predictive value (PPV) - 62.5%; Negative predictive value (NPV) - 98.7%; |
| | c) Brasier N et al [28] | Underlying conditions = yes. Mean Age = 78 ± 13. Location: Switzerland, Germany. | 532 | Sensitivity - 99.6%; Specificity - 97.8%; |
| | d) Desteghe L et al [29] | A group of inpatients with underlying conditions from the Cardiology and Geriatrics ward of a hospital. Mean Age for Cardiology ward = 67.9 ± 14.6 years. Mean Age for Geriatric ward = 83.3 ± 5.8 years. Location: Belgium. | 445 | Cardiology: sensitivity of 54.5 and specificity of 97.5%; Geriatrics: sensitivity of 78.9% and specificity of 97.9%; |
| | e) Pitman et al [30] | The participants had underlying conditions. Mean Age = 35 ± 13 years. Location: semirural town of Soddo in south-central Ethiopia | 1500 | Sensitivity - 75.0%; Specificity - 96.4%; |
| Omron Complete Blood Pressure Monitor + EKG [18] | a) Senoo K et al [31] | A group of consecutive patients with persistent AF who were admitted for catheter ablation. Mean Age = 65.8 years. Location: Japan | 56 | Sensitivity - 100%; Specificity - 86%; |
| | b) Wiesel J et al [32] | The patients were general cardiology patients with underlying conditions. | 199 | Sensitivity - 30%; Specificity - 97%; |

| | | | | |
|---|---|---|---|---|
| | | Age range ≥ 50 years. Location: Europe. | | |
| HeartCheck ™ ECG Pen [19] | a) Quinn et al [33] | Patients with underlying conditions from family practice clinics. Mean Age = 73.7 ± 6.9 years. Location: Canada. | 2054 | Sensitivity - N/A; Specificity - 72%; |
| Beurer ME 90 mobile ECG device [20] | a) Brito R et al [34] | Consecutive patients admitted at the cardiology ward of a tertiary care hospital were enrolled. Mean Age = N/A. Location: Switzerland. | 127 | Sensitivity - 100%; Specificity - 89.7%; PPV - 48%; |
| Zenicor-ECG [21] | a) Usadel L et al [35] | Pediatric patients who may or may not have underlying conditions. Age Range = 0 to 17 years. Location: N/A. | 226 | Sensitivity - 77%; Specificity - 92%; |
| | b) Doliwa P et al [36] | Patients with underlying conditions were recruited from an outpatient cardiology clinic. Mean Age = N/A. Location: N/A. | 100 | Sensitivity - 96%; Specificity - 92%; |
| | c) Svennberg E et al [37] | The participants had underlying conditions. Age ≥ 65 years. Location: Stockholm County and rural region of Halland, Sweden. | 3209 | Sensitivity - 97.8%; Specificity - 88.2%; PPV - 2.8%; NPV - 99.99%; |
| MyDiagnostick [22] | a) Desteghe L et al [29] | A group of inpatients with underlying conditions from the cardiology and geriatrics ward of a hospital. Mean Age for Cardiology ward = 67.9 ± 14.6 years. Mean Age for Geriatric ward = 83.3 ± 5.8 years. Location: Belgium. | 445 | Cardiology: sensitivity of 81.8% and specificity of 94.2%; Geriatrics: sensitivity of 89.5% and specificity of 95.7%; |
| | b) Tieleman et al [38] | Randomly selected patients with underlying conditions who were visiting an outpatient cardiology clinic or a specialized AF outpatient clinic. Mean Age = 69.4 ± 12.6 years. Location: Netherlands. | 192 | Sensitivity - 100%; Specificity - 95.9%; |
| | c) Hermans A et al and Tavernier R et al [39, 40] | Patients with underlying conditions who were admitted to the geriatric ward of a hospital. Mean Age = 84 ± 6 years. Location: Belgium. | 214 | Sensitivity - 88%; Specificity - 97% |
| | d) Zwart L et al [41] | Geriatric patients. Age Range ≥ 65 years. Mean Age = 78.4 years. Location: Europe. | 439 | Sensitivity - 90.0%; Specificity - 99.0%; PPV - 73.5%; NPV - 99.7%; |

| | | | | |
|---|---|---|---|---|
| | e) Vaes B et al [42] | Patients in a primary care setting with underlying conditions. Mean Age = 74.6 ± 9.7 years. Age range: 50 - 99 years. Location: Europe. | 181 | Sensitivity - 94%; Specificity - 93%; Based on A-fib prevalence of 6% of those aged ≥ 65, PPV of 45% and NPV of 99% were estimated. |
| Microlife WatchBP Home A [23] | a) Chan P et al [43] | Patients with underlying conditions. Mean Age: 67.2 ± 11.0 years. Age range ≥ 65 years. Location: Hong Kong. | 5969 | Sensitivity - 80.6%; Specificity - 98.7%; Based on low A-fib prevalence, a PPV of 42.4% and NPV of 99.8% were calculated; Area Under the Curves (AUC) - 0.90. |
| | b) Chan P et al [44] | Patients with underlying conditions. Mean Age: 67.8 ± 10.6 years. Age range ≥ 65 years. Location: Hong Kong. | 2052 | Sensitivity - 83.3%; Specificity - 98.67%; AUC - 0.91; |
| | c) Gandolfo et al [45] | All patients had stroke recent to the study and were with underlying conditions. Mean Age = 77.7 ± 11.34 years. Location: N/A. | 207 | Sensitivity - 89.5%; Specificity - 98.8%; AUC - 0.971; |
| | d) Wiesel et al [32] | The patients were general cardiology patients with underlying conditions. Age range ≥ 50 years. Location: Europe. | 199 | Sensitivity (using majority rule) - 100%; Specificity (using majority rule) - 92%; AUC - 0.92; |
| | e) Kearley et al [46] | Ambulatory patients in general practices with underlying conditions. Mean Age: 79.7 years. Age range: 75.1 - 99.8 years. Location: United Kingdom. | 999 | Sensitivity - 94.9%; Specificity - 89.7%; PPV - 44.1%; NPV - 99.5%; |
| | f) Wiesel et al [47] | Subjects recruited from general internists' offices with underlying conditions. Mean Age: 67 years. Age range: 26 - 89 years. Location: Queens, New York. | 117 | Sensitivity - 100%; Specificity - 93%; |

## Statistical Data Comparison

Three measures were cumulatively evaluated for assessing the overall best device in terms of statistical effectiveness. These measures were the sample size, the number of clinical studies completed (n), and the best overall (averaged) statistical metrics for all the devices that underwent clinical testing (i.e., sensitivity, specificity). There was a clear leader overall for these three categories: Microlife WatchBP Home A.

In terms of clinical studies, Microlife WatchBP Home A held the lead with n = 6; A tie was present for the second highest number of clinical trials which was n = 5 for both AliveCor Kardia Mobile SL and MyDiagnostick.

In terms of the sample size, Microlife WatchBP Home A far outstripped each other device with a cumulative sample size of 9543 across multiple patient populations on a global scale and an average of 1590 patients per study. Next in line was the Zenicor-ECG with a cumulative sample size of 3535 patients and average of 1178 patients per study (n = 3).

A distinct set of statistical metrics were used in the clinical trials: sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the curves (AUC). However, sensitivity (except for n = 1) and specificity were the only common statistical metrics for all ECGs. Thus, sensitivity and specificity were the only metrics that affected the conclusive decision for this section. As for ECGs, sensitivity refers to the ability of an ECG to state that a person who tested positive for a disease has that disease (true positive) [48]. As for ECGs, specificity refers to the ability of an ECG to state that a person who has tested negative for a disease doesn't have that disease (true negative). Microlife WatchBP Home A had an average of 90.88% for sensitivity and 94.81% for specificity. MyDiagnostick was the only device with higher sensitivities and specificities on average than those of Microlife WatchBP Home A: 91.53% for sensitivity and 95.97% for specificity. Although the differences for the statistical metrics were miniscule, the sample size and the study number were robust, in such varied patient populations globally. Thus, Microlife WatchBP Home A was outstanding as the best device in terms of statistical measures.

**Table 2**. "Winner" for this section: Microlife WatchBP Home A

| Criteria | Value |
|---|---|
| Sample Size (cumulative) | 9543 |
| Number of studies | n = 7 |
| Averaged metrics: | |
| Sensitivity (%) | 90.88% |
| Specificity (%) | 94.81% |

## Mechanical Qualities Comparison

Mechanical qualities refer to the simple spatial features of the ECGs. One criterion was chosen for assessing the best device in terms of mechanical qualities: portability. For each device, portability was dependent upon two factors: volume and weight. Devices with the lowest volume and weight were considered the most efficient. The outstanding device in this section was the AliveCor Kardia Mobile SL.

The two AliveCor Kardia Mobile devices ranked higher in portability than the other devices: both their volume and weight were the lowest. The AliveCor Kardia Mobile SL, however, had lower volume and weights than those of AliveCor Kardia Mobile 6L by roughly 111% and 33%, respectively. AliveCor Kardia Mobile SL had a volume of 9.18 $cm^3$ whereas AliveCor Kardia Mobile 6L had a volume of 19.44 $cm^3$. AliveCor Kardia Mobile SL had a weight of 18 grams whereas AliveCord Kardia Mobile 6L weighed 24 grams. Thus, the AliveCor Kardia Mobile SL had the lowest weight and volume of all devices. Therefore, the AliveCor Kardia Mobile SL was the best in the mechanical qualities category.

**Table 3**. "Winner" for this section: AliveCor Kardia Mobile SL

| Criteria | Value |
|---|---|
| Volume ($cm^3$) | 9.18 $cm^3$ |
| Weight (g) | 18g |

## Price Comparison

The price or, in other words, cost was based upon the sole factor of affordability. The ECG with the lowest cost in the lineup was the most affordable ECG. Additionally, the cost for each device was determined in the currency of US dollars and with the shipping location being the US. The Zenicor-ECG device was excluded in the selection process because the price was stated in neither the company website, trusted third-party website (ex. Amazon), or study. Seasonal sales/offers may affect costs of the devices. The standard cost of each EKG was obtained without the exclusion of seasonal sales/offers. For this section, the AliveCor Kardia Mobile SL ECG claimed the title of being most affordable.

The three most affordable devices of the lineup were the WatchBP Home A, AliveCor Kardia Mobile SL and 6L. WatchBP Home A was priced at $150 whereas AliveCor Kardia Mobile 6L was priced at $149. On the other hand, AliveCor Kardia Mobile SL was far lower than both with a starting price of $89. In addition, both AliveCor devices include a month's worth of KardiaCare, AliveCor's premium subscription. The AliveCor Kardia Mobile SL was cheaper than these two competitors by roughly 67%, distinguishing it as the most affordable EKG in the lineup.

**Table 4**. "Winner" for this section: AliveCor Kardia Mobile SL

| Criterion | Value |
|---|---|
| Price ($) | $89 |

## Tech Features Comparison

Tech features were essentially non-statistical metrics with the exclusion of the mechanical qualities: internal memory, battery life, multipurpose, sampling rate, and display. The overall winner for the tech features section was to be the device with the greatest number of wins in the sub-categories. There was a three-way tie for the winner of this category: AliveCor Kardia Mobile SL, AliveCor Kardia Mobile 6L, and Microlife WatchBP Home A.

Internal memory refers to the amount of data each ECG can store, specifically in terms of ECG recordings. Devices that did not support internal storage were excluded. Both AliveCor Kardia SL and 6L did not have an internal storage. As for the other devices, Microlife WatchBP Home A held the lead with an internal storage capacity of 250 averaged ECG recordings. Second in lead was Zenicor-ECG with an internal storage capacity of 200 ECG recordings. The recording duration for both ECGs was significantly different with Home A's stored ECG recording being the average for 3 consecutive ECG recordings, with each being 60 seconds in duration. On the other hand, Zenicor-ECG's recordings lasted for only 10 to 30 seconds with only 1 ECG recording being taken. In addition to the 256 MB of storage that allows for the 250 averaged ECG recordings, Microlife WatchBP Home A also has an extra 40 MB hard disk for additional storage. These distinctions clearly showed that Microlife WatchBP Home A far outpaced Zenicor-ECG in terms of internal memory. Thus, Microlife WatchBP Home A was the winner for the internal memory subcategory.

Battery life refers to the operational time for the devices. If the operational time for a device was given in terms of the number of measurements that could be taken before the battery died, then the operational time in hours was calculated by considering the length per ECG recording. Based on this method, the devices with the greatest amount of operational time were the AliveCor Kardia SL and 6L ECGs. Both had equivalent operational times of 200 hours with 12 months being the typical use. MyDiagnostick was next in line with a maximum of 12 hours of operational time and minimum recording of 500 ECGs with each being 60 to 70 seconds. Regardless, MyDiagnostick was behind by 12 hours' worth of operational time, making AliveCor Kardia SL and 6L have a tie for the battery life subcategory. Thus, both AliveCor Kardia SL and 6L were both winners of the battery life subcategory.

The best device in the multipurpose subcategory was evaluated simply on any abilities other than ECG measurement. Only two ECGs of the lineup had extra abilities: Microlife WatchBP Home A and Omron Complete Blood Pressure Monitor + EKG. The extra ability is, as in their names, the ability to measure blood pressure. One significant

difference is that Omron's ECG is more specific than that of Microlife's for classifying irregular heartbeat. Omron's ECG's classification includes a-fib, tachycardia, bradycardia, and sinus rhythm, whereas Microlife's ECG only classifies the heartbeat as a-fib. A downside to Omron's ECG is that a smartphone is required for seeing the detailed classification of the ECG measurements. Without a smartphone, the ECG measurement will not be classified at all, even as a-fib. This shows that considering the ECG only, with the restriction of any external devices, Microlife WatchBP Home A's ECG is the only device in the lineup that classifies the ECG measurement and has an extra ability, which is the blood pressure measurement. Thus, Microlife WatchBP Home A is the winner of the multipurpose subcategory.

Sampling rate is the number of data points obtained in a second. Sampling rate can be given in terms of hertz (Hz). Nevertheless, it still means the number of data points obtained per second. The winner of this subcategory was the device with the highest sampling rate. Devices that did not have their sampling rates stated were excluded: Omron Complete Blood Pressure Monitor + EKG, Zenicor-ECG, MyDiagnostick, and Microlife WatchBP Home A. Of the devices that had met the criterion, AliveCor Kardia SL and 6L devices had the highest sampling rates of the lineup: 300 samples per second. The device next in the lineup was the Buerer ME 90 mobile ECG device with sampling rate of 256 Hz. Both AliveCor devices outpaced Buerer's ECG by roughly 17% which made both AliveCor Kardia SL and 6L the winners of the sampling rate sub-category.

The display of the device refers to the platform in which the output information is shown to the user. All 8 ECGs in the lineup have screens as their displays. Some require the usage of a smartphone or laptop for viewing the data. Displays that were on the ECG rather than being external such as a smartphone were preferred instead as external devices may not always be available, making ECGs that require the use of external devices unusable in such cases. Thus, eliminating all ECGs that used external displays left the HeartCheck™ ECG Pen, Beurer ME 90 Mobile ECG Device, Zenicor-ECG, and Microlife WatchBP Home A for evaluation. Of these ECGs, the HeartCheck™ ECG Pen had the highest quality display: OLED. Thus, the HeartCheck™ ECG Pen was the winner of the display subcategory.

For the tech features category, there was a three-way tie for the overall winner between AliveCor Kardia SL, AliveCor Kardia 6L, and Microlife WatchBP Home A as each had won two categories. Thus, there were three winners for the tech features category: AliveCor Kardia SL, AliveCor Kardia 6L, and Microlife WatchBP Home A.

**Table 5.** "Winners" for this section: AliveCor Kardia Mobile SL, AliveCor Kardia Mobile 6L, Microlife Watch BP Home A

| Category | Device | Value |
|---|---|---|
| Internal Memory | AliveCor Kardia Mobile SL | N/A |
| | AliveCor Kardia Mobile 6L | N/A |
| | Microlife WatchBP Home A | 250 averaged ECG recordings (additional 40 MB hard disk space) |
| Battery Life | AliveCor Kardia Mobile SL | 200 hours operational time (12 months typical use) |
| | AliveCor Kardia Mobile 6L | 200 hours operational time (12 months typical use) |
| | Microlife WatchBP Home A | N/A |
| Multi-purpose | AliveCor Kardia Mobile SL | N/A |
| | AliveCor Kardia Mobile 6L | N/A |
| | Microlife WatchBP Home A | Blood pressure measurement |
| Sampling Rate | AliveCor Kardia Mobile SL | 300 samples per sec.; 0.5 to 5 min. ECG duration |
| | AliveCor Kardia Mobile 6L | 300 samples per sec.; 0.5 to 5 min. ECG duration |

| | | |
|---|---|---|
| | Microlife WatchBP Home A | N/A |
| Display | AliveCor Kardia Mobile SL | Smartphone (16 bit resolution) |
| | AliveCor Kardia Mobile 6L | Smartphone (14 bit resolution) |
| | Microlife WatchBP Home A | On-ECG LCD display (1024 x 768 pixels) |

## Overall

**Table 6**. Most-Qualified Devices per Category

| Category | Criteria | Most-Qualified Device |
|---|---|---|
| Statistical Data | Sample Size | Microlife WatchBP Home A |
| | Number of Studies | Microlife WatchBP Home A |
| | Sensitivity and Specificity | MyDiagnostick |
| Mechanical Qualities | Portable | AliveCor Kardia Mobile Single-Lead |
| Price | Affordable | AliveCor Kardia Mobile Single-Lead |
| Tech Features | Internal Memory | Microlife WatchBP Home A |
| | Battery Life | AliveCor Kardia Mobile Single-Lead and 6L |
| | Multi-Purpose | Microlife WatchBP Home A |
| | Sampling Rate | AliveCor Kardia Mobile Single-Lead and 6L |
| | Display | HeartCheck ™ ECG Pen |
| Overall | All Categories | AliveCor Kardia Mobile Single-Lead |

The most-qualified device of the entire lineup was the AliveCor Kardia SL. As shown in Table 3, AliveCor Kardia Mobile SL was the most qualified device in the mechanical qualities and price categories. In the statistical data category, the Microlife WatchBP Home A device held the lead. In the tech features category, there was a three-way tie for the winner of the category by AliveCor Kardia SL, AliveCor Kardia 6L, and Microlife WatchBP Home A. As AliveCor Kardia SL had placed as the most qualified device in three categories whereas the runner up had placed as the most qualified device in two categories, AliveCor Kardia SL was chosen as the overall winner of the entire lineup. The runner up was the Microlife WatchBP Home A. In third was AliveCor Kardia Mobile 6L.

**Table 7**. Top 3 "Winners" Overall

| Position | Device |
|---|---|
| First | AliveCor Kardia Mobile SL |
| Second | Microlife WatchBP Home A |
| Third | AliveCor Kardia Mobil 6L |

## Discussion

As shown in Table 3, the winner for the category of statistical data was Microlife WatchBP Home A. Multiple statistical measures were collected for the ECGs. However, sensitivity and specificity were the only common metrics for all 8 ECGs. The winner for mechanical qualities was AliveCor Kardia Mobile SL, price was AliveCor Kardia Mobile SL, and tech features was a three-way tie between Microlife WatchBP Home A, AliveCor Kardia Mobile SL, and AliveCor Kardia Mobile 6L. Overall, AliveCor Kardia Mobile SL held the greatest number of wins. Next in line was Microlife WatchBP Home A and then AliveCor Kardia Mobile 6L. As discussed in the methods, the user will look for the ideal device. AliveCor Kardia Mobile SL satisfies the factors for the ideal device the best in the 8 ECG lineup, which is why it had won in more categories than the other ECGs. In the categories that it didn't win in, it was not far from the winners. There are some important weaknesses that must be acknowledged, however.

AliveCor Kardia Mobile SL is not multi-purposeful, meaning that it does not have the ability to perform functions other than to take an ECG recording. For those who search for functions more than ECG recording, specifically blood pressure reading, the Microlife WatchBP Home A device is recommended.

A greater weakness may be that AliveCor Kardia Mobile SL requires the use of a smartphone to display feedback. Technology is rapidly evolving in the modern world and people are adopting novel technology, smartphones included. However, it is not always possible that the user may have a smartphone by their side. For example, the user may have forgotten to bring their smartphone but needs to take an ECG recording. Without a smartphone, the AliveCor Kardia Mobile SL is unusable. It's not only AliveCor Kardia Mobile SL but other ECGs that require the use of smartphones or computers that have the weakness previously mentioned. Instead, ECGs with in-built displays would serve the user best. If the user is focusing on displays solely, the HeartCheck™ ECG Pen is strongly recommended because of its high-quality OLED display. However, the storage for this device is quite low and it is not multi-purposeful. To meet these criteria as well, the Microlife WatchBP Home A would be best, but the downside is its LCD rather than OLED display. Although the HeartCheck™ ECG Pen is smaller than Microlife WatchBP Home A and may be more convenient, budget-wise Microlife WatchBP Home A ($150) is much cheaper than the HeartCheck™ ECG Pen ($259) by roughly $109. As a result, this decision comes to the user's preferences for having a device with one or more features for the tradeoff of some others.

Regardless, AliveCor Kardia SL is the cheapest among the ECGs in this study and delivers great depth in the classification of an ECG recording: A-fib, Bradycardia, Tachycardia, PVCs, Sinus Rhythm with Wide QRS, and Sinus Rhythm with SVE. Unfortunately, A-fib detection is the only feature that is included in the basic plan, and the other features are available only via purchasing their premium membership known as KardiaCare which costs $9.99 per month. Both AliveCor devices include 1 month's worth of KardiaCare in their starting prices. The KardiaCare premium subscription to access full features is a great drawback to this device, as the overall cost of using this ECG becomes noticeably more expensive; Additionally, the SL model offers a 16-bit resolution which shows more details than the human eye can absorb. If KardiaCare is purchased, then the AliveCor Kardia Mobile 6L is recommended instead. Even though the initial cost for the AliveCor Kardia 6L is greater than that of AliveCor Kardia SL, AliveCor Kardia 6L has more leads than AliveCor Kardia SL, meaning that more information about the heart's condition is revealed by the 6L model. If the user prefers to use a smartphone but is not willing to have KardiaCare, an alternative would be the Complete™ Wireless Upper Arm Blood Pressure Monitor + EKG. It's priced at roughly $200, but its free features compensate for the cost. Omron's Connect App can be used to send data to physicians for review for free and the depth in the classification (a-fib, tachycardia, and bradycardia) of the ECG recording is free as well. Plus, it is multi-purposeful by having an extra feature of blood pressure analysis. However, Omron's device had the lowest sensitivity on average and its specificity was at the 50th percentile roughly in the 8 ECG lineup.

As a result, the choice of the user depends on what the user believes is most important for him/her. If the user wants an ECG with the best statistical values but cannot afford to pay for premium membership such as KardiaCare, then Microlife WatchBP Home A would be best, as shown in Table 3. Otherwise, AliveCor Kardia Mobile SL would be the best choice. AliveCor Kardia Mobile 6L is an alternative too. As AliveCor Kardia Mobile 6L has more leads

than AliveCor Kardia Mobile SL, it should have better sensitivity and specificity on average than the SL theoretically. Results from the data used in this study showed that SL model had a higher specificity value (on avg.) than the 6L model and the 6L model had a higher sensitivity value (on avg.) than the SL model. In fact, many studies on the SL and 6L models were found. However, a substantial portion of them did not include the specificity and sensitivity values, which led to their exclusion. Not only for these ECGs but also for others, more clinical trials must be conducted to determine the devices' true accuracies in real life applications. Statistical measures along with other non-statistical measures such as battery life and sampling rate were not given for some ECGs. These are important aspects in validating an ECG's overall performance. Once again, more clinical studies must be done to identify the performance of the devices that were excluded in some of the comparisons.

## Conclusion

According to the results, AliveCor Kardia Mobile SL is the most qualified device overall. Even though its depth in ECG measurement is limited to A-fib without its premium subscription of KardiaCare, most other devices as well are limited to A-fib only. However, AliveCor Kardia Mobile SL stands as the most portable device and the cheapest. If affordable, the AliveCor Kardia Mobile 6L does offer greater accuracy theoretically because of it having more leads than the SL model. However, the results of this study showed that Microlife WatchBP Home A was the most qualified device in terms of statistical data. In addition, some devices such as Zenicor-ECG and MyDiagnostick were excluded in some cases due to lack of information pertaining to those areas. In conclusion, a much greater number of clinical trials must be performed to accurately assess the ECGs' statistical measures (i.e., specificity, sensitivity) and information in non-statistical areas (such as battery life and sampling rate).

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