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RESEARCH ARTICLE

Study the Effects of Age, Gender, and Body Mass Index on Heart Rate

Fina Nahdiyya, Siti Nurul Khotimah*

Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia

Abstract Heart disease is one of the deadliest diseases in the world in 2019; the increase in deaths has reached 2 million to 8.9 million people since 2000. Heart rate (HR) is an essential medical helpful sign for quickly evaluating health and knowing a person's fitness. Besides cardio exercises, some non-physical activities influence HR, such as age, gender, and body mass index (BMI). This study aims to analyze the RR intervals in leads I, II, III, aVR, aVL, and aVF and determine the effect of age, gender, and BMI on HR. HR measurements were carried out using a portable ECG, the KardiaMobile 6L, during 30 seconds of recording on the subject in resting conditions and normal sinus rhythm. The number of subjects in this study was 168 people in 5 age groups, namely A (4-5 years), B (6-7 years), C (10-13 years), D (19-30 years) and E (55-75 years). Each age group consisted of female and male subjects, but complete BMI category variations were only found in group D. Based on the results of the HR analysis based on age, it can be concluded that with age, HR will decrease. This decrease is estimated at 4.19 bpm/year in the age range of children to adolescents (4.0 to 11.5 years) and 0.16 bpm/year in the age range of adolescents to the elderly (11.5 to 75 years). Based on gender in all age groups, it can be concluded that the average HR of women is not always higher than that of men. In group D (19-30 years), BMI in resting subjects did not affect HR. RR interval values in lead I (0.6997 $\pm$ 0.056), lead II (0.6998 $\pm$ 0.056), lead III (0.6998 $\pm$ 0.056), aVR (0.6998 $\pm$ 0.056), aVL (0.6995 $\pm$ 0.057) and aVF (0.6998 $\pm$ 0.056) indicate that the RR interval values for each lead are identical.

Keywords: KardiaMobile 6L, heart rate, age, gender, BMI.

Introduction

Heart disease is one of the diseases included in the category of the 10 deadliest diseases in the world in 2019, which kills around 17.9 million people each year [1,2]. In Indonesia, heart disease is ranked second among the 10 highest causes of death in men and women of all ages. Deaths increased from 67 cases to 96 cases per 100,000 population from 2000 to 2019 [3]. HR measurement is the simplest way to diagnose several heart diseases [4], such as Tachycardia, Bradycardia, and Hypertension. HR can be affected by physical activity (cardio exercise) and non-physical activity (such as age, gender, and BMI).

HR will generally decrease with age from 40 years to over 80 years [5,6]. This study will measure HR from 4 years (kids) to 75 years (elderly) with a change in teenagers as a hypothesis. HR for women is higher than for men at the age of 18 years to over 60 years [7,8]. Meanwhile, based on BMI, the higher BMI group had a lower HR compared to the lower BMI group in the conditions immediately after running 200 meters [9].

The tool used to record the heart's electrical activity is called an electrocardiograph (ECG). In general, hospitals use the 12-lead ECG, which is the clinical standard today [10,11]. As time progressed, scientists innovated using smartphones to develop ECG to monitor heart activity [12]. One of the ECG that has been developed is the KardiaMobile 6L which holds a European Certificate of Conformity and approved by the American Food and Drug Administration (FDA) as a tool for acquiring, storing, displaying, and transmitting an ECG lead [13]. KardiaMobile 6L has the advantage of being able to detect

***For correspondence:**
nurul@itb.ac.id

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subjects with heart electrical activity for normal sinus rhythm and arrhythmias. This study aims to determine the effect of age, gender, and BMI on HR using KardiaMobile 6L for subjects with normal sinus rhythm.

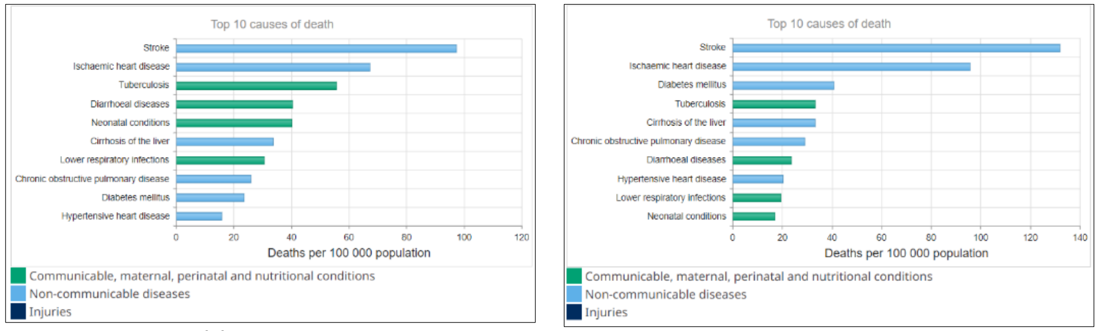

Figure 1. Rank of heart diseases in the top Indonesia causes of deaths in (a) 2000 and (b) 2019 [3]

Materials and Methods

The measurement tool used in this research is KardiaMobile 6L, a portable ECG tool. The procedures carried out are as follows:

Optimization of ECG Signal Digitization in the Lead I for the RR Interval

Data from KardiaMobile 6L will be saved in PDF format; to carry out further exploration, it is necessary to digitize it. This digitization process uses WebPlotDigitizer, which users can access free of charge. The size of the digitized area is in lead I, around 0 seconds to 4.4 seconds. The type of algorithm used is X Step with Interpolation. This algorithm can regularly identify data points on the X axis between X_0 and X_1 and Y_0 and Y_1 [14]. Δt Variations are carried out at this stage to obtain the most accurate data. The Δt (s) variations used are 0.0001, 0.0005, 0.001, 0.005 and 0.01.

Analysis of RR Intervals in Leads I, II, III, aVR, aVL and

After the signal is digitized, the next step is an analysis of the RR intervals in leads I, II, III, aVR, aVL, and aVF. The area analyzed starts from 0 to 30 seconds in leads I, II, III, aVR, aVL, and aVF. To calculate the average RR interval, heart rate, and standard deviation, use equations 1, 2, and [15].

$$\overline{RR} = \frac{1}{N}\sum_{i=1}^{N} RR_i \quad (1)$$

$$HR(bpm) = \frac{60}{\overline{RR}} \quad (2)$$

$$SDRR = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(RR_i - \overline{RR})^2} \quad (3)$$

Reliability of KardiaMobile 6L

Repeated measurements can be used to determine the accuracy and consistency of a method [16]. At this stage, the researcher measured HR of a subject using KardiaMobile 6L with 8 repeated measurements to determine the average value and standard deviation using Equations 4 and 5.

$$\overline{HR} = \frac{1}{N}\sum_{i=1}^{N} HR_i \quad (4)$$

$$SDHR = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(HR_i - \overline{HR})^2} \quad (5)$$

Figure 2 shows the timeline of HR measurements on a subject with 8 repetitions; each measurement records within 30 seconds, which is figured by a short red line. The time interval between the two measurements is very short (minutes) on Figure 2a, however it is long enough (hours) for Figure 2b. The subject is resting while the measurement takes place, which means that the subject is not doing excessive activity that can affect the HR value.

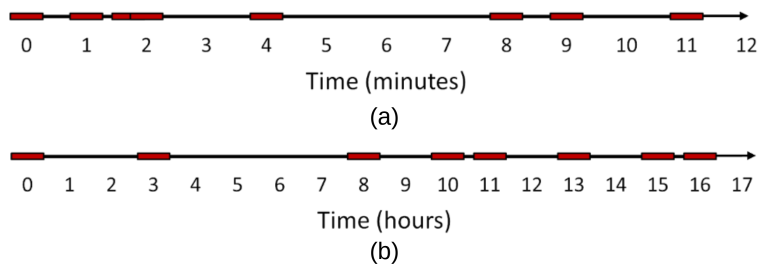

Figure 2. Timeline HR measurement in (a) ∆t= 11 minutes and (b) ∆t= 16 hours

HR Analysis Based on Age, Gender, and BMI

HR data were collected on 168 subjects (male = 84 and female = 84) with normal sinus rhythm from 5 age groups, i.e. group A (4-5 years) consisting of 23 subjects, B (6-7 years) is 20 subjects, C (10-13 years) is 37 subjects, D (19-30 years) is 72 subjects and E (55-75 years) is 16 subjects.

In the HR measurement stage, the first step is to measure the subject's weight and height, then determine each subject's BMI value, which is calculated using Equation 6 [17]. Then the researcher must ensure that the subject does not use jewelry made of metal and that the subject is calm. Using accessories made of metal on the subject being measured can reduce the accuracy of readings by KardiaMobile 6L [18].

$$\mathrm{BMI} = \frac{\mathrm{weight\ (kg)}}{\left(\mathrm{height\ (m)}\right)^2} \tag{6}$$

The collected data will be categorized based on age, gender, and BMI, and then the data will be statistically tested using a paired t-test using Microsoft Excel. Based on age, the t-test was carried out between groups, and based on gender, The t-test was carried out between the sexes in each group. Meanwhile, based on BMI, the t-test needed to be carried out. In the HR analysis based on age, linear regression analysis was carried out. The aim was to predict HR at a certain age. The HR analysis flow based on age, gender, and BMI can be seen in Figure 3.

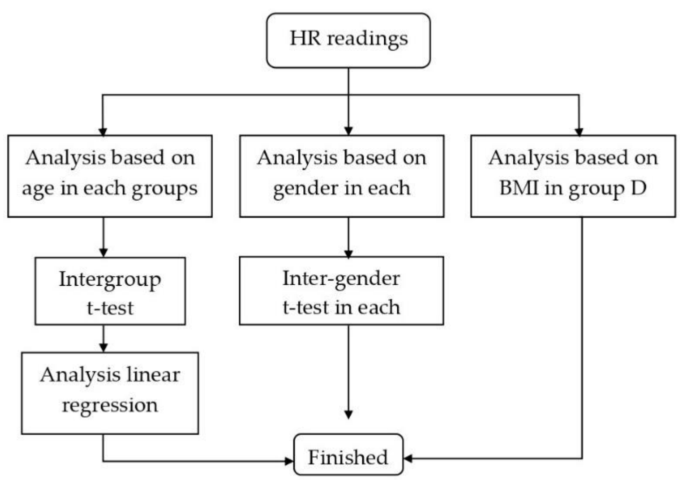

Figure 3. HR Analysis Flowchart Based on Age, Gender, and BMI

Results and Discussion

Optimization of ECG Signal Digitization in the lead I for RR Interval

Figure 4 shows 5 overlapping graphs of digitizing ECG signals with variations in Δt (s) = 0.0001, 0.0005, 0.001, 0.005 and 0.01. The variation of Δt gives the same pattern as the ECG signal in the time domain and slightly different in amplitude values for Δt = 0.01 s.

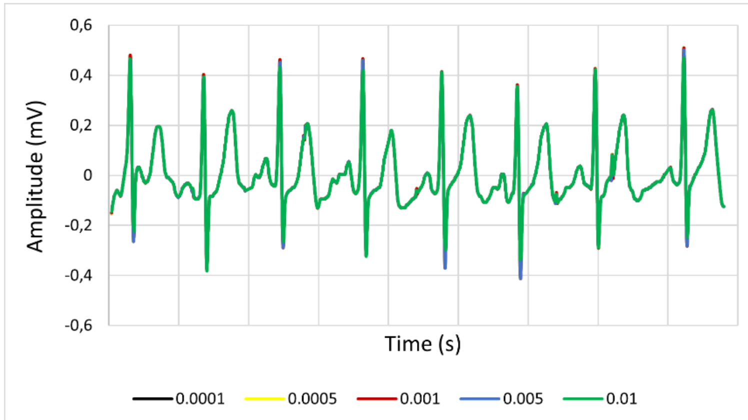

Figure 4. ECG signal digitazation graphs with Δt (s) = 0.0001, 0.0005, 0.001, 0.005 and 0.01

Table 1 explains the Δt values and RR intervals in ECG signal digitization. Based on this table, the average value of the RR interval and the HR value for each Δt has the same value, This means that each Δt does not have a significant difference in RR interval.

Table 1. Δt (s) and RR interval in ECG signal digitazation

$\Delta t(s)$	$\overline{RR} \pm$ SDRR (s)	HR (bpm)
0.0001	0.566 $\pm$ 0.04	106
0.0005	0.566 $\pm$ 0.04	106
0.001	0.566 $\pm$ 0.04	106
0.005	0.566 $\pm$ 0.04	106
0.01	0.566 $\pm$ 0.04	106

Analysis of RR Intervals in Leads I, II, III, aVR, aVL and aVF

Digitization at this stage uses Δt = 0.001 s. The ECG signals analyzed were the ECG results from the 89th subject in leads I, II, III, aVR, aVL, and aVF during the 30-second recording. Table 2 shows the average RR interval data in leads I, II, III, aVR, aVL, and aVF for 1 subject. The table shows that the RR interval (s) in lead I is 0.6997 $\pm$ 0.056, lead II is 0.6998 $\pm$ 0.056, lead III is 0.6998 $\pm$ 0.056, aVR is 0.6998 $\pm$ 0.056, aVL is 0.6995 $\pm$ 0.057 and aVF was 0.6998 $\pm$ 0.056 with the average interval in all leads being 0.6997 $\pm$ 0.056. HR (bpm) based on calculations on lead I is 85.746, lead II 85.738, lead III 85.741, lead aVR 85.735, lead aVL 85.776, lead aVF 85.743 while HR based on KardiaMobile 6L on lead I is 86 bpm. Based on these data, it can be concluded that the HR calculations for leads I, II, III, aVR, aVL, and aVF are the same as the HR for KardiaMobile 6L.

Table 2. RR interval analysis in lead I, II, III, aVR, aVL and aVF for 1 subject

Lead	Lowest RR (s)	Highest RR (s)	$\overline{RR} \pm$ SDRR (s)	HR (bpm)	HR of KardiaMobile 6L (bpm)
I	0.591	0.798	0.6997 $\pm$ 0.056	85.746	86
II	0.591	0.799	0.6998$\pm$ 0.056	85.738	
III	0.591	0.799	0.6998 $\pm$ 0.056	85.741	
aVR	0.590	0.798	0.6997 $\pm$ 0.056	85.735	
aVL	0.589	0.800	0.6995 $\pm$ 0.057	85.776	
aVF	0.589	0.799	0.6998 $\pm$ 0.056	85.743	
Average $\pm$ Standard Deviation			0.6997 $\pm$ 0.056	85.746 $\pm$ 0.015	

Reliability of KardiaMobile 6L

Table 3 is the HR data for 8 measurements on one subject, the 72nd subject. The table shows that HR $\Delta t = 11$ minutes has an average HR of (87 $\pm$ 2.0) bpm with a standard deviation of 2.3%. While HR is measured in $\Delta t = 16$ hours has an average HR of (83$\pm$ 3.3) bpm with a standard deviation of 4%. The results of the standard deviation calculation (<5%) show that KardiaMobile 6L has good accuracy and consistency, so it can be concluded that KardiaMobile 6L has high reliability.

Table 3. HR data for 8 measurements on 1 subject

Measurement	HR (bpm) in ∆t= 11 minutes	HR (bpm) in ∆t= 16 hours
1	85	78
2	88	79
3	89	86
4	85	86
5	89	86
6	86	80
7	86	83
8	90	83
$\overline{\text{HR}}$ ± SDHR	87 ± 2.0	83 ± 3.3

HR Analysis Based on Age, Gender, and BMI

The HR value (bpm) for each age group is expressed as an average ± its standard deviation as follows: group A (113 ± 10.9), group B (106 ± 10.6), group C (84 ± 9.2), group D (83 ± 9.1) and group E (76 ± 7.4). Based on previous research, at the age of (3 – 5) years, the HR is (80 – 140); at the age of (6 – 12) years, the HR is (70 – 120); and at the age of (13 – 18) years the HR is (60-100) [19], at the age of 18-30 years, had an HR of (81 ± 14.4) [7], while at the age of (50 – 79) years, had an HR of (75 ± 1.9) [5,6]. Based on all of the data, it can be concluded that the HR of all groups did not have a significant difference from the results of the previous studies.

Figure 5 displays the average value of HR, lowest and highest on the vertical axis to the median value of each age group. Based on this figure, the older age group has a lower HR than the younger age group.

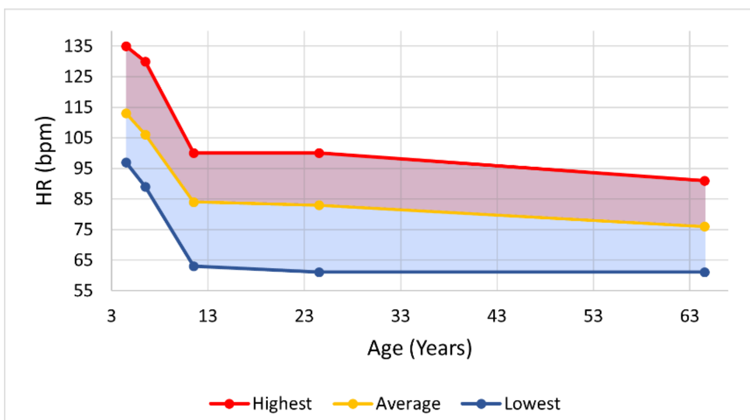

Figure 5. Average HR, Lowest and Highest Based on Age

Based on the t-test conducted on groups A and B shows a p-value of 0.045 (<0.05) means that there is a significant difference between HR groups A and B. The t-test in groups C and D shows a p-value of 0.0758 (> 0.05), meaning that there is no significant difference between HR groups C and D. The T-test in groups D and E shows a p-value of 0.012, meaning that there is a significant difference between HR groups D and E. In the regression analysis, there are 2 equations, $\text{HR} = -4.1923\ \text{age} + 132.44$ for $4 \leq$

$\text{age (years)} \leq 11.5$ and $\text{HR} = -0.1566\ \text{age} + 86.247$ for $11.5 \leq \text{age (years)} \leq 75$. Figure 6 is a linear regression value of HR based on age.

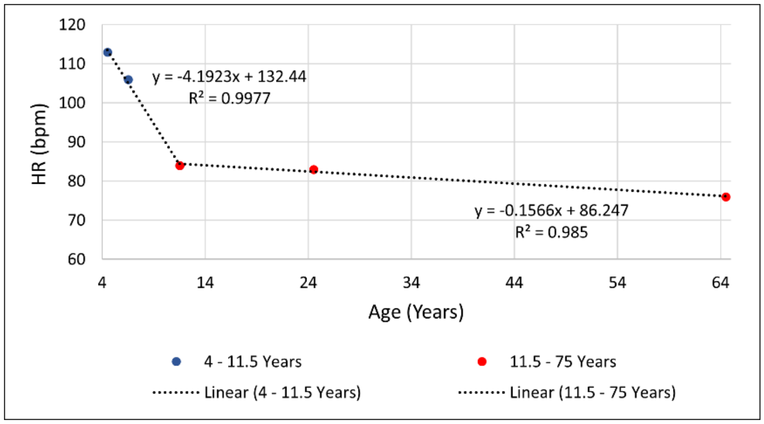

Figure 6. HR Linear Regression Value Based on Age

HR analysis based on gender was performed on 5 age groups. Table 4 shows the heart rate of research subjects based on age and gender. Of 168 subjects, 84 (50%) were female, and 84 (50%) were male.

Table 4. Heart Rate of Research Subjects by Age and Gender

Age Group (years)	Gender	The number of subjects	Percentage (%)	$\overline{HR} \pm$ SD (bpm)	HR (bpm)		
					HR	Lowest	Highest
A (4-5)	Female	11	47.8	115 ± 11.2	113	97	135
	Male	12	52.2	110 ± 10.6			
B (6-7)	Female	13	65.0	109 ± 11.0	106	89	130
	Male	7	35.0	100 ± 7.8			
C (10-13)	Female	22	59.5	85 ± 8.3	84	63	100
	Male	15	40.1	82 ± 10			
D (19-30)	Female	30	41.7	82 ± 7.7	83	61	100
	Male	42	58.3	84 ± 9.9			
E (55-75)	Female	8	50.0	78 ± 4.9	76	61	91
	Male	8	50.0	74 ± 9.1			

Figure 7 is the average value of HR by gender. In groups A, B, C, and E, women's HR is higher than men's. In contrast, in groups D, the average HR of women is lower than that of men. Based on these results, the average HR of women is sometimes higher than men. Meanwhile, based on previous research, women's HR is higher than men's at 18 years to more than 60 years [7,8]. In this study, the t-test conducted in each group shows p-values between 0.06 and 0.50 so there is no significant difference between the HR of females and males.

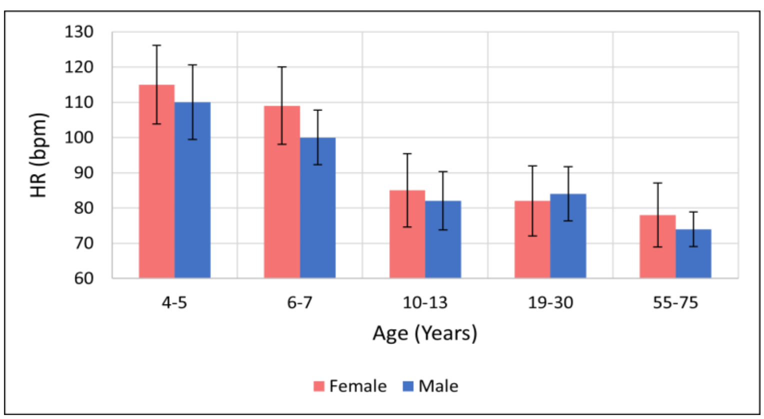

Figure 7. HR Average Value Based on Gender

HR analysis based on BMI was carried out in group D (19-30 years) with 72 subjects. Based on the measured height and weight, there are 5 categories of BMI, namely 13 subjects are in the underweight category with HR (84 $\pm$ 8.5), 42 subjects are in the normal category with HR (84 $\pm$ 9.7), 11 subjects are overweight with HR (82 $\pm$ 8.3), 5 subjects are in obesity I with HR (79 $\pm$ 8.6), and 1 subject is in obesity II with HR 87 bpm.

Based on the t-test carried out between underweight and obesity I categories and between normal weight and obesity I show a p-value of 0.398 and 0.315 (<0.05), meaning a significant difference in HR in the underweight and obesity I categories and between categories normal weight and obesity I. Meanwhile, the t-test in other categories showed a p-value between 0.519 and 0.802 (>0.05), meaning there was no significant difference between HR in these categories. Based on previous research, HRV values for normal young adult's vs overweight young adults and normal adult's vs overweight adults did not have significant differences [20]. A previous study has shown that HR immediately after 200 meters of running can be affected by BMI [9]. Figure 8 shows the HR distribution value based on BMI at 19-30 years old.

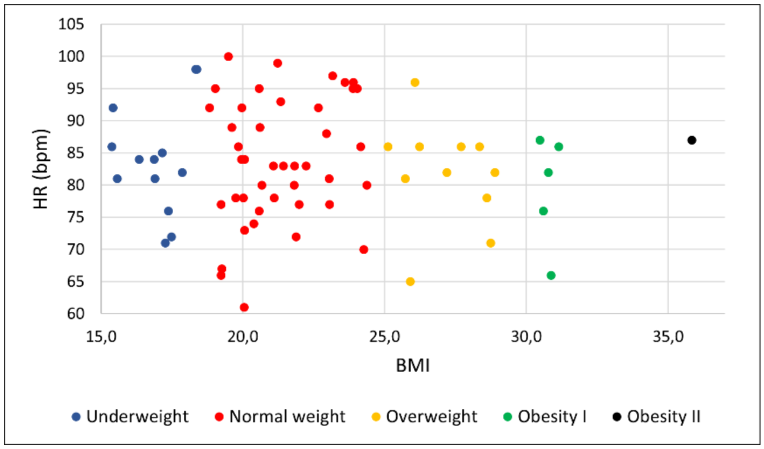

Figure 8. Value Distribution of HR Based on BMI in Group D

Conclusions

Based on the results, HR will decrease with age through two equations, namely $\mathrm{HR} = -4.1923\ \mathrm{age} + 132.44$ for $4 \leq \mathrm{age\ (years)} \leq 11.5$ and $\mathrm{HR} = -0.1566\ \mathrm{age} + 86.247$ for $11.5 \leq \mathrm{age\ (years)} \leq 75$. Based on gender, it can be concluded that the HR in women is slightly higher than men for group ages (4-5) years, (6-7) years and (55-75) years. HR on subject $19 \leq \mathrm{age\ (years)} \leq 30$ in resting condition not affected significantly by BMI for 5 categories. Based on the analysis of the RR intervals in leads I, II, III, aVR, aVL, and aVF, it can be concluded that the HR value based on calculations is not different from the HR value based on direct data from KardiaMobile 6L.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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