Biological Heart Rate Age Estimation Based on Regression Analysis

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***Abstract*—The changes in heartbeat signals are affected by two parameters of the autonomic nervous system, the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system promotes excitement; the parasympathetic nervous system promotes relaxation and sleep. The balance between the two is important. SDNN in the heart rate variation parameters is obviously related to age. The older the age, the smaller the SDNN value. In the past, studies have proposed the that the autonomic nervous activity age uses SDNN parameters to correspond to the age of the group norm. Then observe the body's autonomic nervous system activity to see whether it is in an aging or youthful state. This study uses regression analysis to take the average SDNN of subjects of different ages in the norm for both men and. The calculated relationship formulas between autonomic nervous activity age and SDNN are: Age=77.045*E-0.02*(SDNN) (male, R2=0.9814); Age=86.838*E-0.022*SDNN (female, R2=0.9905). This formula will be of great help to the subsequent application of wearable physiological measurement equipment to improve health by observing the relationship between changes in HRV age and living habits.**

Keyword:Heart Rate Variability, Age estimation, Regression Analysis.

I. Introduction

In today's era, people's lives are often dominated by fast pace and high pressure. With the popularity of social media and a 24-hour work culture, many people often stay up late, affecting their sleep quality and physical health. Coupled with the convenience of modern technology, the amount of exercise for many people has also been significantly reduced. These lifestyle changes may not show obvious adverse effects on the body in the short term, but over time they may lead to an increased risk of chronic diseases, such as cardiovascular disease, obesity, and diabetes. Therefore, through a simple and easy way, everyone can regularly understand their physical condition, especially physiological indicators such as heartbeat and heartbeat variability, which are closely related to the autonomic nervous system and are crucial to promoting health awareness and disease prevention [1].

ECG is the abbreviation of Electrocardiography. It is a waveform diagram drawn by capturing the weak electric waves generated when the heart beats, or the vibrations on the blood vessel walls when the heart beats. The ECG waveform is shown in Figure 1.

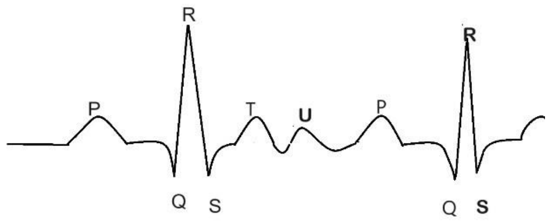

Figure 1. Illustration of ECG rhythm

The ECG waveform is divided into six parts: P wave, Q point, R point, S point, T wave, and U wave. The calculation basis of heartbeat and heartbeat variation is based on the distance between two R points. First, R peak must be detected for further HRV parameter estimation. The steps for R peak detection are as follows:

Step 1: QRS area positioning. Since the QRS area has a higher amplitude in ECG measurement, the amplitude difference can be used to detect and locate the QRS area.

Step 2: R peak detection, average the maximum and minimum values in the QRS area to obtain the relative amplitude. The maximum value in the relative amplitude is the position of the R peak.

Step 3: Processing of R-R spacing, average the values of R-R spacing, and regard the average distance error exceeding 20% as noise and delete it.

HRV, also known as heart rate variability, is a calculation that evaluates the activity of the autonomic nervous system by observing the electrocardiogram. The autonomic nervous system is divided into sympathetic nerves and parasympathetic nerves. The sympathetic nerves are responsible for the body's tasks such as movement, alarm, and anger, which can cause the heartbeat speeds up and myocardial contraction increases, which means the cardiac output increases. The parasympathetic nerves are responsible for the absorption, recovery, regeneration and other activities of the organs, which will slow down the heartbeat and reduce the myocardial contractility, that is, reduce the cardiac output. Due to the two systems control heart respectively, regulate the beating speeds up and slows down for any situation at very short response. Therefore, the stability of the heart beating can be observed to detect the activity of the autonomic nervous system [2].

The following are common HRV parameter and their corresponding mathematical formula [3]:

$$SDNN = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (RR_i - RR_i)^2} \quad \textbf{(1)}$$

$$RMSSD = \sqrt{\frac{1}{N} \sum_{i=1}^{N-1} (RR_{i+1} - RR_i)^2} \qquad (2)$$

$$SDSD = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (\Delta RR_i - \Delta RR_i)^2} \qquad (3)$$

$$Mean_{R-R} = \frac{\sum_{i=1}^{N} RR_i}{N} \qquad (4)$$

$$CV_{R-R} = \frac{SDNN}{Mean_{R-R}} \qquad (5)$$

Among them, SDNN has a close relationship with age; the subsequent HRV age model uses SDNN as a parameter for further regression analysis.

II. Method.

A. ANS Watch

ANS Watch instrument has many functions. ANS Watch measures systolic blood pressure and diastolic blood pressure in a non-invasive way, and can calculate heartbeat, heart rate variability HRV, high-frequency component HF (%), low-frequency component LF (%), Low-frequency component/high-frequency component ratio LF/HF, and the number of irregular heartbeats within 5 minutes and other parameters.

Figure 2. Name and function of ANS Watch (1) Wristband (contains biosensor) (2) Power switch (Power On-Off) (3) LED indicator (power on, test, charging, Bluetooth) (4) Micro-USB charging slot

B. ANS Watch Operating procedures

Software installation steps:
1. Search ANSWatch on Google Play and you will find the app dedicated to this instrument: ANSWatch-Mini (Figure 3)
2. After installation, the APP shortcut of <ANSWatch-Mini> will appear on the mobile phone desktop.
3. Tap <ANSWatch> APP to enter the startup screen (Figure 4), then press <Tools> to set the language, birthday and gender to complete the setting (Figure 5); the installation is complete.

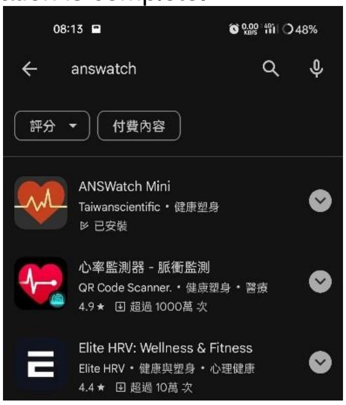

Figure 3, APP for ANSWatch Mini

Figure 4, Startup screen of APP

Figure 5, Setup screen of APP

ANS Watch recording procedures:
1. Left wrist; the power switch is close to you; the midline is aligned; the front edge of the wristband is aligned with the dividing line between the palm and the wrist (Figure 6)
2. Put the wrist blood pressure monitor on your left wrist; put a yellow soft pad under the wrist
3. Press the Power button to turn on ANS Watch, press the APP shortcut of <ANSWatch-Mini> on your phone with your right hand, and then press <BP+HRV> to start the test. The test takes about 7 minutes (2 minutes for blood pressure; 5 minutes for heart rate variability)
4. When measuring, stay quiet, don't talk, and don't move your whole body.

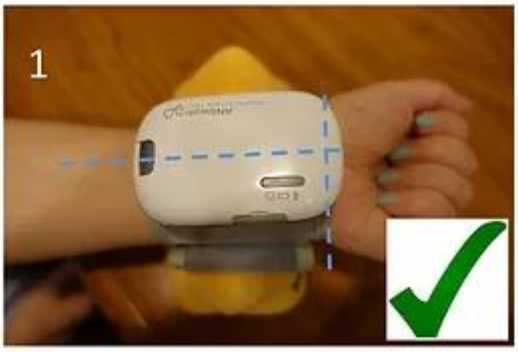

Figure 6 ANS Watch Wear

C. ANS Watch output results

The output results are: SYS systolic blood pressure (mmHg), DIA diastolic blood pressure (mmHg), HR heart rate (1/min), HRV heart rate variation (ms), HRV biological age, LF sympathetic nerve ratio (%), HF parasympathetic nerve proportion (%), LF sympathetic nerve activity, HF parasympathetic nerve activity. Figure 7 and Figure 8 are the HRV-AGE graphs built in the Heart Rhythm Master app. From the graph, we can see that the HRV-AGE of Heart Rhythm Master is based on the points on table 1, the X-axis is age, the Y-axis is SDNN, and the two points are drawn as straight lines. However, normally the physiological signal should be a smooth curve, so after consideration, we decided to use the points in table 1 as a reference and use the linear regression analysis method to estimate the HRV-AGE formula.

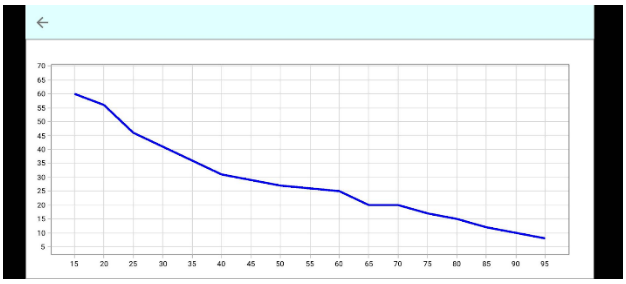

Figure 7, Relation of age (x-axis) and SDNN for male group

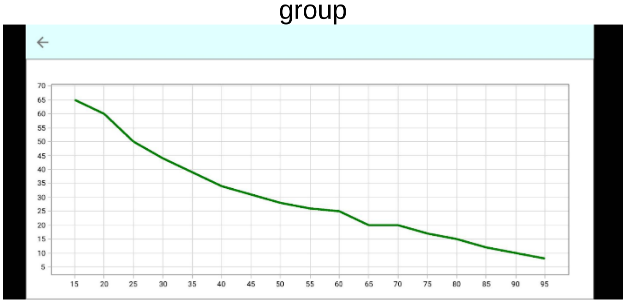

Figure 8, Relation of age (x-axis) and SDNN for female group

Table 1, The mean SDNN for various age. The data is derived from ANS Watch

age	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Male	60	56	46	41	36	31	29	27	26	25	20	20	17	15
Female	65	60	50	44	39	34	31	28	26	25	20	20	17	15

D. Linear Regression Analysis

Linear regression is a type of regression analysis that uses a least squares function called a linear regression equation to model the relationship between one or more independent variables and a dependent variable. The R2 value is a value used to evaluate the reliability of linear analysis. The closer the R2 value is to 1, the higher the reliability. The calculation formula is as follows.

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}} \qquad (6)$$

III. Results

Apply the HRV-age table to the linear regression formula, input the data of men and women respectively. The X-axis in the linear regression is age and the Y-axis is SDNN. The graph and regression formula are obtained as follows. Figure 9 is the regression analysis of male group. The linear regression formula of Male Age=77.045*E-0.02*SDNN, R^2=0.9814. Figure 10 is the regression analysis of women group, and the linear regression formula of women is Female Age=86.838*E-0.022*SDNN, R^2=0.9905. Figure 11 is linear regression results regardless of gender, linear regression formula Age=81.795*E-0.021*SDNN, R^2=0.9825.

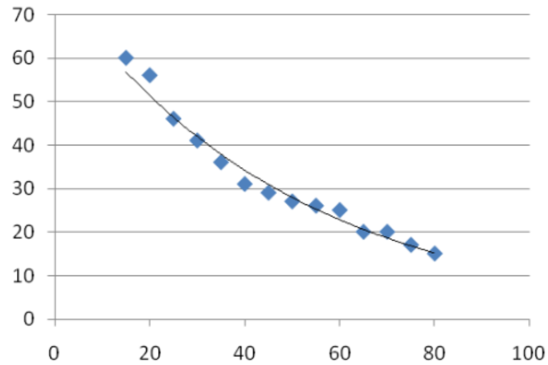

Figure 9, HRV age regression plot for male group.

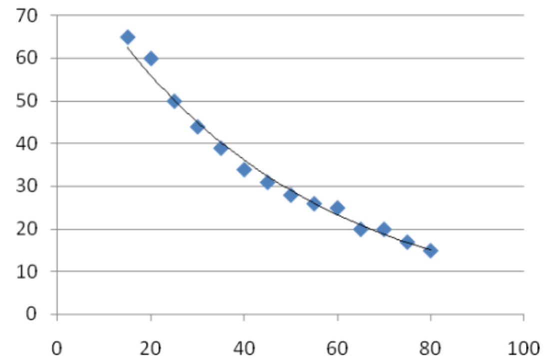

Figure 10, HRV age regression plot for female group.

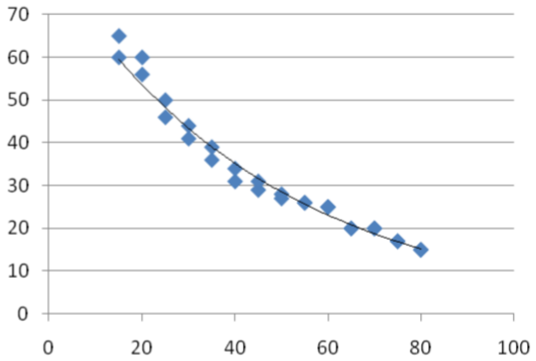

Figure 11, HRV age regression plot for all group.

IV. Conclusion

This study uses ANS Watch to calculate the HRV age model of men and women, which can be subsequently applied to wearable physiological monitoring devices, which will be very helpful for health monitoring.

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