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Applying the Distributional Data Analysis Tool of Heart Rate Density with Collected Daily Heart Rate Data from the Past 10-Years from a Type-2 Diabetes Patient to Investigate a Part of Heart Health Conditions Based on GH-Method: Math-Physical Medicine (No. 514)

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Abstract

Recently, the author conducted a series of medical research projects by applying a distributional data density analysis tool on his glucose, weight, blood pressure, and heart conditions by using his collected big data regarding certain biomarkers over the past multiple years. In this article, he only utilizes the collected biomarker data, resting heart rate in early morning, from himself, where the data covers a long time span of 7.5 years for this particular study. Furthermore, he can interpret the results and explore more information since he is most familiar with his own health conditions. The finding regarding his own body is definitely applicable to other patients. The main purpose of writing this series of research articles is to demonstrate the applicability and power of using this specific distributional data density analysis tool.

In the past, when he researched certain biomarkers and their relationships with other influential factors, such as body weight, fast plasma glucose (FPG), food consumption quantity, he mostly used the average values of those biomarkers. However, we know that most biomarkers like body weight glucose and heart rate would fluctuate along the time scale in the form of a "wave". Waves have one common key factor of the "amplitude" from this particular biomarker, where two other key factors are needed for frequency and wavelength. Therefore, without focusing on the biomarker waveform and depending only on its mean value, we lose many vital, interesting, and useful hidden information. This type of mean value, such as HbA1C, or sparsely collected finger-pierced glucose or blood lipid data from quarterly lab testing can only provide partial views of health conditions. However, those biomarkers still have some missing information that carries certain hidden internal turmoil or vital signs, e.g. biomarker variations or its severe stimulations due to all types of external and/or internal stimulators. By applying this basic knowledge of distributional data analysis, he has defined a new term known as the "general biomarker density or Bio-density% (BMD%)" in order to explore additional, different, deeper and useful hidden information in the collected biomarker data and their associated waveforms.

The term of heart-rate density (HRD) is defined as the occurrence frequency at a specific person's heart rate value, for example 8.58% occurrence rate at 55 bpm heart beat value for the author. In this way, he can then calculate and examine each heart rate's occurrence rate within a heart rate range of 44 bpm to 107 bpm over the past 7.5 years. The selected time span of 7.5 years is dependent on the study which is suitable to specific patients (in this case, himself). He started to track his resting heart rate in the early morning since 4/1/2014. By examining the changes of the peak heart rate value with their associated HRD% from year to year, he can easily observe his "heart rate" situation's moving trend and understand his actual health problems or necessary health improvement effort clearly.

As a matter of fact, he has been aware that his resting heart rate is slower; however, until now, through the use of his developed HRD analysis tool, ***he is shocked to discover that his normal heart rates occupy only around 1/3 of the time (actually 36%) while his low (below normal) heart rates dominate approximately 2/3 of the time (actually 64%) over the past 7.5 years. This finding fact***

provides a warning in regard to his potential of having "bradycardia". This numerical exercise also demonstrated to him the power and usefulness of density % tools.

The above description provides the reason he keeps searching for applicable tools to analyze collected big data of any biomarker. If this type of biomarker examination method is accepted by the medical community, it can be an extremely beneficial tool for doctors to quickly study the health conditions of their patients. Furthermore, the author programmed this algorithm into an iPhone APP software. Through the combination of his publishes papers and medical books along with a widely distributed APP for patient's use in the future, he believes that worldwide chronic diseases patients can benefit from his research work. Hopefully, his research papers would not be limited within the scope of a "descriptive style using 26 alphabets" but instead as a "quantitative style using 10 digits". Numbers do not lie as long as we don't use fake, unorganized, and/or uncleaned data. Statistics is a tricky tool to use for any research work because it has the obvious characteristics of garbage in and garbage out (GIGO). It is also important to know that by using statistics with different selected time-windows for certain studies will result into varying conclusions.

In summary, the author has chosen to perform his research work using the tools of ***Heart Rate Density % (HRD%) with his collected resting heart rate data which is measured every morning when he wakes up and while resting in bed*** over the past 7.5 years (4/1/2014 - 9/13/2021).

He has selected a consistent resting heart rate range covering 44 bpm to 107 bpm with an equal interval of 1 bpm with a total of 64 heart rate points on the x-axis, in order to express his heart rate density % diagram and heart rate density % amplitude on the y-axis (between 0% and 8.58%).

By using his developed APP software program on the iPhone, he can then generate and display these heart rate density data and heart rate density curves.

Through a closer examination of each diagram in this article, he can describe the following conclusive statements:

His normal heart rates occupy only around 1/3 of the time (actually 36%), while his low (below normal) heart rates dominates approximately 2/3 of the time (actually 64%) over the past 7.5 years. This finding fact provides a warning to him that he may have "bradycardia".

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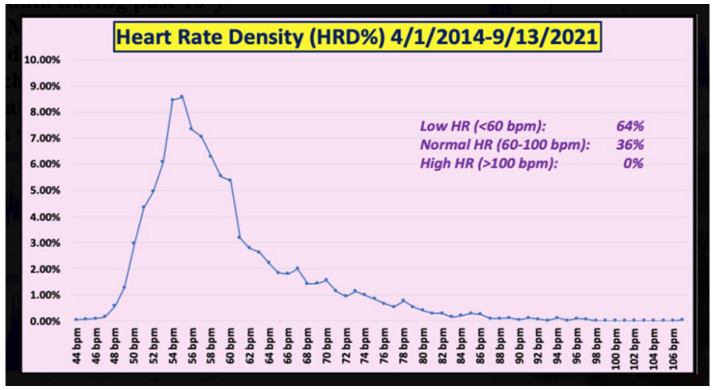
Performing the research in this article has identified one particular potential problems related to his heart, which provided guidance in understanding his overall health conditions.



Introduction

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Methods

MPM Background

To learn more about his developed GH-Method: math-physical medicine (MPM) methodology, readers can read the following three papers selected from his ~500 published medical papers.

The first paper, No. 386 describes his MPM methodology in a general conceptual format. The second paper, No. 387 outlines the history of his personalized diabetes research, various application tools, and the differences between biochemical medicine (BCM) approach versus the MPM approach. The third paper, No. 397 depicts a general flow diagram containing ~10 key MPM research methods and different tools.

In particular, his paper No. 453 illustrates his GH-Method: math-physical medicine in great details, "Using Topology concept of mathematics and Finite Element method of engineering to develop a mathematical model of Metabolism in medicine in order to control various chronic diseases and their complications via overall health conditions improvement".

The Author'S Case of Diabetes and Complications

The author has been a severe T2D patient since 1996. He weighed 220 lb. (100 kg, BMI 32.5) at that time. By 2010, he still weighed 198 lb. (BMI 29.2) with an average daily glucose of 250 mg/dL (HbA1C of 10%). During that year, his triglycerides reached to 1161 (diabetic retinopathy or DR) and albumin-creatinine ratio (ACR) at 116 (chronic kidney disease or CKD). He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him regarding his needs of kidney dialysis treatment and future high risk of dying from severe diabetic complications. Other than cerebrovascular disease (stroke), he has suffered most known diabetic complications, including both macro-vascular and micro-vascular complications.

In 2010, he decided to launch his self-study on endocrinology, diabetes, and food nutrition in order to save his own life. During 2015 and 2016, he developed four prediction models related to diabetes conditions: weight, PPG, fasting plasma glucose (FPG), and A1C. As a result, from using his developed mathematical metabolism index (MI) model in 2014 and the four prediction tools, by end of 2016, his weight was reduced from 220 lbs. (100 kg, BMI 32.5) to 176 lbs. (89 kg, BMI 26.0), waistline from 44 inches (112 cm, nonalcoholic fatty liver disease /NAFLD) to 33 inches (84 cm), average finger glucose reading from 250 mg/dL to 120 mg/dL, and lab-tested A1C from 10% to ~6.5%. One of his major accomplishments is that he no longer takes any diabetes medications since 12/8/2015.

In 2017, he has achieved excellent results on all fronts, especially his glucose control. However, during the pre-COVID period of 2018 and 2019, he traveled to approximately 50+ international cities to attend 65+ medical conferences and made ~120 oral presentations. This hectic schedule inflicted damage to his diabetes control, through dinning out frequently, post-meal exercise disruption, jet lag, and along with the overall metabolism impact due to his irregular life patterns through a busy travel schedule; therefore, his glucose control and overall metabolism state were somewhat affected during this two-year heavier traveling period.

During 2020 with a COVID-19 quarantined lifestyle, not only has he published ~400 medical papers in 100+ journals, but he has also reached his best health conditions for the past 26 years. By the beginning of 2021, his weight was further reduced to 165 lbs. (BMI 24.4) along with a 6.1% A1C value (daily average glucose at 105 mg/dL), without having any medication interventions or insulin injections. These good results are due to his non-traveling, low-stress, and regular daily life routines. Due to his knowledge of chronic diseases, practical lifestyle management experiences, and developed various high-tech tools contribute to his excellent health status since 1/19/2020, which is the start date of being self-quarantined.

On 5/5/2018, he applied a CGM sensor device on his upper arm and checks glucose measurements every 5 minutes for a total of ~288 times each day. He has maintained the same measurement pattern to present day. In his research work, he uses the CGM sensor glucose at time-interval of 15 minutes (96 data per day). By the way, the difference of average sensor glucoses between 5-minute intervals and 15-minute intervals is only 0.4% (average glucose of 114.81 mg/dL for 5-minutes and average glucose of 114.35 mg/dL for 15-minutes with a correlation of 93% between these two sensor glucose curves) during the period from 2/19/20- to 8/13/21.

Therefore, over the past 11 years, he could study and analyze the collected 2+ million data regarding his health status, medical conditions, and lifestyle details. He applies his knowledge, models, and tools from mathematics, physics, engineering, and computer science to conduct his medical research work. His medical research work is based on the aims of achieving both "high precision" with "quantitative proof" in the medical findings.

The following timetable provides a rough sketch of the emphasis of his medical research during each stage:

- 2000-2013: Self-study diabetes and food nutrition, developing a data collection and analysis software.
- 2014: Develop a mathematical model of metabolism, using engineering modeling and advanced mathematics.
- 2015: Weight & FPG prediction models, using neuroscience.
- 2016: PPG & HbA1C prediction models, using optical physics, artificial intelligence (AI), and neuroscience.
- 2017: Complications due to macro-vascular research such as cardiovascular disease (CVD), coronary heart disease (CHD) and stroke, using pattern analysis and segmentation analysis.
- 2018: Complications due to micro-vascular research such as chronic kidney disease (CKD), bladder, foot, and eye issues such as diabetic retinopathy (DR).
- 2019: CGM big data analysis, using wave theory, energy theory, frequency domain analysis, quantum mechanics, and AI.
- 2020: Cancer, dementia, longevity, geriatrics, DR, hypothyroidism, diabetic foot, diabetic fungal infection, linkage between metabolism and immunity, and learning about certain infectious diseases such as COVID-19.
- 2021: Applications of linear elastic glucose theory (LEGT) and perturbation theory from quantum mechanics on medical research subjects, such as chronic diseases and their complications, cancer, and dementia. Using metabolism and immunity.it's as the base, he expands his research into cancers, semantic, and COVID-19.

To date, he has collected more than two million data regarding his medical conditions and lifestyle details. In addition, he has written 498 medical papers and published 400+ articles in 100+ various medical journals, including 6 special editions with selected 20-25 papers for each edition. Moreover, he has given ~120 presentations at ~65 international medical conferences. He has continuously dedicated time and effort on medical research work and shared his findings and learnings with other patients worldwide.

Bradycardia

The following paragraphs is an excerpt from Mayo Clinic online publications:

"Overview

A normal resting heart rate for adults ranges from 60 to 100 beats per minute. Generally, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness.

Bradycardia is a slower than normal heart rate. The hearts of adults at rest usually beat between 60 and 100 times a minute. If you have bradycardia (brad-e-KAHR-dee-uh), your heart beats fewer than 60 times a minute. Bradycardia can be a serious problem if the heart doesn't pump enough oxygen-rich blood to the body. For some people, however, bradycardia doesn't cause symptoms or complications.

Symptoms

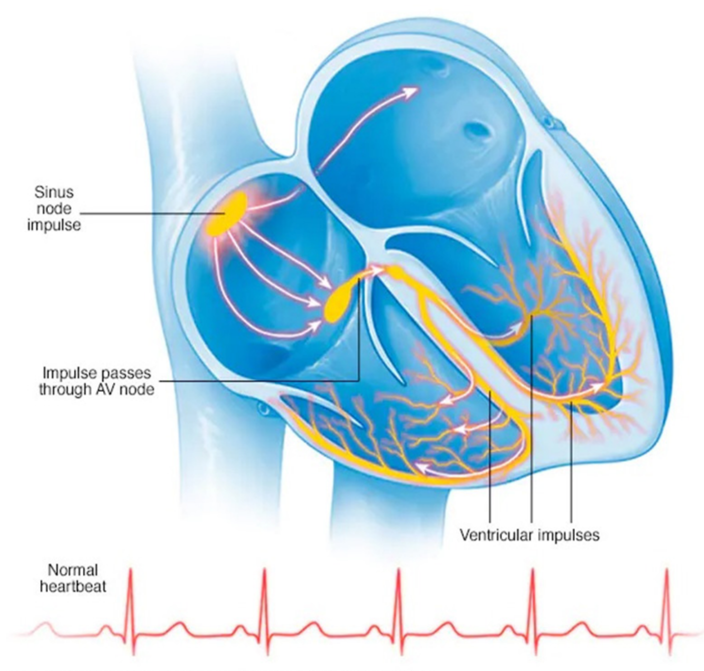
If you have bradycardia, your brain and other organs might not get enough oxygen, possibly causing these symptoms:

- Near-fainting or fainting (syncope)
- Dizziness or lightheadedness
- Fatigue
- Shortness of breath
- Chest pains
- Confusion or memory problems
- Easily tiring during physical activity

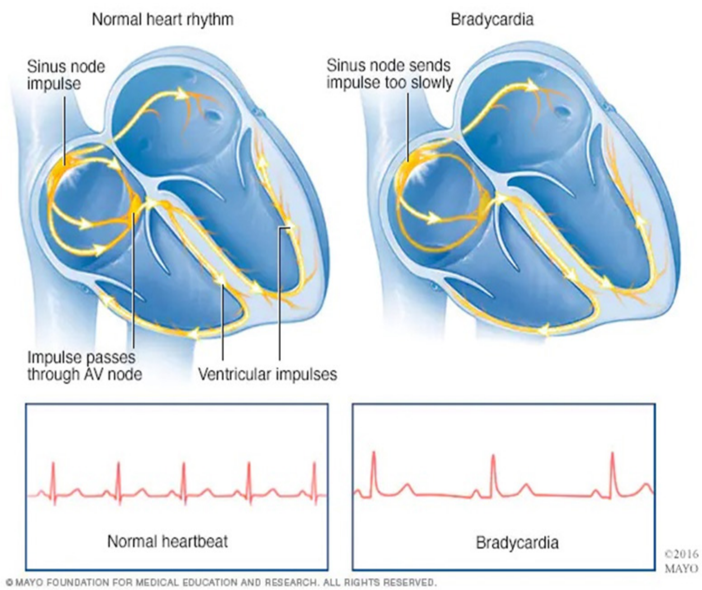
When a slow heart rate is normal?

A resting heart rate slower than 60 beats a minute is normal for some people, particularly healthy young adults and trained athletes. For them, bradycardia isn't considered a health problem.

Causes



Normal heartbeat



Bradycardia

Bradycardia can be caused by:

- Heart tissue damage related to aging
- Damage to heart tissues from heart disease or heart attack
- Heart disorder present at birth (congenital heart defect)
- Infection of heart tissue (myocarditis)
- A complication of heart surgery
- Underactive thyroid gland (hypothyroidism)
- Imbalance of chemicals in the blood, such as potassium or calcium
- Repeated disruption of breathing during sleep (obstructive sleep apnea)
- Inflammatory disease, such as rheumatic fever or lupus
- Medications, including some drugs for other heart rhythm disorders, high blood pressure and psychosis

Electrical circuitry of the heart

Your heart comprises four chambers — two upper (atria) and two lower (ventricles). A natural pacemaker (the sinus node), situated in the right atrium, normally controls your heart rhythm by producing electrical impulses that initiate each heartbeat.

These electrical impulses travel across the atria, causing them to contract and pump blood into the ventricles. Then these impulses arrive at a cluster of cells called the atrioventricular (AV) node.

The AV node transmits the signal to a collection of cells called the bundle of His. These cells transmit the signal down a left branch serving the left ventricle and a right branch serving the right ventricle, which causes the ventricles to contract and pump blood — the right ventricle sending oxygen-poor blood to the lungs and the left ventricle sending oxygen-rich blood to the body.

Bradycardia occurs when electrical signals slow down or are blocked.

Sinus node problems

Bradycardia often starts in the sinus node. A slow heart rate might occur because the sinus node:

- Discharges electrical impulses slower than is normal
- Pauses or fails to discharge at a regular rate
- Discharges an electrical impulse that's blocked before causing the atria to contract

In some people, the sinus node problems result in alternating slow and fast heart rates (bradycardia-tachycardia syndrome).

Heart block (atrioventricular block)

Bradycardia can also occur because electrical signals transmitted through the atria aren't transmitted to the ventricles (heart block, or atrioventricular block).

Heart blocks are classified based on the degree to which signals from the atria reach your heart's main pumping chambers (ventricles).

- First-degree heart block. In the mildest form, all electrical signals from the atria reach the ventricles, but the signal is slowed. First-degree heart block rarely causes symptoms and usually needs no treatment if there's no other abnormality in electrical signal conduction.
- Second-degree heart block. Not all electrical signals reach the ventricles. Some beats are "dropped," resulting in a slower and sometimes irregular rhythm.
- Third-degree (complete) heart block. None of the electrical impulses from the atria reaches the ventricles. When this happens, a natural pacemaker takes over, but this results in slow and sometimes unreliable electrical impulses to control the beat of the ventricles.

Risk factors

Age

A key risk factor for bradycardia is age. Heart problems, which are often associated with bradycardia, are more common in older adults.

Risk factors related to heart disease

Bradycardia is often associated with damage to heart tissue from some type of heart disease.

Therefore, factors that increase your risk of heart disease can also increase the risk of bradycardia. Lifestyle changes or medical treatment might decrease the risk of heart disease associated with the following factors:

- High blood pressure
- Smoking
- Heavy alcohol use
- Recreational drug use
- Psychological stress or anxiety

Complications

If bradycardia causes symptoms, possible complications can include:

- Frequent fainting spells
- Inability of the heart to pump enough blood (heart failure)
- Sudden cardiac arrest or sudden death

Prevention
The most effective way to prevent bradycardia is to reduce your risk of developing heart disease. If you already have heart disease, monitor it and follow your treatment plan to lower your risk of bradycardia.

Prevent heart disease
Treat or eliminate risk factors that may lead to heart disease. Take the following steps:

- Exercise and eat a healthy diet. Live a heart-healthy lifestyle by exercising regularly and eating a healthy, low-fat, low-salt, low-sugar diet that's rich in fruits, vegetables and whole grains.
- Maintain a healthy weight. Being overweight increases your risk of developing heart disease.
- Keep blood pressure and cholesterol under control. Make lifestyle changes and take medications as prescribed to correct high blood pressure (hypertension) or high cholesterol.
- Don't smoke. If you smoke and can't quit on your own, talk to your doctor about strategies or programs to help you break a smoking habit.
- If you drink, do so in moderation. For healthy adults, that means up to one drink a day for women of all ages and men older than age 65, and up to two drinks a day for men age 65 and younger.

Ask your doctor if your condition means you should avoid alcohol. If you can't control your alcohol use, talk to your doctor about a program to quit drinking and manage other behaviors related to alcohol abuse.

- Don't use recreational drugs. Talk to your doctor about an appropriate program for you if you need help ending recreational drug use.
- Manage stress. Avoid unnecessary stress and learn coping techniques to handle normal stress in a healthy way.
- Go to scheduled checkups. Have regular physical exams and report signs or symptoms to your doctor."

Heart Rate Density (HRD)
For the case of one particular patient i, the collected biomarker data can be expressed by pairs of data in the format of (t_{ij}, X_{ij}), j = 1 … T, where the t_{ij} represent recording times and X_{ij} is the biomarker level at time instant t_{ij}, and T is the overall observation length of weight. *For the case in this article, the total T is 64 (e.g. from 44 bpm to 107 bpm with an equal interval of 1 bpm between two heart rate end-points).*

Therefore, he can describe the above mathematical problem into a more simplified equation for one patient only. The ***heart rate % (HRD% or D%)*** for one patient can be defined in terms of a continuous format as follows:

$$D(x) = \left(\int_{1}^{T} Y(t)\, dt\right) / T$$

with $x1 < Y(t) < x2$

where x1 and x2 are ∫ boundaries of his selected heart rate range.

The heart rate density % (HRD% or D%) equation for one patient, such as himself, can also be defined in terms of ***a discrete format*** as follows:

$$D(x) = \left(\sum_{j=1}^{T} Y(t_j)\right) / T$$

with $x1 < Y(t) < x2$

where x1 and x2 are boundaries of his selected heart rate range.

He then develops his APP software program using the above-described algorithm.

Results
Figure 1 shows his resting heart rate measured on his bed each early morning once he wakes up from a period of 7.5 years (from 4/1/2014 to 9/13/2021). This time-domain figure contains the daily heart rate, 90-days moving average heart rate, and the combination of two heart rates into one diagram. It should be pointed out that the average heart rate (mean value) of 57 bpm or 58 bpm would miss the vital heart rate wave fluctuation. More importantly, other than knowing his heart rates are generally slow, he had no idea that actually 2/3 of his total heart rates are below 60 bpm.

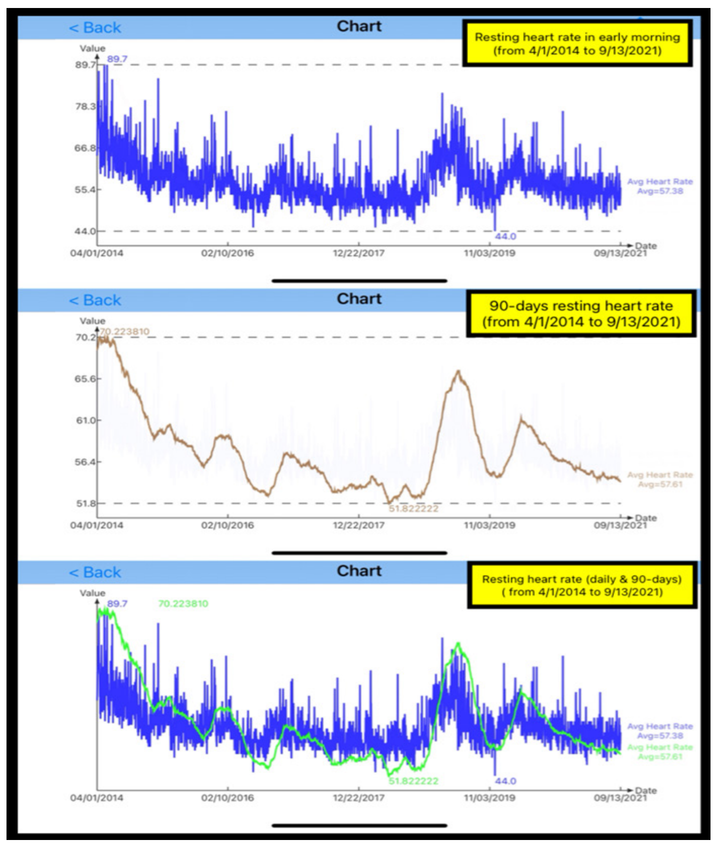


Figure 1: Time-domain of resting heart rates of 7.5 years (4/1/2014 - 9/13/2021)

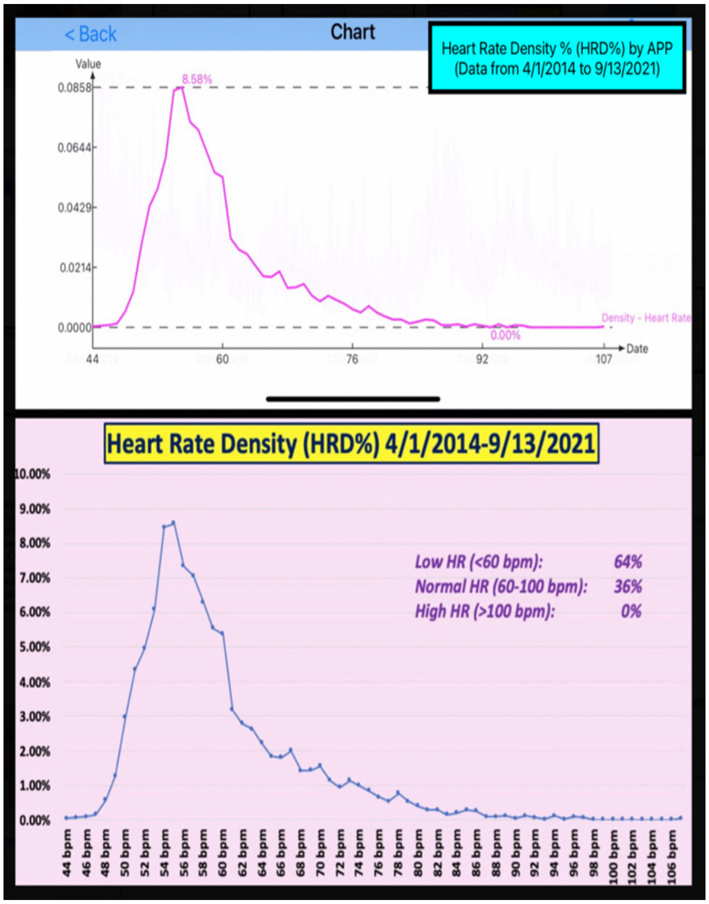


Figure 2: Density-domain of resting heart rate (4/1/2014 - 9/13/2021)

Figure 2 illustrates the density-domain diagram of his resting heart rates from 4/1/2014 to 9/13/2021. The top diagram is generated by using his developed APP on the iPhone. The bottom diagram is produced by using Excel on the PC based on his original data of resting heart rate. The key finding in Figure 2 is that ***his normal heart rates occupy only around 1/3 of the time (actually 36%,) while his low (below normal) heart rates dominates approximately 2/3 of the time (actually 64%) over the past 7.5 years.***

Conclusions

In summary, the author has chosen to perform his research work using the tools of ***Heart Rate Density % (HRD%)*** with his collected ***resting heart rate data which is measured every morning when he wakes up and while resting in bed*** over the past 7.5 years (4/1/2014 - 9/13/2021).

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References

For editing purposes, majority of the references in this paper, which are self-references, have been removed for this article. Only references from other authors' published sources remain. The bibliography of the author's original self-references can be viewed at www.eclairemd.com.

Readers may use this article as long as the work is properly cited, and their use is educational and not for profit, and the author's original work is not altered.

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