

Proposed Analytical Method for Assessing Individual Benefit: a Case Study

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Abstract Exercise often improves health status as evidenced by improvements in physiological measures such as heart rate variability. With modern technology, such as heart rate apps for smartphones, an individual can track his or her own data on a daily basis. They may also go a step further and enter their data into a spreadsheet for further analysis. In this way they can study their own data, e.g., when a change in training occurs, to see if there is a benefit following the change. The present case study provides an example of how the approach can be used

Keywords: Exercise, heart rate variability, self-measurement, health

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1. Introduction

Training in various sport-related activities is often directed at improving performance in those activities. For example, runners may seek to improve their speed and / or distance endurance. A common side-benefit of the training is improved health status. Running, for example, improves the health of the autonomic nervous system (ANS), evidenced by improved heart rate variability (HRV) testing [1]. This is important because the ANS controls many vital functions such as heart rate and digestion. Consequently, a healthy ANS is an important prerequisite for a long and healthy life [2,3].

HRV pertains to the time between heartbeats. Normally this time varies a bit in neurologically healthy individuals. This is different from the problem of irregular heart rate observed in arrhythmia. HRV is the natural and normal fluctuation of time between beats and indicates how dynamic, adaptive, and resilient the individual's autonomic nervous system is. Stating it another way, HRV assesses how quickly the ANS can “switch gears” as needed, to coordinate optimum function. HRV can be conveniently assessed with daily measurements thanks to user-friendly technology that allows people to measure and collect their own data [4].

One of the measures in HRV is the root mean square of successive differences, abbreviated as rMSSD. It is a *time domain* metric, measured in milliseconds (ms), and used in the present study. Larger rMSSD values reflect a healthier, more adaptive ANS compared to smaller values [5]. In this report the terms HRV and rMSSD are used interchangeably.

The purpose of this study is to provide an example of how potential benefits can be assessed when a training routine is changed, using the evidence-based measure of HRV.

2. Methods

This project meets the *exempt* criteria determined by the Institutional Review Board at Purdue University Global (PUG) as defined by the DHHS Regulations for the Protection of Human Subjects (45 CFR 46); and is also in compliance with PUG's Federal Wide Assurance 00010056.

Procedures

A total of 36 consecutive days in 2023 are studied with one early morning HRV measurement per day. Data collection ended and groups were formed when they all reached a normal distribution.

Running

The author in this study has been a runner since 2016 and serves as the subject, as well as data collector and analyzer. On July 19, 2023, I made a minor modification in my running practice routine. Specifically, I changed my warm-up from a *continuous* 1-mile run to an *interval-type* 1-mile run. The change was made to see if it would help me slow down a bit at the beginning of a race. Previously, my over-ambition at the beginning of a race tends to cause early exhaustion. The method worked for me the first time I tried it in a race (Milledge Mile in Athens, Georgia, on July 29, 2023; felt great the whole distance).

HRV protocol

HRV was measured daily while in the supine position early in the morning before getting out of bed for the day. The readings were obtained with the smartphone app known as Camera Heart Rate Variability [6]. The app uses photoplethysmography (PPG) technology, where the user's finger is placed over the light and camera on the back of a smartphone that has the app installed (Figure 1). The set-up has good agreement with ECG technology [6,7]. The measurements were obtained under the following controlled conditions:

- Minimum of 5-minutes rest in the supine position prior to taking the reading, to achieve a true rested state, and
- 1-minute recording, continuing in the rested state and supine position.

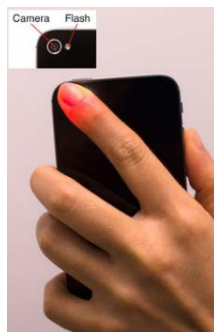


Figure 1. Finger on back of a smartphone for measuring and recording heart rate. Image courtesy of Chan *et al* [8].

Data analysis

Analysis began in late July 2023 when I noticed the rMSSD metric increasing (improving) compared to my previous readings. Then I looked to see what, if any changes were made to my running routine. A key difference was the warm-up method described above. At that point there were 10 consecutive daily HRV measurements following the date of the training modification, which occurred on July 18, 2023. Consequently, the first HRV measurement to be used in the group of readings that followed the modification (now referred to as the *Post* group), was the July 19, 2023 reading. I then wanted to compare the *Post* group to two other groups, with the same number of readings (and days) in each group, to cover a 30-day study period. The 10 readings immediately prior to the modification are referred to as the *Pre 2* group, and the 10 before *Pre 2* is the *Pre 1* group (Table 1, Figure 2).

One of these groups, *Pre 2*, failed to show a normal data distribution according to the Kolmogorov-Smirnov (KS) test ($p < 0.05$). A reasonably normal distribution is required for the parametric test I wanted to use, the independent samples *t* test. And so, my next goal was to keep collecting new data until all three groups showed normal distribution. This occurred with only two additional measurements, bringing the number of measurements in each group to 12 ($p > 0.05$).

The three groups were compared to each other in the

stat software program, InStat 3.10 (9). Consequently, three *t* tests were performed comparing the groups as follows:

Pre 1 vs Pre 2

Pre 1 vs Post

Pre 2 vs Post

Two-tailed *p*-values from the *t* test that were < 0.05 were considered statistically significant while those ≥ 0.05 were considered not statistically significant. For readers who subscribe to the potential problem of multiple testing, where a statistically significant *p*-value might randomly occur, the Bonferroni-corrected alpha would be 0.0167 (calculated with: conventional alpha of 0.05 / 3 *t* tests = 0.0167). In addition, effect size was calculated to assess the magnitude of group differences, using the pooled standard deviation method. An effect size of 0.01 - 0.19 is considered small, 0.20 - 0.49 moderate, and 0.50 or greater as a large effect [10].

Table 1. Raw data, with 12 measurements in each of the three groups

Date	rMSSD	Group
6/25/23	29.0	Pre 1
6/26/23	29.6	Pre 1
6/27/23	38.5	Pre 1
6/28/23	27.2	Pre 1
6/29/23	22.6	Pre 1
6/30/23	19.9	Pre 1
7/1/23	26.5	Pre 1
7/2/23	28.5	Pre 1
7/3/23	24.0	Pre 1
7/4/23	41.8	Pre 1
7/5/23	22.0	Pre 1
7/6/23	34.8	Pre 1
7/7/23	32.1	Pre 2
7/8/23	24.3	Pre 2
7/9/23	22.9	Pre 2
7/10/23	22.6	Pre 2
7/11/23	36.5	Pre 2
7/12/23	38.6	Pre 2
7/13/23	26.9	Pre 2
7/14/23	36.3	Pre 2
7/15/23	37.4	Pre 2
7/16/23	25.3	Pre 2
7/17/23	36.4	Pre 2
7/18/23	31.8	Pre 2
7/19/23	38.2	Post
7/20/23	26.0	Post
7/21/23	28.0	Post
7/22/23	49.0	Post
7/23/23	33.1	Post
7/24/23	32.5	Post
7/25/23	46.2	Post
7/26/23	53.2	Post
7/27/23	38.3	Post
7/28/23	40.8	Post
7/29/23	39.3	Post
7/30/23	42.3	Post

rMSSD is the HRV metric.

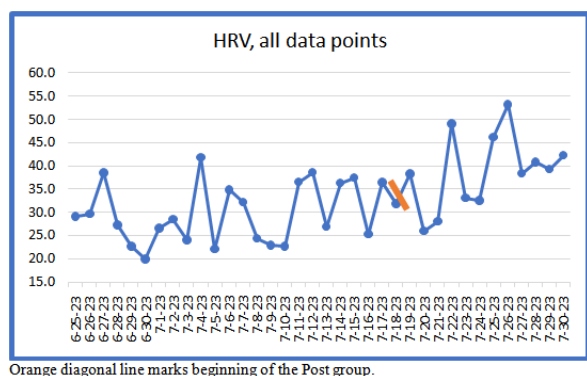


Figure 2. All HRV data points

3. Results

Equal variance was observed between groups ($p > 0.05$) allowing the use of the equal variance option of the independent samples t test.

The Post group showed the highest (best) mean, 38.9 ms, compared to 28.7 ms in Pre 1 and 30.9 ms in Pre 2 (Table 2, Figure 3). Stating it another way, Pre 1 versus Pre 2 showed a difference of only 2.2 ms; while the difference was considerably larger between Post versus Pre 1, and Post versus Pre 2: 10.2 ms and 8.0 respectively (Table 2).

Table 2. Mean (standard deviation [SD]) by group.

Group	Mean	SD
Pre 1	28.7	6.7
Pre 2	30.9	6.2
Post	38.9	8.2

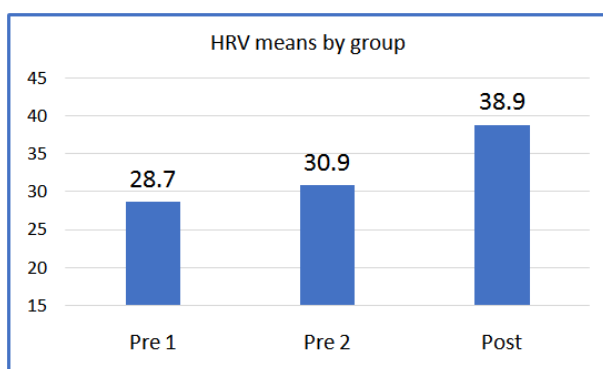


Figure 3. Means by group in chart format.

Mean differences were statistically significant ($p < 0.05$ or 0.0167) according to the t test only in comparisons that involved the Post group. As well, effect sizes were very large (> 1.0) for these comparisons (that involved the Post group) (Table 3).

Table 3. t test and effect size (ES) results

Group comparison	p-value	ES
Pre1 vs Pre2:	0.4046	0.3
Pre1 vs Post	0.0029	1.4
Pre2 vs Post	0.0131	1.1

4. Discussion

The method used in this study is one possible way to

determine potential benefits following a training change. In this case study, the best heart rate variability findings were observed following the training change compared to baseline.

The exact mechanism of improved HRV from running is currently somewhat unclear but relates to the nervous system becoming more parasympathetic dominant. This in turn allows for a healthier, more adaptive autonomic nervous system [1].

The present study is like a previous study of mine where I compared resting heart rate (RHR) between different types of running. That study showed significant improvement (decrease) in RHR when Fleet Feet group training (of Greenville, SC) was added to my routine ($p < 0.05$) [11]. In the present study, RHR was statistically the same across all three groups. In the earlier study [11], HRV was not assessed because I was not measuring it at that time.

A strength of the present case study is that measurements were obtained daily, thereby allowing a strong pre-intervention baseline to compare to. Another strength is that a true resting state was achieved prior to, and during the finite 1-minute measurement period. These controls allow for a valid (apples-to-apples) comparison between groups.

Another strength of the study is that the method of analysis may be useful to assess efficacy of training methods regarding performance. For example, a runner may have 1-mile run times recorded *before* versus *after* a change in training such as doing longer runs.

Heart rate variability is one of many numerical, evidence-based predictors of health available to individuals. One of the advantages of having information in the form of numerical data is that it allows for objective statistical analysis. This in turn helps to objectively guide the individual on questions of potential benefits from changes in his or her training routine.

Limitations

Potential bias is present in the form of the author being the participant, data collector, and analyzer. Nonetheless, the raw data is presented in this paper so others can verify the findings.

Twelve data points per group represents small sample sizes. However, this type of research design is intended to quickly answer research questions an individual may have regarding training changes. If statistical requirements are met (e.g., normal distribution of the data), then small sample sizes would seem to become less of a potential issue.

Finally, since this is a case study of one individual, results may or may not apply to other runners.

5. Conclusion

This case study provides an example of how possible benefits from a training change can be statistically analyzed at the level of the individual. The study in this case showed improvement in heart rate variability following a change in running routine. Further research of other individuals and their training modifications is a reasonable next step.

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