PRELIMINARY STUDY ON THE EFFECTS OF EXERCISE ON PULSE VOLUME (PV), PULSE FLOW (PF), AND COMPENSATED SHOCK INDEX (CSI) USING PULSE FLOWMETER

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ABSTRACT

This preliminary study evaluates the Pulse Flowmeter's ability to measure short-term hemodynamic changes by measuring Pulse Volume (PV), Pulse Flow (PF), and Compensated Shock Index (CSI) before and after varying exercise intensities. Measurements were taken at a resting baseline and immediately after 1 minute of hard exercise, 3 minutes of regular exercise, and 10 minutes of recovery. Results from this preliminary study of four subjects indicated that PV and PF generally increased after exercise, while CSI showed consistent decreases, suggesting cardiovascular adaptation and improved circulatory efficiency. The largest PV and PF increases occurred in the youngest and most physically active subject, whereas the most substantial CSI increase occurred in a non-exercising adult subject. While these findings suggest that the Pulse Flow Meter (PFM) is sensitive to short-term hemodynamic changes associated with exercise, further investigation using a larger and more diverse pool of participants is required before reaching concrete conclusions.

INTRODUCTION

Monitoring vital signs before and after exercise provides insight into cardiovascular and circulatory health. This study aims to assess the responsiveness of Pulse Flow Meter (PFM) in detecting dynamic physiological changes.

STUDY DESIGN

Under controlled indoor conditions, an observational study was conducted using noninvasive measurements taken by the Pulse Flowmeter. During data collection, the participants were laid flat on their back on top of a portable bed with electrodes attached to their right leg. These electrodes are never removed or tampered with throughout the whole study.

SUBJECTS

Four participants (three adults and one youth) were included in this initial study.

Subject #	Sex	Age	Weight (lb)	Height (in)	Medical History	Regular Exercise (Y/N)
1	M	56	152	66	None	Y
2	F	54	155	66	Migraines	Y
3	F	49	200	65	None	N
4	M	17	162	70	Nuss Procedure	Y

PROCEDURE

In the study, measurements were taken following four stages of varying degrees of physical activity as follows:

Stage	Description	Duration
Pre-Exercise	Preceding any physical activity, a resting measurement is taken as a baseline for comparison later in the study.	N/A
Hard Exercise	Participants exercised using a rowing machine at a fast	1 min

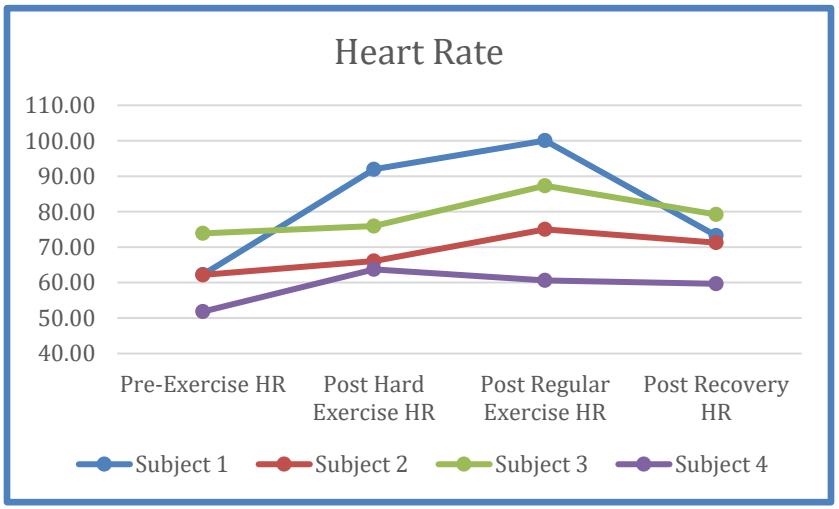
	pace to mimic a high-intense exercise.	
Regular Exercise	Participants exercised using a rowing machine at a moderate pace to mimic a regular exercise.	3 min
Recovery	Participants abstained from physical activity following the last measurement.	10 min

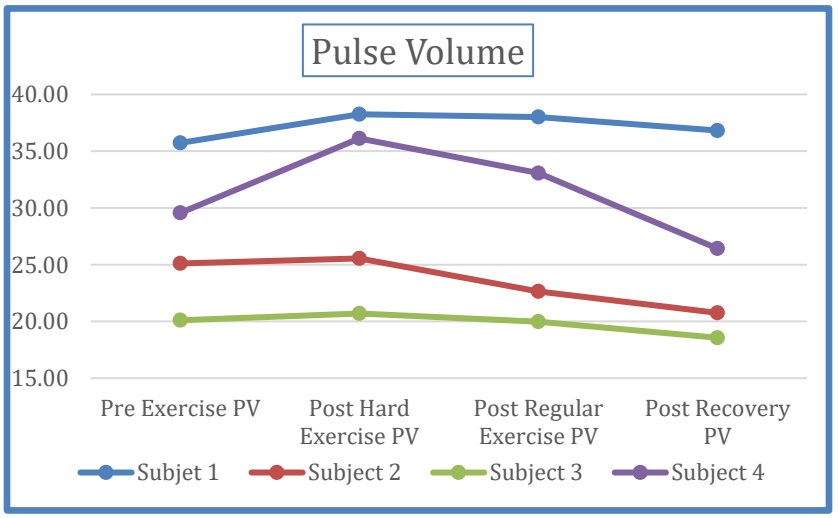
DATA COLLECTION AND ANALYSIS

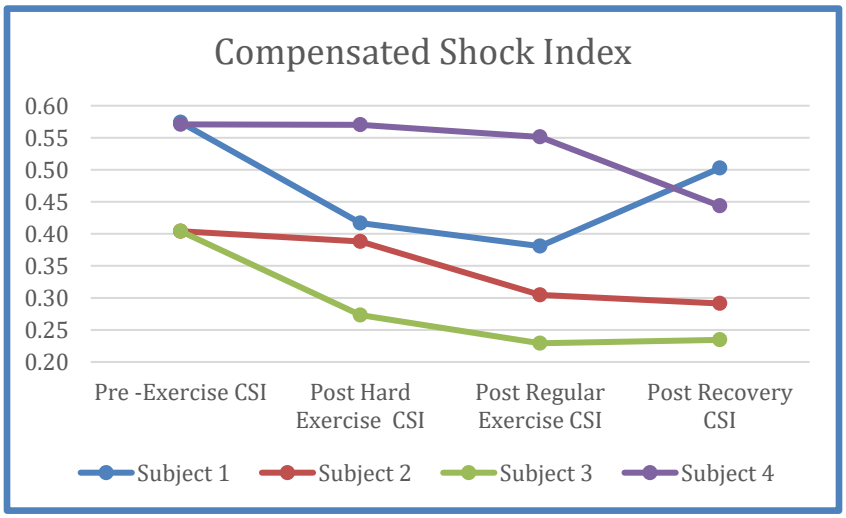
Data was sampled in real time by the PVM and then exported to a spreadsheet for offline analysis. Percentage changes in PV, PF, and CSI were calculated relative to each subject's baseline.

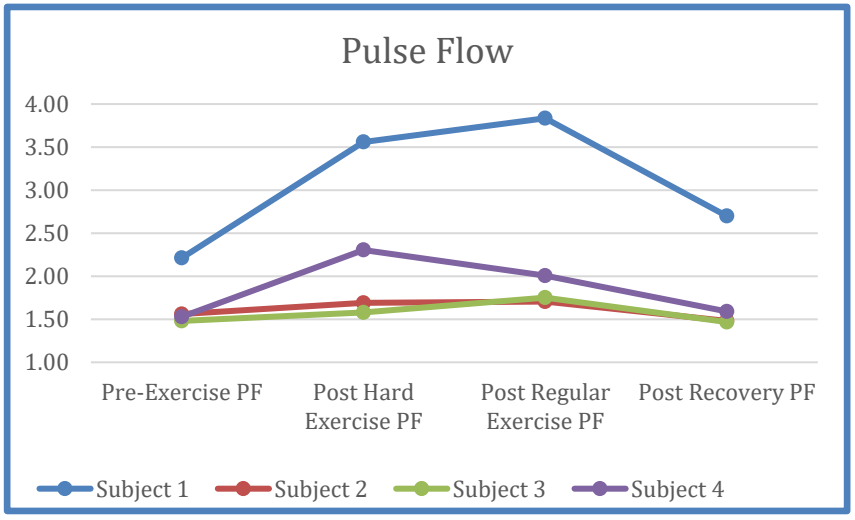
RESULTS

The raw data is summarized in the 4 graphs below. PV, PF, HR and CSI for each of the 4 subjects is shown on the 4 respective graphs, each showing the results for all 4 subjects. The average of these parameters in all 4 subjects is shown in the final graph below:

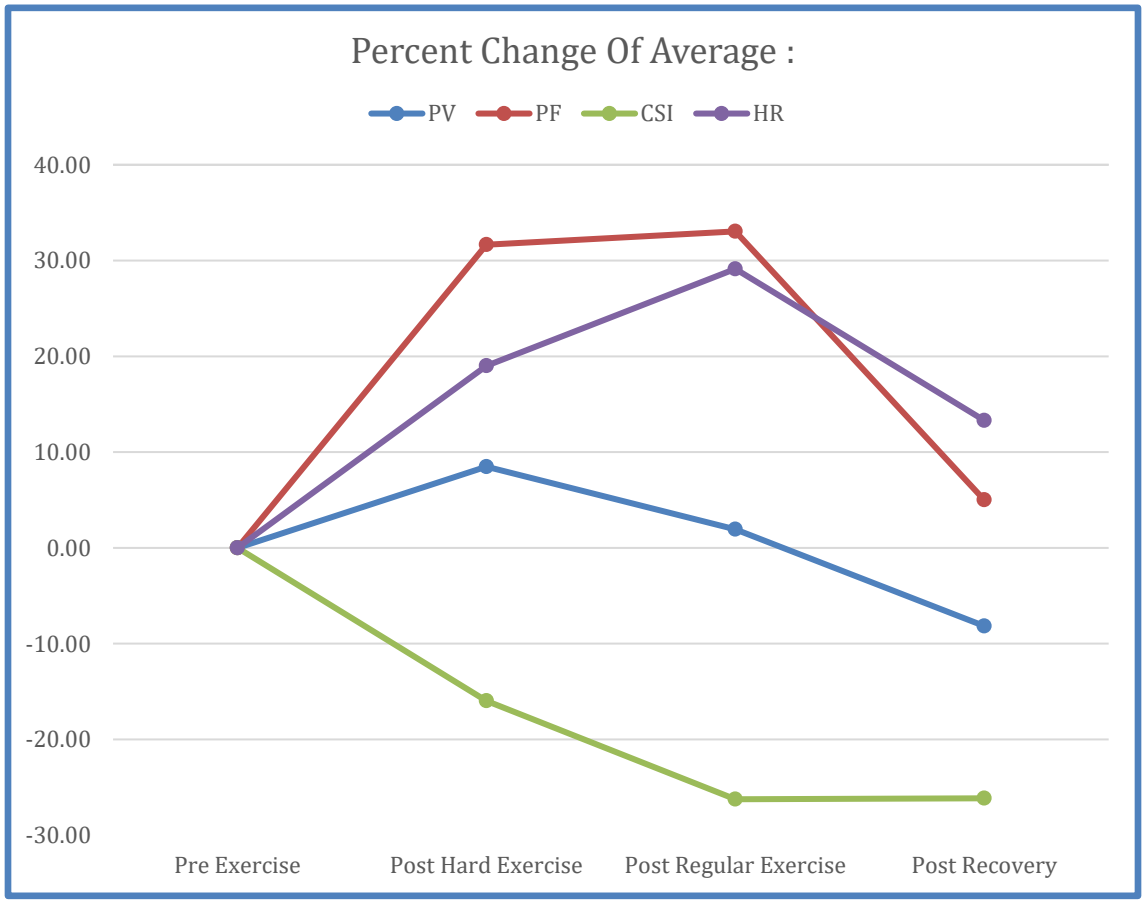








The averages of PV, PF, HR and CSI for all 4 patients are shown in the following chart. The changes in each parameter are expressed as percentage change from baseline. Thus, they all start at 0%. Now let's examine the change in each of these parameters with hard exercise, regular exercise and recovery. Notice that they are strikingly different from one another.



HEART RATE: The average HR behaved as one would expect. It increased with hard exercise, continued to increase with mild exercise (probably because the recovery period was short) and then headed back to baseline, although not completely, after the final recovery period. Undoubtedly it would have returned completely to baseline with a longer final recovery period.

PULSE VOLUME: The average PV behaved in an interesting, though not obvious, fashion as it appears to be sensitive to the hard exercise but not to the regular exercise as it recovers fully to baseline after the regular exercise, almost as if the regular exercise never even happened. And then it dips 10% below baseline after the recovery period, suggesting that the body is constricting the peripheral blood flow as it is no longer needed and overshoots a bit, a common phenomenon in physiologic systems. With a longer recovery period, it, too, should return to baseline.

PULSE FLOW: Given these observation, the average PF behaved in an unsurprising fashion. It more or less follows the HR curve but "more so." Because PF is the product of HR and PV it jumped higher that HR with hard exercise but, because PV recovered quickly, essentially ignoring the regular exercise, PF starts to recover more quickly than HR and returns almost exactly to baseline after the recovery period.

COMPENSATED SHOCK INDEX: From our studies on GI bleeders, it appears that the CSI is the most sensitive indicator of the body's cardiovascular compensatory mechanisms. One subject in a clinical trial we conducted of GI bleeders at the Mayo Clinic presented with modest upper GI bleeding, normal HR and BP and normal PFM parameters suggesting that he was stable and quite possibly had stopped bleeding by the time he was admitted. However, his CSI dropped by a huge 35% in the 30 minutes he was observed prior to going to endoscopy, suggesting that he had an ongoing active bleed -- and that was what was found at endoscopy. In the present study, the results suggest that CSI may also be the most sensitive indicator of the body's response to exercise. CSI dropped about 18% post hard exercise, continued to drop to about 25% after regular exercise and then, only barely starts to recover even after the final recovery period, suggesting that there is a physiologic process from which a prolonged recovery is required.

DISCUSSION - DOES THE RESPONSE OF PFM MEASUREMENTS CORRELATE WITH PHYSICAL FITNESS

This is difficult to answer with such a small sample and because we have no quantitative measurement of the physical fitness of these subjects. However, there were some intriguing observations. Three of the subject (#1, #2, and #4) indicated that they were engaged in regular physical exercise. Subject #3 was not. Of course, stating that you are engaged in physical exercise is not a very good way of assessing someone's physical fitness. But it is intriguing to see if there is anything that could distinguish subject #3, the supposed "couch potato," from the other subjects.

Pulse Volume - PV was the lowest in subject #3. However, it was well within the normal range. But, as opposed to the other 3 subjects, subject #3 had essentially no PV change with exercise.

Pulse Flow - Subject #3 had no change in PF with exercise - but subject #2 also had no change.

Heart Rate - Nothing terribly revealing here

Compensated Shock Index - Once again, as with our study on GI bleeders, the CSI seems to be the most sensitive parameter. In subject #3 it was lower than the other 3 subjects, dropping with from 0.40 to 0.23 with exercise, where it plateaued with no visible return to baseline during the entire study period, even after the recovery period was complete. It is well known that individuals with poor physical fitness take longer to recover from exercise than those who are fit. The persistent elevation of HR and low PV in subject #3 result in a CSI that is lower than the others.

LIMITATIONS OF THIS PILOT STUDY

Small sample size

The recovery periods were too short

The exercise was not quantified

The degree of physical fitness was not quantified

CONCLUSIONS

This was a valuable pilot study that, in the tradition of good pilot studies, generated more questions than answers and suggests that a meaningful follow-up study is indicated.

The follow-up study will need to have more subjects to provide meaningful conclusions supported by rigorous statistical analysis. As each patient is their own control, statistically meaningful data can be analyzed with paired Student's t-testing which would require about 30 subjects.

We will need a quantifiable form of exercise. A treadmill may be the best form of exercise for this. Most people are familiar with treadmill exercise and treadmill speed and duration of exercise, both quantifiable parameters can be selected. Furthermore, treadmills exercise the lower extremities where we make our measurements. The one patient in which we made measurements on before and after treadmill exercise transiently doubled his PV.

We will need a tool to grade the aerobic physical fitness of the subjects with one or more measurable parameters. It may be desirable to use the "gold-standard" for measuring aerobic capacity which is by measuring oxygen consumption.

The follow-up study should be done in conjunction with an exercise physiologist at a university after obtaining IRB approval. This will be necessary if the results are to be published in a peer reviewed journal.

If the PFM could be used as an index of physical fitness, one that would augment or even bypass the need for measuring oxygen capacity, there might be a research and even the possibility of consumer product that would be of interest to fitness facilities