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Blood Pressure Pulse Transient Time of Intermittent Fasting Subjects

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Abstract

Intermittent fasting is a phenomenon that can be observed in many cultures. The effect of intermittent fasting on pulse transient time (PPT) has not previously been investigated much. In this article, PTT is defined as the time difference between the ECG R-wave and the PPG peak. PTTs of intermittent fasting subjects are evaluated together with heart rate (HR) and systolic pressures over fasting time. Nine volunteers are involved, some of them fasted more than once resulting in 13 PTTs measurements and 100 data points. We identified three PTT patterns over the time course of fasting described by:

1) A sharp change in PTT after breakfasting.
2) Slow change of PTT over the fasting time.
3) Presence or absence of circadian rhythm in PTT curve.

Polynomials rather than cosiner functions are employed in PTT fittings.

Keywords: Intermittent Fasting, Photoplethysmography, Systolic Pressure, PTT Patterns, PTT Circadian Rhythm.

I. INTRODUCTION

Hypertension is considered as one in every of the foremost common diseases of the cardiovascular system. Overweight and obesity became a worldwide trend due to improvements of the living standards as well as changing of dietary patterns [1-3]. Because of excessive intake of high-calorie, high-fat foods at dinner, additionally to less exercise at night time, excessive heat is converted into fat stored within the body, and an outsized number of blood lipids are deposited on the vas wall, causing atherosclerosis, thus the prospect of hypertension is increased. Fasting is employed as therapy, and it's a valuable practice that's globally well-known [4].

This therapy is understood as diet therapy and it forestalls the treatment of certain diseases, except for the correct amount of drinkable and intensely low-calorie supply, during an awfully limited time [5].

Previous clinical observations and experimental studies have confirmed the weight-loss effect of this therapy on patients stricken by obesity [6-8], and so the antihypertensive effect was observed on patients suffering from hypertension [9-12] additionally, losing weight and a practicing healthy lifestyle are two favors of fasting and will give long-lasting antihypertensive effects [13].

Various forms of fasting are performed since the earlier periods, for several reasons such as of both faith and health improvement. Fasting methods are divided into two types according to continuity; these types are intermittent fasting (IF) and periodic fasting (PF). Intermittent fasting is, for example, fasting every other day or fasting twice hebdomadally. Intermittent fasting is also a spiritual commitment that is performed by many different believers worldwide. It generally involves stop consuming drink or food, broadly from before sunrise up to sunset. Additionally, they arrange themselves for hunger and thirst throughout the day. Those who will fast often arise before sunrise; have an early morning meal, and then they will return to sleep. Other individuals who fast may forego the primary meal. Intermittent fasting, therefore, lands up in temporary changes to the individual's familiar patterns of eating and sleeping. While the effect on human health of intermittent fasting is uncertain, previous studies have shown that it should have potentially beneficial effects on the prevention and treatment of diseases like obesity, type 2 diabetes, and cardiovascular diseases [14-15].

Previous animal studies have shown that sign (BP) falls during the fasting period then increases again after eating [16]. Only some clinical studies have investigated the results of intermittent fasting on BP control and course in hypertensive patients. One such study was performed by Perk et al [17], who concluded no change before and after intermittent fasting in Ambulatory Blood Pressure Monitoring (ABPM) of hypertensive patients under treatment. Ural et al investigated the course of BP before and after intermittent fasting in Stage 2–3 hypertensive patients receiving combination treatment and also determined no difference [18].

However, other than an extremely few studies of hypertensive patients, no studies have investigated the results of intermittent fasting on Blood Pressure Variability (BPV) in prehypertensive and/or newly diagnosed hypertensive patients.

One of the foremost important human vital signs that determine the system condition, still because the full human organism is a physical phenomenon, thanks to that peculiarity, the measurement of BP is one in every of the foremost commonly performed diagnostic procedures in practice.

Permanent observation of the BP level, especially in mature and maturity is critical thanks to the morning hygiene procedures.

Existing techniques developed for BP measurements are often divided into two groups, namely, the techniques of direct (invasive) and indirect (non-invasive) measurements. During direct measuring the catheterization of the system is executed, i.e. the sensor is placed directly within the arterial channel [19]. Such technique provides high accuracy and continuity of measurements; however, it's connected with a spread of risks and will be applied only in clinics under the surveillance of skilled medical staff. Non-direct or non-invasive techniques have supported by the processing and analysis of assorted values related to force per unit area [20-21]

Traditionally, these techniques use some obstacles located on the simplest way of the heartbeat wave (PW) movement within the vascular channel and measure the bloodstream reaction on this obstacle [22-23]. The obstacle means the occlusion cuff creates an external pressure, thereby changing the character of the blood flow within the area of blood vessels under the cuff and below it. Assessing these changes and comparing them with the atmospheric pressure into the cuff, one can evaluate the parameters of the vital signs.

Indirect techniques of BP measurement are much safer and convenient. However, they have disadvantages, like less accuracy and stability in measurements. They're supported by the occlusion of blood vessels by the cuff and, due to this; they cause considerable inconvenience for a patient with it pumping. Besides, they permit performing only periodical measurements in discrete time points. However, in a very number of important practical cases, just continuous and rather enduring monitoring of BP is required. Thanks to this, investigations progressing to develop new techniques for BP measurement, which don't require any occlusion by the cuff, are performed recently [24-28].

Arterial pressure is simply one parameter from a group of important vital signs (VS) data associated with the functioning of the human vascular system that's a closed regulatory system. The connections must exist between all of those values. Such VS parameters as rate (HR), pulse wave velocity (PWV), and pulse variability parameters (HRV) may be easily and accurately measured by existing devices [29-31]. By using these connections, it may be possible to perform cuff less measurement of BP with accuracy like the accuracy inherent to the "cuff measurement techniques", which allow us to consider some possibilities for solving this task. With the advancement of digital sensors, signal processing, machine learning algorithms, and improved physiologic models, pulse waveform analysis using photoplethysmography (PPG) for the assessment of pressure level (BP) has become more feasible [32-35]. There are many challenges while measuring PPG signals; it requires noise elimination, multi-site measurement, multi photodetectors development, event detection, event visualization, different models, and also a radical global health framework [336-44]. Several disadvantages are related to this method, including the necessity to conduct a personal calibration for every person, supported skin colour and clinical factors, and therefore the drift in calibration over short-time intervals [45]. The time delay between the electrical activity of the guts (ECG) and therefore the pressure level wave is a vital physiological parameter. Photoplethysmography (PPG) is typically accustomed to measure the pressure wave signal. Allen, in [46] overviewed PPG and its, historical background, electronic circuits, current technology, and application. The delay between the ECG R-wave and therefore the PPG is thought of as pulse transient time (PTT) in literature and utilized in new cuff-less pressure systems as discussed in [47]. Different pressure models supported PTT are presented in [48]; including linear, Log, inverse, and a few more, however, the linear method is that the most well-liked individualized calibrated model. The wearability feature for such a system is addressed by a replacement design of one ECG/PPG sensor [49]. The technique of cuff-less vital sign measurement isn't error-free. Motion artifacts, signal noise, missed R-wave, electrode contact failure, and other limitations are presented in sleep medicine research [50]. However, continuous vital sign measurement; can't be performed with conventional pressure devices. Tang et al [51]. developed ambulatory force per unit area monitoring supported PTT measurements. Cuff-less technology [52] under development wherein the near future it'll be available to the general public seeking a far better lifestyle and patients requiring continuous care and monitoring of vital signs.

The purpose of this study was to assess the results of intermittent fasting on PTT in normotensive subjects.

II. METHOD

In this research we used a home-made system which was well described in [53], it consists of a 12-lead ECG board, 4-channels PGG board, and a computer interface card (PICO log – 16 channels, 12 bits). The PTTs are obtained using a Pan Tompkins open-source Matlab script [54] that detects the R-wave and PPG peak time positions and find the delay time. We consider a linear model [53] for the PTTs data fittings that as the blood pressure increases the pressure wave pulse transient time decreases. Nine healthy subjects volunteered in this research. Measurements start from early morning till late in the evening after breakfast. The subjects are divided into three groups according to their ages. Group 1 for ages > 50, includes one subject (subject 1) whose age is 62 years, but his PTT and other parameters measured three times while fasting and one time when not fasting; on different separated days. Group 2, includes 3 subjects with age range: 40-50 years, one subject was measured twice. Group 3 includes 5 subjects with an age range of 20-40 years; one subject was measured twice on different days. PTTs were obtained for the Left finger and right foot toe. The PTTs data points amount to 100 measurements for nine subjects.

III. RESULTS

The results are divided into different patterns of PTT over time and fitting a mathematical expression to the group PTTs.

III.I PTT Patterns

Fig. 1. Shows the left finger PTTs over time for subject 1. The black-colored tracing, '■' points, refers to PTT measurements in the normal non-fasting day; this trace does not show any pattern other than could be variations due to PTT circadian rhythm. The '■' red and '■' blue tracing refer to PTT fasting measurements on two separate days, one week apart. There is a sharp drop in the PTT pattern corresponding to after breakfast time (7:30 pm). This pattern of sharp PTT drop is even much clear in right foot toe PTTs (see Fig. 2).

The HR variation is plotted in Fig. 3, where it shows a sharp increase in HR. The sharp increase in HR is when subject 1 is fasting on day 1 '■' and day 2 '■'. When subject 1 is not fasting '■', the HR pattern could be due to circadian rhythm.

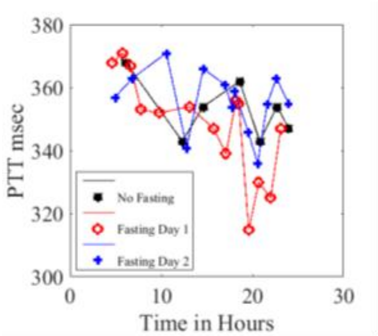

Fig. 1. Left finger PTTs for subject 1 when not fasting '■', day 1 fasting '■', and day 2 fasting '■'.

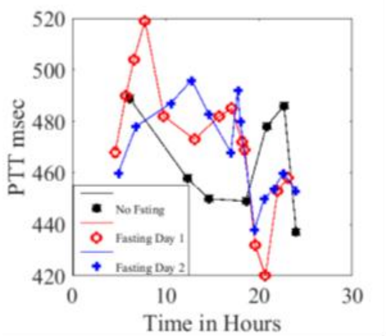

Fig. 2. Right foot toe PTTs for subject 1 when not fasting '■' colored black, day 1 fasting '■' colored red, and day 2 fasting '■' colored blue.

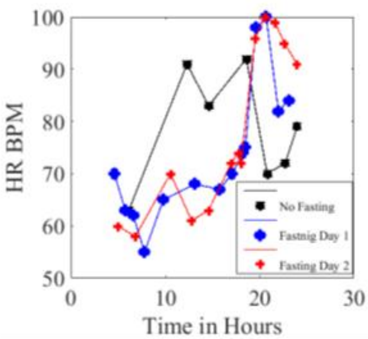

Fig. 3. Subject 1 HR when not fasting '■' colored black, day 1 fasting '■' colored blue, and day 2 fasting '■' colored red.

Fig. 4. Shows the right foot toe PTTs of subject 2 from group 2, the blue '■' line tracing shows the PTTs of a fasting day and the black '■' colored tracing shows no fasting day PTTs. Fasting, in this case, has increased PTT but PTT change with a lower rate around breakfast time and its pattern of change is not sharp as seen in subject 1 pattern. The same slow change pattern is seen for left finger PTTs shown in Fig. 5. also fasting has increased the level PTTs.

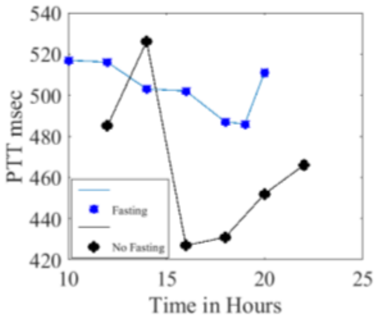

Fig. 4. Right foot toe PTTs of subject 2 when not fasting '■' colored black. Fasting PTTs colored in blue '■'.

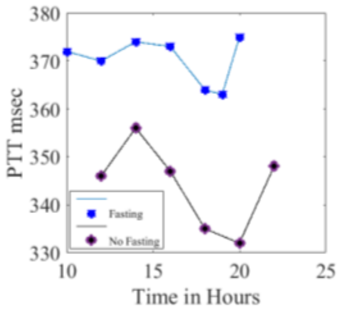

Fig. 5. Left finger PTTs of subject 2 when not fasting '■' colored in deep purple. Fasting PTTs colored in blue '■'.

Fig. 6. shows the fasting systolic blood pressure, the top blue tracing, it increases between the times 15 to 19 while PTTs of Fig. 5. decreases in the same pattern. In general, PTT is inversely related to blood pressure. Also fasting has lowered the HR for subject 2 in Fig. 6. Where the black tracing is for fasting day and the red tracing '■' represents the HR when subject 2 is not fasting.

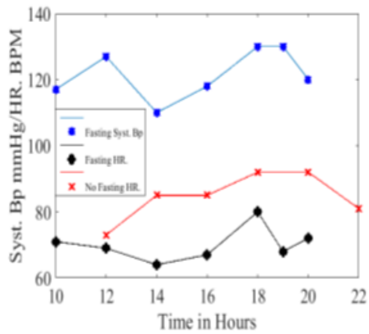

Fig. 6. Subject 2 systolic BP, top blue trace. HR, when not fasting '■' colored red and fasting HR '■' colored in black.

Fig. 7. Shows the PTTs over time of subject 3 from group 3. The right toe PTTs are traced in blue '■' for a fasting day where PTT decreases slowly from midday towards the evening and is not very different on average from the PTTs of a no fasting day. The same pattern applies for the left finger PTTs of subject 3 shown in Fig. 8.

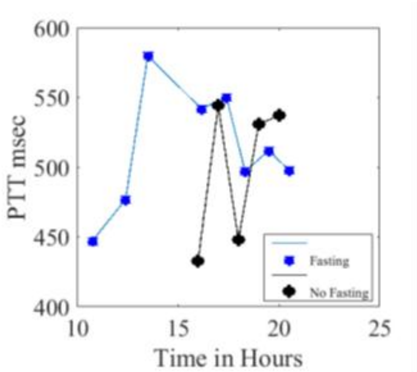

Fig. 7. Subject 3 right foot toe PTTs for a fasting day in blue tracing '■'. PTTs for no fasting day is black colored '■'.

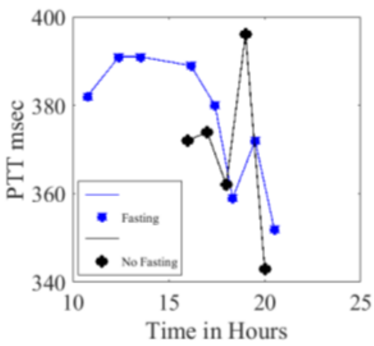

Fig. 8. subject 3 left finger PTTs for a fasting day traced in blue '■'. PTTs for no fasting day is black colored '■'.

Subject 4 PTTs from group 3 are shown in Fig. 9. for the right foot toe. The fasting day blue top tracing has higher PTTs than a no fasting day, bottom black tracing The same pattern can be noticed for the left finger PTTs of Fig. 10.

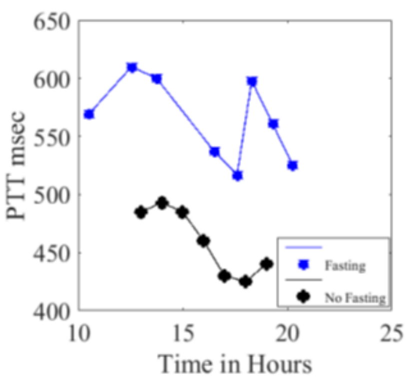

Fig. 9. Right foot toe PTTs of subject 4 when not fasting '■' colored black. Fasting PTTs colored in blue '■'.

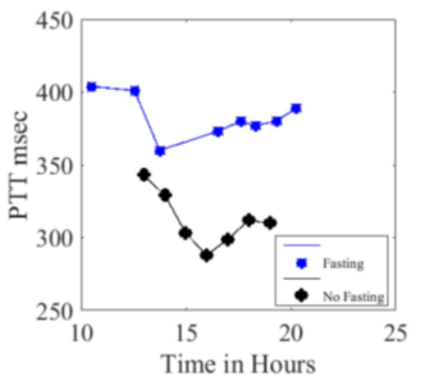

Fig. 10. left finger PTTs of subject 4 when not fasting '■' colored in black. Fasting PTTs colored in blue '■'.

Fig. 11 shows subject 5 from group 3 right foot toe PTTs colored '■' blue. The overall PTTs are lower in case of fasting and have a slow decrease pattern. The no fasting higher PTTs are on the top, colored in '■' black. The left finger fasting PTTs are lower (blue line), most of the time, compared to the no fasting PTTs shown in Fig.12.

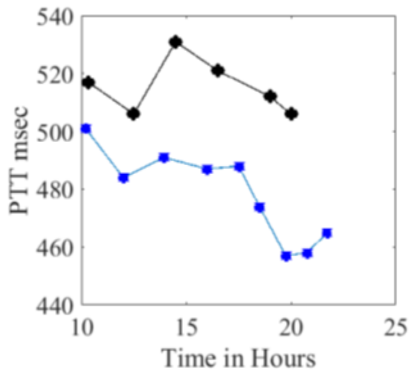

Fig. 11. subject 5 right foot toe fasting PTTs, traced in blue '■' and no fasting is traced colored in black '■'.

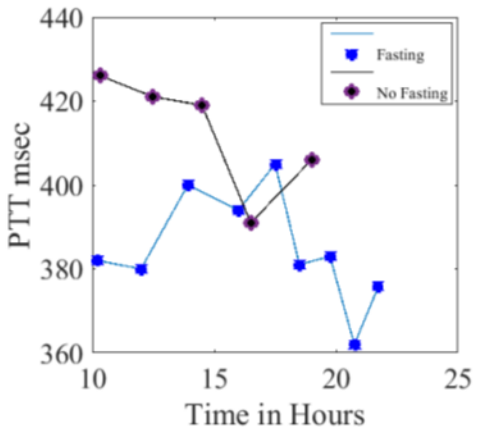

Fig. 12. Subject 5 left finger fasting PTTs in blue '■' and PTTs for a no fasting day in deep '■' purple.

Subject 5 systolic blood pressure measured over a fasting time (Fig 13) in blue '■' color and when not fasting in black '■' color. The fasting pressure is higher compared to a no fasting day pressure, opposite to the PTTs pattern shown in Fig. 12. The pressure increased immediately after breakfast.

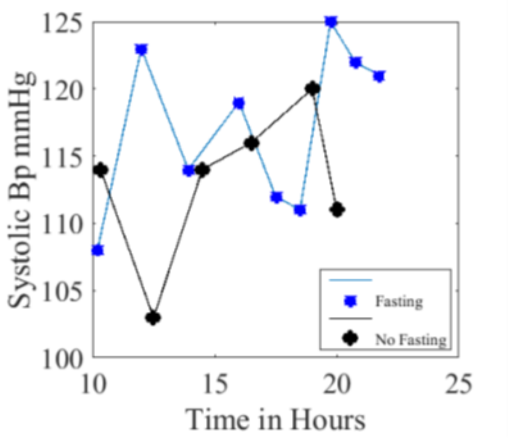

Fig. 13. Subject 5 fasting systolic pressure blue '■' colored and no fasting pressure in black '■' color tracing.

Subject 6 fasting PTTs are plotted as a function of systolic pressure and fasting time as shown in Fig. 14. PTTs decreases with time while pressure increases.

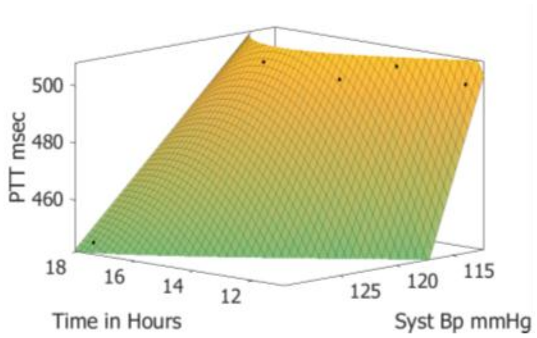

Fig. 14. Subject 6 PTTs as a function of fasting time and systolic (Syst.) pressure.

IV. MODEL FITTINGS

PTTs of subject 1 (group 1) three fasting days measurements are pooled, plotted, and fitted with a six-degree polynomial function (equation no 1) as shown in Figure 15. Circadian blood pressures are usually fitted with a double cosine function [55]. Polynomials gave better fitting fasting results. The oscillating function amplitudes are decreasing with time showing a circadian rhythm but also a sharp drop in PTTs after breakfasting indicating an increase in blood pressure.

The linear model Poly6:

$$f(x) = p1*x^6 + p2*x^5 + p3*x^4 + p4*x^3 + p5*x^2 + p6*x + p7 \quad (1)$$

Coefficients (with 95% confidence bounds) are given below:

p1 = -6.25 (-17.17, 4.673)

p2 = 7.451 (-4.898, 19.8)

p3 = 33.44 (-12.18, 79.05)

p4 = -23.42 (-60.59, 13.75)

p5 = -43.29 (-96.06, 9.488)

p6 = 0.5183 (-24.92, 25.96)

p7 = 478 (465.5, 490.6)

R-square: 0.5025

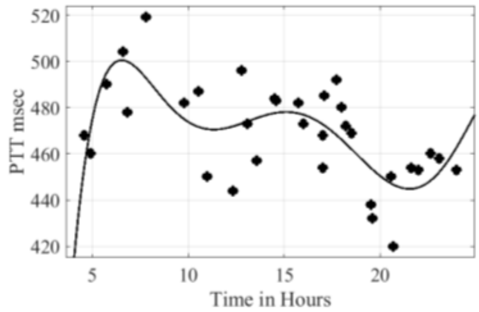

Fig. 15. Subject 1 PTTs data fitted to a polynomial function.

Group two fasting PTTs are pooled, plotted, and fitted with the six-degree polynomial as shown in Fig. 16. The PTTs oscillating amplitudes are increasing with time indicating fasting lowering effect for this group mainly from 6 pm to 8 pm.

The linear model coefficients (with 95% confidence bounds):

p1 = -0.4618 (-20.44, 19.51)

p2 = -8.419 (-38.82, 21.98)

p3 = 20.88 (-78.8, 120.6)

p4 = 29.42 (-83.44, 142.3)

p5 = -47.56 (-183, 87.85)

p6 = -21 (-107.8, 65.84)

p7 = 469.9 (428.4, 511.4)

R-square: 0.1594

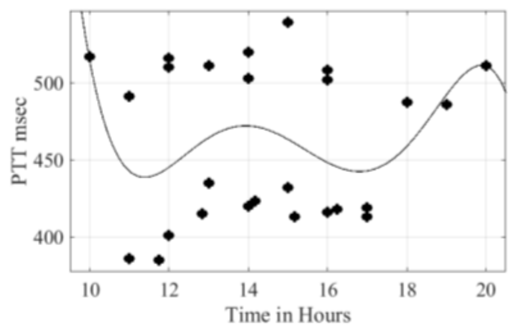

Fig. 16. Group 2 PTTs data fitted to a polynomial function.

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Group three fasting PTTs are pooled, plotted, and fitted with the six-degree polynomial as shown in Fig. 17. The PTTs oscillating amplitudes are slightly increasing with time but after breakfasting the PTTs are decreasing indicating a fasting pressure elevating effect, for this group mainly from 7 pm to 9 pm.

The linear model coefficients (with 95% confidence bounds) are given below:

p1 = 13.79 (-4.905, 32.49)

p2 = -17.08 (-39.86, 5.691)

p3 = -63.49 (-150.3, 23.3)

p4 = 51.91 (-26.44, 130.3)

p5 = 73.73 (-35.93, 183.4)

p6 = -25.62 (-83.88, 32.64)

p7 = 487.1 (455, 519.2)

R-square: 0.09624

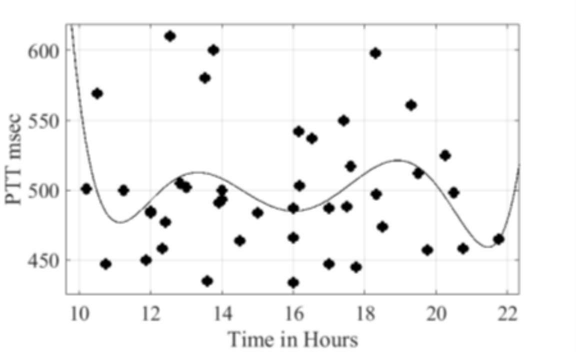

Fig. 17. Group 3 PTTs data fitted to a polynomial function.

V. DISCUSSION

The PTT can be considered as a distinct physiological parameter to be noticed, it reflects the cardiovascular system health and the arterial wall stiffness. In this preliminary work, the number of people involved is small, the results show the non-invasive effects of fasting. Three PTT versus time patterns of fasting modulation can be discussed. A sharp drop of PTT after breakfasting was noticed in subject 1 data. This may be due to the sudden hydration (irrigation) of the arterial system, the fluid volume increase, and the age effect. The second pattern can be described by a slow decrease of PTT over time and a slow increase after breakfast, subject 2 is an example. The third pattern depicts some circadian rhythm as seen subject 5 left finger PTTs. The mean level of fasting PTT can be above or below non-fasting PTT, this needs to be investigated further. The polynomial fittings show the oscillating behavior of PTT over time course indicating a circadian rhythm of a cohort. The coefficient p7 indicates a mean PTT value. The correlation coefficient for group 1 (subject 1) is the highest, = 0.71, group 2 correlation coefficient 0.4 and is very low for group 3 (six PTTs measurements). These fittings can be applied individually for better results.

VI. CONCLUSION

With the advancement of wearable devices, we have utilized PTT, an indicator of cuff-less BP, in fasting studies. In this preliminary research, we investigated how Intermittent Fasting modulates Blood Pressure Pulse Transient Time. According to our knowledge, intermittent fasting and PTT measurements are not wildly available in the literature. Our results show that intermittent fasting produces noticeable changes and different PPT time patterns. These changes are more apparent in the immediate time after breakfast. Also HR and BP change in synchronous with PTT. We think intermittent fasting effects on PPT and hence BP should be analyzed further, with PPG techniques as it is a continuous wearable system. This will permit long term PTT pattern recognition and feature extractions.

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