How to standardize the pulse-taking method of traditional Chinese medicine pulse diagnosis

Yu-Feng Chung, Chung-Shing Hu, Cheng-Chang Yeh, Ching-Hsing Luo

Abstract

The aim of this report is to propose standard pulse taking procedure of Traditional Chinese Medicine Pulse Diagnosis. In order to acquire full information from taking a wrist pulse, this proposal adopts a tactile sensor with 12 sensing points at one sensing position, such as Cun, Guan, or Chi. Simultaneously Palpation (SP) and Pressing with One Finger (PWOF) are adopted to explore their differences of the detected pulse signals. According to vertical dynamic characteristics, the results of a Pearson product moment reveal that the correlation coefficients of PWOF and SP are highly correlated from Fu to Chen. In addition, according to unique characteristics of body state, the results of a paired samples t test reveal that the SP and PWOF are indifferent at a specific pulse taking depth. Hence, if using the pulse-taking instrument with tactile sensors, it is concluded that pulse signals taken by familiar SP and PWOF methods are shown in statistical indifferences among seven parameters (Vppmean, Vppmax, HR, LENGTH, WIDTH, AS, and DS).

Keywords: Pulse diagnosis, Parametric, Traditional Chinese Medicine, Pulse-taking, Sensor array

1. Introduction

There are four diagnostic methods in Traditional Chinese Medicine (TCM): inspection, listening and smelling, inquiry, and palpation. Palpation is very important in clinical procedures, providing diagnosis of TCM: inspection, listening and smelling, inquiry, and palpation. Palpation is very important in clinical procedures, providing diagnosis. The first step for the quantification of pulse diagnosis is to acquire wrist arterial signals. According to three positions and nine indicators of Nanjing [4–6] and Zhou Xue Hai [7], the pulse taking method can be divided into Simultaneously Palpation (SP) and Pressing with One Finger (PWOF), as shown in Fig. 1. The entire trend of body state is verified by SP, and unique characteristics of viscera and bowels are verified by PWOF. Furthermore SP is used to analyze the dynamic characteristics of pulse signal (vertical dynamic characteristics: Fu, Zhong, and Chen; horizontal dynamic characteristics: Cun, Guan, and Chi). PWOF is used to analyze the static characteristics of pulse signal at specific pulse taking depth (Fu, Zhong, or Chen) or pulse taking position (Cun, Guan, or Chi). In clinic, however, one insists that pulse taking method is SP, the PWOF just find pulse taking position, such as Cun, Guan, and Chi. Using PWOF cannot obtain the clear wrist signals of interaction among three fingers. The other one insist that pulse taking method is PWOF, the subtle gradation of pulse conditions cannot simultaneously be recognized by SP. And the subtle gradation of pulse conditions is key point of body state.

Therefore, this confused viewpoint has to be testified for designing automatic pulse taking platform. Both SP and PWOF exist or only SP or PWOF exists in automatic pulse taking platform, which has to be checked. The feasible pulse taking platform with tactile capacitive array sensor has been reported [8]. The study adopts this pulse taking platform for acquiring equipment. Two analytical methods are proposed to discuss these wrist pulse signals, the Discrete Mode (DM) and the Surface Fitting Mode (SFM), and this report uses these methods to evaluate the relationship between SP and PWOF. The experimental hypothetical diagram is shown in Fig. 2. Whether in relation to the entire trend or just at the specific pulse taking depth, the results of our proposal indicate that SP and PWOF are highly correlated in the trend domain and have no significant difference at the specific pulse taking depth. According these results, the standard pulse taking procedure is suggested to adopt SP, but the analytical concepts include SP and PWOF model.

2. Materials and methods

In this section, a non-invasive measurement system is adopted to record a wrist pulse, founded on a tactile sensor. Full information
related to wrist pulse can be obtained by this system. Analytical methods, such as DM and SFM, are introduced to evaluate the difference between SP and PWOF.

2.1. Tactile sensor and platform for noninvasive measurements

Previous noninvasive measurements of the pulse waveform of the radial artery have not been able to provide full information regarding pulse conditions; the more information on pulse conditions, the better the definitions of the parameters. An array regarding pulse conditions; the more information on pulse conditions, the better the definitions of the parameters. An array with respect to the radial artery have not been able to provide full information regarding the radial artery, as shown in Fig. 4. The graph shows the PWOF (pressing with one finger).

(a) The graph shows the SP (simultaneous palpation) for the taking-pulse method.

(b) The graph shows the PWOF (pressing with one finger).

Fig. 1. (a) The graph shows the SP (simultaneous palpation) for the taking-pulse method. (b) The graph shows the PWOF (pressing with one finger).

2.2. Subjects and data collection

The ethics approval was obtained by the R.O.C. Air Force Academy and National Cheng Kung University. The approved number was 0970006465. Volunteer participants were recruited through questionnaires from the R.O.C. Air Force Academy and National Cheng Kung University. Finally, participants are five R.O.C Air Force Academy students, and one is our own lab student. We attempt to minimize variations depending on gender, age and health conditions. The subjects are all males (average age of 20.64 ± 6.84) who have no significant diseases and have been checked by a doctor. All of the subjects are asked to stop exercising and to rest for 10 min before the pulse conditions are sampled. During the pulse condition sampling, the subjects are asked to sit on an adjustable chair. And they are forbidden to move their arterial wrists. The number of sampling data totals 25. Each subject’s pulse is taken by both PWOF and SP. The pulse strength of Guan is greater than that of Cun and Chi [13,14].

In this study, PWOF refers to pulse taking only at the Guan position, PWOFG, while SP refers to simultaneous pulse taking at Cun, Guan and Chi, although only Guan’s (SPG) data is analyzed. First, the physician carries out the pulse-taking and marks the Cun, Guan and Chi positions. Then the participants place the marked position of the arterial wrist under the sensor block and adjust the screw about 12 times (from lightly touching skin to bone), the depth of each time is 0.5 mm. Each acquisition time is about 15 s. This procedure is explained in Fig. 6.

2.3. Pre-processing signal block

This section includes two parts: filter design and baseline wander removal design. The wrist pulse is read out from DAQ (D600, PPS, USA), and is not pure (in terms of interference) for analysis. A high-pass filter is designed to remove unwanted signal in the high frequency band. If the wrist pulse signal is pure, the algorithm used will not be complicated. Therefore, a 3-points average smoothing filter is designed to smooth the wrist pulse signal. After using the smoothing filter, it is easy to analyze the pulse signal to obtain characteristics of pulse conditions such as the frequency of the wrist pulse.

Many solutions such as wavelet algorithms, curve fitting algorithms, and filter designs, among others, have been proposed to overcome motion artifacts in biosignals; the better the method, the lower the variance that is obtained. This is our criterion for deciding to remove baseline wander.

This study tried to choose a wavelet algorithm and curve fitting algorithm to stabilize the baseline of the wrist pulse. The wavelet approach obtains lower variance from acquired data, signifying that the wavelet is more effective in removing baseline wander, as shown in Fig. 7. The biorthogonal wavelet was chosen for considering the linear-phase. This characteristic is very important for array sensor (i.e. multi-channel signals). In addition, the evaluation criterion is based on the SNR, the definition of SNR as below:

\[
\text{SNR} = \frac{\text{Mean}(\sum \text{peak of power spectral of denoised signal})}{\text{Mean}(\sum \text{peak of power spectral of noise})}
\]

The higher SNR we obtained, the better performance we got. Following this definition, the bior3.1 was chosen to stabilize the wrist artery signals in this study.

2.4. Waveform test block and analytical procedure

There are two aspects worthy of discussion. One is the entire trend of pulse conditions, and the other is a comparison at a specific pulse taking depth. The entire trend means the
relationship between the parameters of pulse conditions and pulse taking depths and positions. We can obtain a holistically healthy state from the entire trend; conventionally, this characteristic is acquired from the SP. The other useful unique characteristic is to find out the healthy state of the viscera and bowels through PWOF. In this proposal, we choose the maximum of \( V_{pp} \) as the compared pulse taking depth to check the unique characteristics.

It is important to quickly obtain useful information regarding pulse conditions in a multi-channel sensor system. The waveform test block is designed to solve the computation problems encountered in a multi-channel sensor system. The parameters derived from this test block are the Heart Rate (HR) and the peak to peak of the wrist pulse (\( V_{pp} \)). Following these parameters, two analytical methods are proposed. One is the discrete mode (DM), and the other is the surface fitting mode (SFM). These two methods are used to investigate the differences between SPG and PWOFG.
2.5. Discrete mode

In this section, these defined parameters were revised from Chapter 5 of Part II of Fei’s publications [15]. The core parameters $V_{ppMeanDM}$, $HR_{DM}$, $LENGTH_{DM}$, $WIDTH_{DM}$, $AS_{DM}$ and $DS_{DM}$ are derived from each channel to represent the pulse conditions, as shown in Fig. 8. The definitions of these parameters are described below:

$V_{ppMeanDM} = \frac{1}{12} \sum_{n=1}^{12} V_{ppn}$,  

where $V_{ppn}$ is the mean of each channel at each pulse taking depth.

$HR_{DM} = \text{Mod}(HRn)$,  

$HRn = \frac{1}{T} = \frac{1}{t_1 + t_2}$,  

where $HRn$ is defined at a channel of $V_{ppnMax}$. $V_{ppnMax}$ is the maximum of $V_{ppn}$ at each pulse taking depth. In this proposal, we assume the heart rate of the wrist pulse is the same or that the deviated heart rate satisfies the requirements of clinical conditions among different pulse taking depths.

$LENGTH_{DM} = \sum_{n=1}^{12} K_n \times LN_{chn}$,  

where $LN_{chn}$ is dominated by two factors: $V_{ppn} \geq V_{ch}$ and $HR_{DM} - \Delta \leq HRn \leq HR_{DM} + \Delta$, if the channel satisfies these requirements, then $LN_{chn}$ and $K_n$ are set to 1 and otherwise set to zero. In this proposal, $V_{ch}$ and $\Delta$ are set to 5 and 10, respectively, by experimental experience.

The definition of $WIDTH_{DM}$ is similar to $LENGTH_{DM}$.

$WIDTH_{DM} = \sum_{n=1}^{12} K_n \times WN_{chn}$,  

$AS_{DM} = \frac{V_{ppnMax}}{t_1}$,  

where $AS_{DM}$ is defined to describe the ascending slope of the two-dimension pulse signal, as shown in Fig. 8.
DS_DM = \frac{V_{ppMax}}{t_2}, \tag{7}

where DS_DM is defined to describe the descending slope of the two-dimension pulse signal, as shown in Fig. 8.

The trend and unique characteristics of SPG/PWOFG are checked through these parameters.

2.6. Surface fitting mode

The core parameters $V_{ppMax_{-SFM}}$, HR_SFM, LENGTH_SFM, WIDTH_SFM, AS_SFM and DS_SFM are derived from a surface fitting equation to represent the pulse conditions, as shown in Fig. 9. In this proposal, the polynomial surface fitting equation is chosen to represent the wrist pulse of 12 channels.

$$V_{pp}(x,y) = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}xy + p_{02}y^2 + p_{21}x^2y + p_{12}xy^2 + p_{03}y^3, \tag{8}$$

where $x$ represents the width axis of pulse conditions, and $y$ represents the length axis of the pulse conditions. $p_{0x}$ represents the surface fitting coefficient. The definitions of these parameters are described below:

$V_{ppMax_{-SFM}}$ is the maximum of the surface fitting equation, and the definition of the HR_SFM of Surface Fitting Mode is the same as the Discrete Mode.

$$HR_{-SFM} = HR_{-DM}, \tag{9}$$

$$LENGTH_{-SFM} = \frac{\text{Length}(V_{pp}(x,y) \geq r \times V_{ppMax})}{\text{DataLength}}, \tag{10}$$

where $\text{Length}(V_{pp}(x,y) \geq r \times V_{ppMax})$ represents the amount of $V_{pp}(x,y) \geq r \times V_{ppMax}$ along the pulse length, i.e. $y$ axis. $r \times V_{ppMax}$ represents the area of the surface that is of interest; $r$ was set to 0.8 in this proposal.

$$\text{DataLength} = \frac{3}{\text{Interval}} + 1, \tag{11}$$

where the interval represents the surface fitting resolution. In this proposal, the interval is set to 0.2.

The definition of the WIDTH_SFM is similar to LENGTH_SFM.

$$WIDTH_{-SFM} = \frac{\text{Width}(V_{pp}(x,y) \geq r \times V_{ppMax})}{\text{DataWidth}}, \tag{12}$$

where $\text{Width}(V_{pp}(x,y) \geq r \times V_{ppMax})$ represents the amount of $V_{pp}(x,y) \geq r \times V_{ppMax}$ along the pulse width, i.e. $x$ axis. $r \times V_{ppMax}$ represents the area of the surface of interest; $r$ is set to 0.8 in this proposal.

$$\text{DataWidth} = \frac{2}{\text{Interval}} + 1, \tag{13}$$

$$AS_{-SFM} = \sum_{n=1}^{m} AS_n, \tag{14}$$

$$DS_{-SFM} = \sum_{n=1}^{m} DS_n, \tag{15}$$

where $\text{AS_n}$ and $\text{DS_n}$ represent the area of the surface of interest; $n$ is set to 0.8 in this proposal.
where ASn represents the ascending slope (based on three-
dimension surface) from the upper reaches of the area of interest
to $V_{ppMax}$, as shown in Fig. 9; DSn represents the descending slope
(based on three-dimension surface) from $V_{ppMax}$ to the lower
reaches of the area of interest, as shown in Fig. 9.

The trend and unique characteristics of the SPG/PWOFG are
checked through these parameters.

2.7. Statistical method

According to the defined parameters, this study is designed to
check the differences between SP and PWOFG. For the purpose
of statistical analysis, we use the SPSS 17.0 program. The Pearson
product-moment correlation coefficient and a paired t test are
carried out to examine the relationship between SPG and PWOFG.

3. Results

3.1. Results of the proposed pulse taking platform

Conventionally, the TCM pulse taking platform was based on
a single sensor. The waveform of a wrist artery is a triple-humped
wave or a double-humped wave through previous pulse taking
platforms with a single sensor. The proposed pulse taking plat-
form for this study obtains the same waveform for the wrist
artery, as shown in Fig. 7. Since the same waveform is acquired by
our reported platform, the results of previous research based on
a single sensor can apply to our experiment. Wrist pulse signals
for 12 channels are additionally acquired at each pulse taking
position. Therefore, we propose DM and SFM to discuss three-
dimensional wrist pulse signals.

3.2. Correlation at different pulse taking depths between SPG and
PWOFG

Using modern technology, we want to check the difference
between the SP and PWOFG. Therefore, the Pearson product-
moment correlation coefficient is carried out to verify it.
The correlation coefficient of the DM is higher than that of the
SFM. Regardless of what analytical method is adopted, the SPG
and PWOFG are highly positively correlated. The detailed infor-
mation is tabulated in Table 1.

3.3. The paired t test at a specific pulse taking depth between SPG
and PWOFG

The maximum wrist pulse is chosen to check the difference
between the SPG and PWOFG. A paired samples t test is carried
out to verify the difference, and the results reveal that the SPG
and PWOFG are not significantly different among these para-
eters. The detailed information from the comparison at the
specific pulse taking depth is shown in Tables 2 and 3.

4. Discussion

In this work, we use a tactile sensor system to obtain full
information regarding wrist pulse, in order to investigate the dif-
ferences between the PWOFG and SPG. Previous non-invasive measure-
ments of the pulse waveform of the radial artery have focused on a
single sensor; this could not provide full information on pulse
conditions and the optimal pulse taking position was hard to find.
Our proposal simultaneously provides 12 sensing points at Guan for
deriving information on pulse conditions at one pulse taking depth, as

shown in Figs. 8 and 9. With this information, we can evaluate the
differences between the PWOFG and SPG.

In ancient times, TCM physicians understood the entire trend of
pulse conditions by the SP, and obtained the unique characteristics
of pulse conditions, such as the location of disease, the mechanism
of disease, and the degree of disease, among others, by the PWOFG.
Physicians employed these two methods to obtain full information
from a wrist pulse. However, the different viewpoint has appeared
in clinic at present, they insist only SP or only PWOFG just can take
the wrist pulse. This confused issue will be problem in automatic
pulse taking platform. Therefore, based on a tactile array sensor and
the high computational capability of personal computers, we
investigate the correlation between SPG and PWOFG to solve this
confused viewpoint. The entire trend represents the holistic healthy
state, and it is a dynamic characteristic based on different pulse
taking depths and positions. In this proposal, we use the Pearson
product moment correlation coefficient to verify the entire trend of
vertical dynamic characteristics. The correlation coefficients of these
parameters are tabulated in Table 1; the results indicate that
PWOFG and SPG are highly correlated. This means that once the
mechanism of disease is determined by SP/PWOF, the PWOFG/SP
trend is the same as the SP/PWOF. Therefore, we infer that the SP
and PWOFG are indifferent from the viewpoint of the entire trend of
vertical dynamic characteristics.

On the other hand, physicians tend to focus on the maximum
strength of a wrist pulse, $V_{ppMax}$. In the pulse taking process.
In clinical practice, the heart rate, strength, length and width of the
wrist pulse at the optimal pulse taking position are mean-
ingful and obvious [16]. We can easily find the unique character-
istics at this pulse taking depth. Then, we verify the difference
between the SPG and PWOFG at this depth. The detailed results of
our experiment are listed in Tables 2 and 3. From the viewpoint of
static, SPG and PWOFG are indifferent at the specific pulse
taking depth.

In summary, the PWOFG and SPG are highly correlated in
relation to the entire trend and at the specific pulse taking depth.
Based on our result, it is no discrimination between SP and PWOFG
when check the state of viscera and bowels. However, PWOFG
cannot simultaneously provide comparison among Cun, Guan,
and Chi. Hence, SP will obtain more information than PWOFG based
on array sensor platform. These results indicate the possible
standard pulse taking procedure. That means pulse taking method
adopts SP, and analytical procedure include SP (to find out the
holistic characteristics of body state) and PWOFG (to find out the
unique characteristics of body state) concepts.

Additionally, this proposal also reveals the approach of quantified
feasibility of pulse diagnosis. The three axes mechanism with tactile
array sensor for taking the pulse are needed to save time in sampling
a wrist pulse and for obtaining more complete information such as
the pulse length, pulse width, pulse trend, the horizontal static
characteristics and horizontal dynamic characteristics at Cun–Guan–
Chi [17]. Following this approach, time spent on pulse taking is saved
(only six times are required); physicians conventionally need to take
the pulse 24 times. In addition, the proposed pulse taking system
provides the spatial feature of a wrist pulse, thereby opening a new
analysis approach based on a tactile array sensor. Hence, the
proposed diagnosis platform and analytical methods possess the
possibility of obtaining full information on wrist pulse signals and
greater ease in finding the optimal pulse taking position using a
sensor array block.

5. Conclusions

In conclusion, the experiments reported in this paper have
demonstrated that these new platforms can be practically
implemented and also that they provide adequate results. Among several parameters proposed by this study, SP and PWOF are indifferent. Hence, the pulse taking measurement is suggested to adopt SP. However, the analysis concepts should include SP and PWOF for obtaining the full information of physiological information of patients and integrating the clinical experiences of physicians. An important area for future research in the years to come will involve the analysis of pulse conditions at Cun–Guan–Chi. Following the proposed results, the use of automatic pulse taking in three positions with nine indicators will open a quantification approach for invigorating TCM.

**Conflict of interest statement**

None declared.

**Acknowledgments**

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**References**


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**Table 1**

The correlation between the SP and PWOF based on the discrete mode and the surface fitting mode.

<table>
<thead>
<tr>
<th>Core parameters</th>
<th>Pulse taking method</th>
<th>Discrete mode $r$</th>
<th>Surface fitting mode $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ppMean}$</td>
<td>SP</td>
<td>0.798*</td>
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<td></td>
<td>PWOF</td>
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<td>$V_{ppMax}$</td>
<td>SP</td>
<td>0.832*</td>
<td>0.770*</td>
</tr>
<tr>
<td></td>
<td>PWOF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>SP</td>
<td>0.633*</td>
<td>0.538*</td>
</tr>
<tr>
<td></td>
<td>PWOF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>SP</td>
<td>0.717*</td>
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<td>(× 2.5 mm)</td>
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<td>WIDTH</td>
<td>SP</td>
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<td>(× 2.5 mm)</td>
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<td></td>
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<tr>
<td>AS</td>
<td>SP</td>
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<td>PWOF</td>
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<td>DS</td>
<td>SP</td>
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<td></td>
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* Represents significance $p < 0.05$.

**Table 2**

The result of the paired $t$ test based on the discrete mode.

<table>
<thead>
<tr>
<th>Core parameters</th>
<th>Pulse taking method</th>
<th>Mean</th>
<th>SD</th>
<th>$t$-value</th>
<th>$p$-value</th>
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<tbody>
<tr>
<td>$V_{ppMean}$ (mV)</td>
<td>SP</td>
<td>17.289609</td>
<td>3.393628</td>
<td>1.139</td>
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<td></td>
<td>PWOF</td>
<td>18.582957</td>
<td>4.305394</td>
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<td>HR</td>
<td>SP</td>
<td>70.521739</td>
<td>7.681802</td>
<td>0.176</td>
<td>0.862</td>
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<tr>
<td></td>
<td>PWOF</td>
<td>70.608696</td>
<td>7.715033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>SP</td>
<td>2.739130</td>
<td>0.448977</td>
<td>0.680</td>
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<td>(× 2.5 mm)</td>
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<tr>
<td>WIDTH</td>
<td>SP</td>
<td>2.6252174</td>
<td>0.486984</td>
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<td>(× 2.5 mm)</td>
<td>PWOF</td>
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<td>0.572761</td>
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<td>AS (mV/s)</td>
<td>SP</td>
<td>1.768913</td>
<td>0.389827</td>
<td>1.151</td>
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<td>PWOF</td>
<td>1.660783</td>
<td>0.417546</td>
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<tr>
<td>DS (mV/s)</td>
<td>SP</td>
<td>–0.508034</td>
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<td>PWOF</td>
<td>–0.427217</td>
<td>0.238917</td>
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**Table 3**

The result of the paired $t$ test based on the Surface Fitting Mode.

<table>
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<th>Core parameters</th>
<th>Pulse taking method</th>
<th>Mean</th>
<th>SD</th>
<th>$t$-value</th>
<th>$p$-value</th>
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<tr>
<td>$V_{ppMean}$ (mV)</td>
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<td>55.687600</td>
<td>11.200454</td>
<td>–0.719</td>
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<td>PWOF</td>
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<td>HR</td>
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<td>0.862</td>
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<tr>
<td></td>
<td>PWOF</td>
<td>70.608696</td>
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<tr>
<td>LENGTH</td>
<td>SP</td>
<td>0.294720</td>
<td>0.1090335</td>
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<td>0.760</td>
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<td>(× 2.5 mm)</td>
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<td>0.302400</td>
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<tr>
<td>WIDTH</td>
<td>SP</td>
<td>0.371000</td>
<td>0.2254459</td>
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<td>(× 2.5 mm)</td>
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<td>AS (mV/s)</td>
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<td>11.7824248</td>
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<td>DS (mV/s)</td>
<td>SP</td>
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<td>PWOF</td>
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