Chinese Traditional Medicine Journal

ISSN : 2693 6356
2024 | Vol 7 | Issue 2

Potential benefits of Qi Gong meditation in quantifiable physiology: A five-year longitudinal observation

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Abstract Thousands of years of practice have gone into Qi Gong, a mind-and-body intervention for better health and relief from illness. An excellent research assessing the health benefits of Qi Gong has been impeded due to the absence of quantitative metrics for tracking the practice's quality and advancement.

In order to create these numerical metrics, we used wearable sensors to track one person's vital signs while they meditated on Qi Gong for five years. Significant increases in blood oxygen saturation, pulse rate, respiration rate, and perfusion index were seen in this retrospective and exploratory investigation as a result of Qi Gong practice and physiological adaptation to its long-term training. Physiological alterations in vital signs include a noteworthy two-fold rise in the pulse-respiration rate ratio during Qi Gong meditation, compared to resting, sleeping, and moderate cycling circumstances, when the ratios remained at 4.

In sum, this is the first report of its kind to cover a five-year longitudinal study. After they're proven in a well-planned cohort study, these simple, non-invasive vital signs can be used as biomarkers to measure how well people follow breathing control techniques when practicing Qi Gong. They can also be used to quantify the quality of Qi Gong practice in clinical trials that include Qi Gong intervention.

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In sum, this is the first report of its kind to cover a five-year longitudinal study. After they're proven in a well-planned cohort study, these simple, non-invasive vital signs can be used as biomarkers to measure how well people follow breathing control techniques when practicing Qi Gong. They can also be used to quantify the quality of Qi Gong practice in clinical trials that include Qi Gong intervention.

2. Introduction

Breathing, mental and physical relaxation, and Qi Gong are the tenets of this ancient practice of meditation. Thousands of years ago, in the Yellow Emperor's Classic of Internal Medicine (Huang Di Nei Jing), a classic text of traditional Chinese medicine (TCM), it was observed that Qi Gong might improve health and prevent illnesses.1, Chapter 1 of this book indicates, "the sages were tran-quilly content in nothingness and the true vital forces accompanied them always; their vital (original) spirit was preserved within; thus, how could illness come to them?" This ancient text established a link between illness prevention and the practices of deep breathing and mental emptiness. It also linked the act of breathing with the vital spirit, or qi, in traditional Chinese medicine. Qi is the Chinese concept that differentiates between alive and dead things. Nevertheless, the connection to contemporary human anatomy and physiology remains unclear. From an energy metabolic point of view, oxygen is essential for human survival, because air contains oxygen. The role of oxygen in the synthesis of adenosine triphosphate (ATP), the biological energy currency, is a well-established fact in contemporary physiology. Life-giving ATP is synthesised from the chemical compound oxygen. The human body includes regulatory systems that detect when blood oxygen levels are low and react by increasing heart rate and breathing rate to restore blood flow, as oxygen is essential for survival. Important clinical markers for critical care patients to keep an eye on include blood oxygen level, heart rate, and breathing rate. Is it possible to utilise vital signs, which are well-known for their significance, to track changes in blood oxygen utilisation and investigate how Qi Gong exercise enhances qi? Research on meditation has mostly taken the form of clinical trials and mechanistic investigations, in contrast to studies utilising Qi Gong. Meditating is a contemporary take on an old Buddhist practice. Similar to Qi Gong practice, several types of meditation include clearing one's thoughts, calming one's body, and breathing in a relaxed manner. Hence, the terms meditation and Qi Gong are considered synonymous throughout this piece. By 2021, over 300 clinical trials will have been published, and they may all be found by searching for "Qi Gong"2 or "meditation"3 on the the

Research trial registry website (ClinicalTrial.gov). From 1973–2021, a search of PubMed for randomised controlled trials yielded 1,113 articles and 330 reviews. Publications on these subjects are on the rise, which may indicate that there are major initiatives to test this non-pharmaceutical intervention on human subjects. Among the many health benefits of Qi Gong and meditation described in these publications are its ability to lower blood pressure in hypertension patients (4,5), alleviate pain in cancer patients, and enhance their quality of life.6 For example, to determine if Qi Gong meditation reduced hypertension, researchers would monitor participants' blood pressure, one of the clinically significant illness variables utilised in studies aimed at treating or alleviating symptoms of disorders. In contrast to pharmaceutical clinical trials, which allow for easy monitoring of intervention adherence by direct medication administration to study participants, Qi Gong and meditation interventions are unique. So yet, there is no foolproof way to monitor how well one is doing with Qi Gong or meditation. Multiple reviews and meta-analyses on meditation intervention have pointed up the need for increased scientific rigour.7e9 There was a strong request to enhance methodological rigour, consistency, and follow-up over the long term.8 Is

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it possible to quantify the quality and adherence of a meditation intervention by using vital signs?

In recent years, wearable devices have emerged to facilitate the practice of meditation. For example, the MUSE, an electroenceph- alogram (EEG)-based biofeedback product, developed by Toronto- based company InteraXon,[10] is commercially available to teach meditation by providing feedback based on EEG activity during meditation. Besides EEG, heart rate variability (HRV) has also been used as a biomarker for stress and applied in breathing therapy. It has been demonstrated that elongated breathing cycles can in- crease HRV resulting in stress relief.[11] HeartMath Inner Balance, an HRV-based biofeedback product developed by HeartMath LLC,[12] is also commercially available to assist in breathing exercise by providing real-time feedback based on HRV. Can these wearable devices be applied to Qi Gong practice to assess practice quality?

With the intention of identifying a wearable device to track physiological changes during Qi Gong practice, the author piloted using MUSE and HeartMath Inner Balance in Qi Gong practice and found that both devices were helpful for achieving and maintaininga meditative state. However, the results of the measures from both devices did not correlate well with the subjective experience of a high-or low-quality practice session. In addition, these 2 devices have not been widely accepted in clinical studies. To overcome these shortcomings, the author turned to easily accessible vital signs measured by the Microsoft Band, Apple Watch, and Masimo MightySat oximeter.[13] In this study, vital sign data collected over 5years of Qi Gong practice were analyzed retrospectively to explore and assess the usefulness of vital signs as biomarkers for the physiological benefits of Qi Gong practice. The results indicated thatthe change in pulse-respiration ratio has the potential to be used toquantify the physiological state achieved during Qi Gong practice, which has not been reported in any prior longitudinal observations.In conjunction with blood oxygen saturation level, the pulse- respiration ratio also has the potential to be used to assess cardiorespiratory resilience. These findings provide objective measures to quantify adherence to slowed breathing during Qi Gong practice and to quantify its long-term training effects. The author hopes that once validated in a larger cohort, the pulse- respiration ratio, in combination with the blood oxygen satura- tion level, can be applied to improve human studies with Qi Gong interventions.

Material and methods

2.1. Wearable devices

Microsoft Band 2 (Microsoft Corp., Redmond, WA) and Apple Watch Series 3 or 4 (Apple Inc., Cupertino, CA) were used during Qi Gong practice sessions. The devices recorded and processed the data and transmitted the summary data to an iPhone through Bluetooth. Both devices provided summary and average data dur- ing each practice, including the duration of exercise, minimum and maximum heart rate, average heart rate, and calorie expenditure. Only the duration of exercise and average heart rate data were used in this analysis. Masimo oximeter MightySat (Masimo Corp., Irvine, CA)[13] is a Food and Drug Administration (FDA)-approved medical device that was used to monitor vital signs before, during, and after Qi Gong meditation practice. The oximeter recording has a sam- pling rate of 1 recording per second. The MightySat oximeter out- puts 5 data types: pulse rate (beats per minute, bpm), respiration rate (breaths per minute, brpm) based on the plethysmographic waveform, oxygen saturation (SpO_2, %), perfusion index, and pleth variability index (PVI).[13] The perfusion index was calculated from oximeter plethysmography as the ratio of the pulsatile blood flow to the non-pulsatile blood in peripheral tissue. It has been demonstrated that the perfusion index is correlated with periph- eral vascular tone and can predict the incidence of hypotension during spinal anesthesia.[14] The PVI was used to monitor variation inrespiration and was not used in data analysis.[15]

2.2. Qi Gong meditation practice

A healthy female in her 50s without experience with Qi Gong practice started practicing Li Shaobo Zhenqi Yunxing Fa (LSBZQYXF) in 2015.[16] In brief, the practice was performed in a sitting position, and the body was maintained in a fully relaxed posture. Minor attention was focused on the lower abdominal, lower Dantian region while maintaining a clear mind. Breathing was split into 2 phases: a normal inhalation phase and a prolonged exhalation phase. The exhalation was fully relaxed without forceful action with the qi sinking to the lower Dantian in the same expi- ration. Practices were performed daily with few exceptions. The LSBZQYXF was practiced 1610 times between June 2015 and December 2020. The duration of each practice varied from 20 min to 2 h. The average duration of practice was 38.9 min, and the total practice time was 1044 h in this period. To reduce unforeseen factors contributing biases to the recording, such as circadian rhythm or feeding effects, practices were done in fasting states

Wearable device recordings

Microsoft Band was used in 2016, and Apple Watch Series 3 or 4 was used from 2017 to 2020. Both types of devices were placed onthe left wrist. Data recorded and processed on the devices and the summary data were transmitted to an iPhone through the Blue- tooth. Recordings were conducted from the beginning to the end of each practice with these devices. A total of 982 recordings of the average pulse rate during the practice were collected from 2016 to2020.

Masimo oximeter MightySat was placed on the fourth finger of the left hand and connected to either an iPad or an iPhone through Bluetooth for data recording. Every oximeter recording had a before-resting control, meditation practice, and after-meditation

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control. In 2016, the resting controls, before and after practice, were recorded for 3 min. However, preliminary analysis revealed that vital signs did not return to a resting level 3 min after practice. Thus, from mid-2017 to the end of 2020, the before-resting controls were adjusted to 5 min, and the after-meditation controls were extended to 10 min. A total of 138 oximeter recordings were collected and used in this study.

2.3. Data processing and analyses

The MightySat oximeter data were evaluated by plots of the raw recordings to visually check the quality of the recording. The pulse- respiration rate (PR/RR) ratio was calculated by dividing the pulse rate by the respiration rate. To combine the MightySat oximeter data collected from 2016 to 2020, the after-meditation control data were trimmed to the last 3 min. Oximeter recordings of each practice were selected as follows: (1) the first 5 s of the before- resting control were removed to avoid starting variations; (2) the last 10 s of meditation data were trimmed out from practice data points to remove noise generated by taking note of the ending time; (3) only the last 3 min of after-meditation control were selected, excluding the last 10 s to avoid noise. Statistical analysis ofoximeter data was performed only on the selected data.

Data were analyzed with the open-source statistical software R (Statistical Computing, Vienna, Austria)[17] and RStudio (RStudio PBC, Boston, MA).[18] The ggplot package (ggplot2) in R was used for data visualization.[19] The summary and average data collected with the Microsoft Band and Apple Watch were collected in Microsoft Spreadsheet and imported into R for analyses. On the dates when only the oximeter recordings were available, average pulse rates of those dates were computed from the oximeter data. The average pulse rates during meditation practices were analyzed. The nor- mally distributions of average pulse rate data are presented asviolin plots. To evaluate the significance of changes, the Student's *t*-test package (*t* test) in R was used to perform a two-sided test at a 95% confidence level.

Results

2.4. Typical MightySat recordings of Qi Gong practice

Three typical tracings from the MightySat oximeter recordings are shown in Figs. 1e3. Figs. 1A, 2A and 3A showcase the raw data of SpO_2, pulse rate, respiration rate, perfusion index, and PVI. Figs. 1B,2B and 3B depict the PR/RR ratios computed from the instanta- neous pulse and respiration rates shown in Figs. 1A, 2A and 3A. A typical Qi Gong practice tracing in Fig. 1B shows an increase in the PR/RR ratio during practice compared with before and after con- trols. Fig. 2B shows a raw data tracing from a practice that had a period of sleepiness noted in the practice note. During the sleepi- ness period, the PR/RR ratio dropped to the resting control level. Asimilar phenomenon was observed in separate recordings done under the sleep condition (the result not shown here). This feature presents a potential application of the PR/RR ratio to assess the quality of a Qi Gong practice by monitoring the adherence to pro- longed exhalation. Fig. 3B shows the PR/RR ratio during a mild cycling exercise. Small PR/RR ratio fluctuations occurred at the beginning and the end of the cycling. During cycling, the PR/RR ratio remained at a similar level to before and after control condi- tions. Different from resting controls, the pulse and respiration rates were significantly elevated simultaneously during cycling, as shown in Fig. 3A. To further evaluate the dynamic correlations between pulse rate, respiration rate, and SpO_2, the raw data were broken into 5-min segments. The means and standard deviations (SD) of 5-min segments are plotted in panels C, D, and E of Figs. 1e3.As shown in Fig. 1C and D, pulse rates were increased when SpO_2 dropped during Qi Gong meditation practice. As shown in Fig. 3CeE, pulse rate was again negatively correlated with SpO_2. As shown in Fig. 3C and E, the pulse rate was positively correlated with the respiration rate during mild cycling exercise. By contrast, during Qi Gong meditation practice, the respiration rate was maintained at a slow rate, as shown in Fig. 1E. In agreement with known physi- ology, the intended action of slowing the respiration rate during meditation resulted in reduction of SpO_2, which in turn triggered

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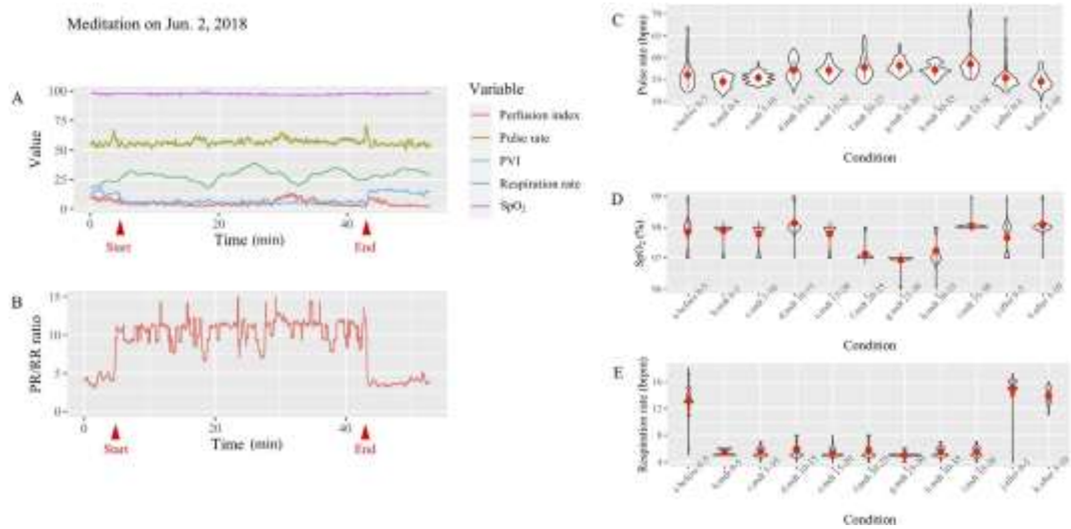


Fig. 1. Oximeter recording of a single Qi Gong meditation practice.

Notes: A: A typical recording output from a meditation practice. The red arrows indicate the start and the end of the meditation practice. Five data types were reported by a Masimo oximeter, MightySat: SpO_2, pulse rate, respiration rate, perfusion index, and PVI. B: The PR/RR ratio showed a significant increase during meditation practice. C: Segmented statistics of pulse rate during the practice. D: Segmented statistics of oxygen saturation during the practice. E: Segmented statistics of respiration rate during the practice. C, D, and E summarize statistics of 5-min segments of A. C shows a slight increase in pulse rate that is negatively correlated with the slight drop (about 1%) in SpO_2 shown in D. E shows a decrease in respiration rate during meditation practice. SpO_2: oxygen saturation; PVI: pleth variability index; PR/RR: pulse-respiration rate ratio.

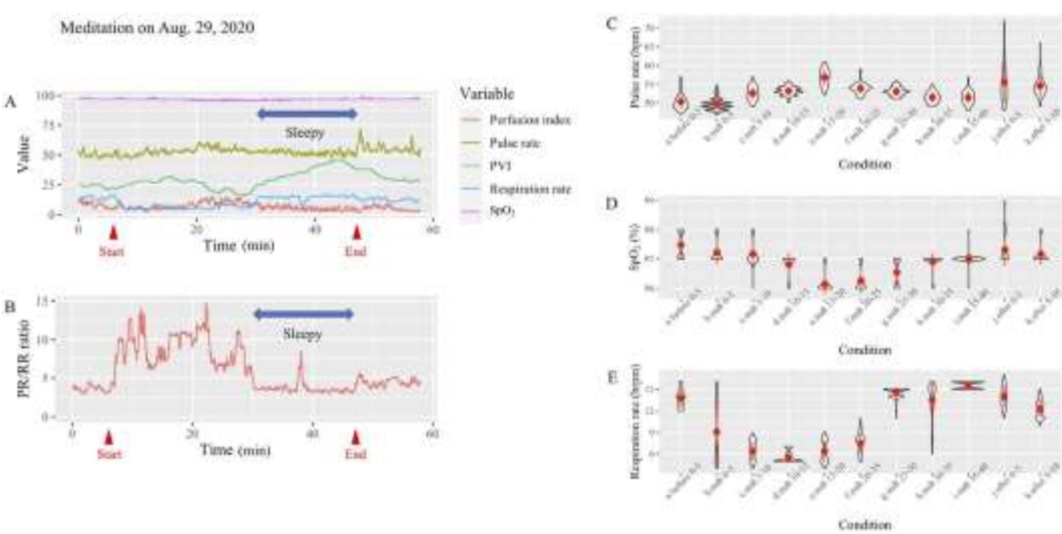
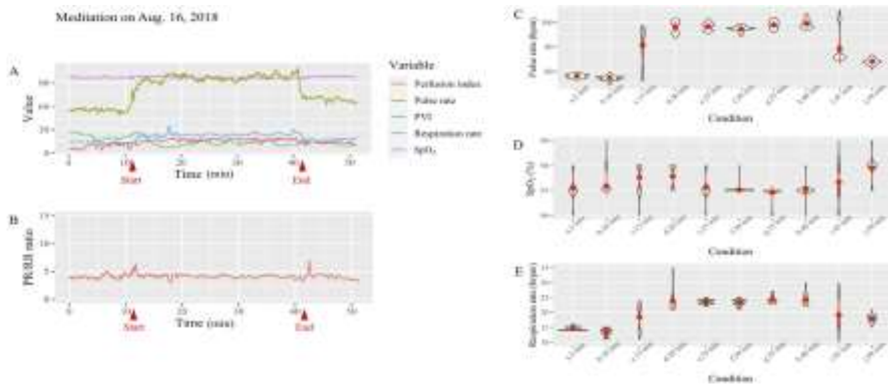


Fig. 2. Typical Qi Gong meditation recording with poor quality.

Notes: A: An example of a recording output of a meditation practice that is of poor quality. The red arrows indicate the start and the end of the meditation practice. The blue bar indicates a period of sleepiness noted in the practice notes about 20 min after the start of meditation practice. B: The PR/RR ratio showed a significant drop during the time of sleepiness noted during meditation practice. C: Segmented statistics of pulse rate during the practice. D: Segmented statistics of oxygen saturation during the practice. E: Segmented statistics of respiration rate during the practice. C, D, and E summarize statistics of 5-min segments of A. During the sleepiness phase from 25 to 40 min of meditation practice, the pulse rate decreased (C), SpO_2 increased toward the resting level (D), and the respiration rate increased (E). SpO_2: oxygen saturation; PVI: pleth variability index; PR/RR: pulse- respiration rate ratio.

Fig. 3. Oximeter recording of a mild cycling exercise.
Notes: Cycling in seated position took place between the red arrows. A: Five measures resulted from the oximeter recording. The onset of increased pulse rate was correlated



with the beginning of a mild cycling exercise. B: The PR/RR ratio did not increase significantly during mild cycling. C: Segmented statistics of pulse rate during the practice. D: Segmented statistics of oxygen saturation during the practice. E: Segmented statistics of respiration rate during the practice. C, D, and E summarize statistics of 5-min segments of A. Means ± SDs are shown in red. When the SpO_2 shown in (D) was maintained at around 97%, the pulse rate (C) and respiration rate (E) increased proportionally, which resulted in the PR/RR ratios being maintained below 5. SpO_2: oxygen saturation; PVI: pleth variability index; PR/RR: pulse-respiration rate ratio.

the increase of pulse rate and PR/RR ratio. As shown in Figs. 1 and 3, the increase of the PR/RR ratio is a unique measure to demonstrate the difference between Qi Gong meditation practice and mild cycling exercise.

2.5. Summary statistics of instantaneous recording data of Qi Gong practice

Recordings of 138 practices with 420 508 data points were used to evaluate distributions, and the summary statistics of vital signs as well as the PR/RR ratio. The results are shown in Fig. 4. The violin plots indicate the distribution patterns of data points, and the box plots show the results of summary statistics, in which the red dots indicate the mean values, and the red lines show the standard deviation (SD). The summary statistics are also listed in Supplemental Table 1. In comparison with before and after controls, Qi Gong meditation shifted the pulse rate higher by 2 bpm on average (before meditation 51.3 ± 3.9 bpm, during meditation 53.7 ± 3.6 bpm, and after meditation 52.7 ± 3.8 bpm), as shown in Fig. 4A. The respiration rate was decreased by 5.5 brpm on average (before meditation 13.0 ± 2.0 brpm, during meditation 7.5 ± 2.5 brpm, and after meditation 12.5 ± 2.1 brpm), as shown in Fig

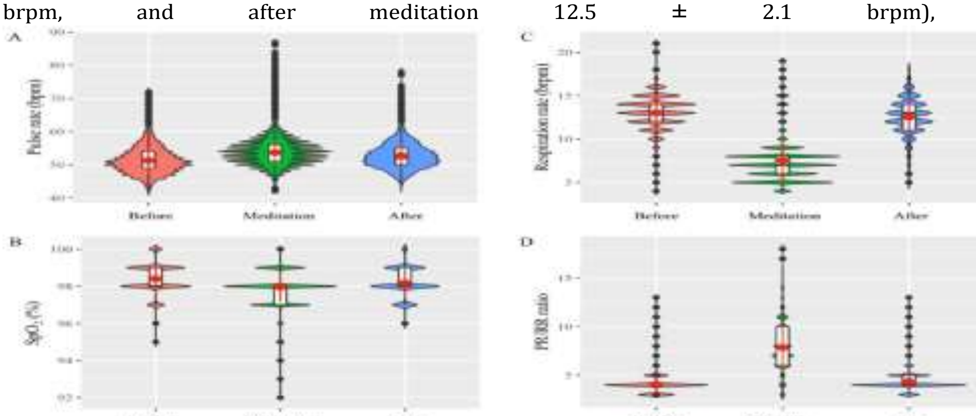


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Fig. 4. Distributions and summary statistics of vital sign data and the PR/RR ratio.
Notes: Distributions of vital signs recorded with the MightySat oximeter are presented here in violin plots. Summary statistics are presented as box plots, where red dots represent means and red lines represent SDs. PR/RR: pulse-respiration rate ratio.

SpO_2 was decreased by 0.4% on average (before meditation 98.4% ± 0.8%, during meditation 98.0% ± 0.8%, and after meditation
98.2% ± 0.7%), as shown in Fig. 4C. The PR/RR ratio increased nearly 2-fold (before meditation 4.1 ± 1.0, during meditation 7.9 ± 2.4, and after meditation 4.4 ± 1.1), as shown in Fig. 4D. The changes be- tween Qi Gong meditation and before or after controls were all significant ($P < .001$). Among the changes, the mean PR/RR ratio of
7.9 in the Qi Gong meditation condition has not been reported before. This finding can be used as a quantitative measure to explore the physiological mechanism of Qi Gong meditation.

Fig. 5 shows the non-linear correlations among the instanta- neous vital sign data in response to Qi Gong meditation training. To illustrate the progressive adaptation in long-term Qi Gong medi- tation training, the mean values grouped by years were graphically presented. The mean values of data collected in 2016 and 2020 are depicted in Fig. 5, and the same data collected in 5 years are shown in Supplemental Fig. 1. The left side of Fig. 5 (5A, 5C, 5E, 5G, 5I, and 5K) shows the mean data of resting control collected immediately prior to the meditation practice. The right side of Fig. 5 (5B, 5D, 5F, 5H, 5J, and 5L) shows the mean data during Qi Gong meditation practice. In Fig. 5A and C, the PR/RR ratio before resting control was between 3 and 6 in 2016 and was expanded to 3e13 in 2020, indicating a more flexible cardiorespiratory coupling under the resting condition after years of Qi Gong meditation training. In Fig. 5E, respiration rates increased to 16 brpm when pulse rates >65 bpm in 2016 but were maintained around 13 brpm in 2020, which demonstrates the increased resilience in pulse-respiration regula- tion under the resting condition. This small change was achieved gradually starting in 2017, as shown in Supplemental Fig. 1E. As shown in Fig. 5K, the resting SpO_2 level corresponded to the lower perfusion index curve in 2020 than in 2016, which indicates an adaption achieved with long-term Qi Gong meditation training. As shown in Fig. 5B, J, and L, the correlations between SpO_2 and the PR/RR ratio, pulse rate, and perfusion index shifted downward from 2016 to 2020 during Qi Gong meditation practice, which reflects a reduction in responses to the decrease of SpO_2 level during Qi Gong meditation. As shown in Fig. 5D, the perfusion index was relatively similar between 2016 and 2020 when PR/RR ratios <10. When PR/ RR ratios >10, the perfusion index values in 2016 varied by 7 units (2e9 units), and they only varied by 4 units (5e9 units) in 2020. Fig. 5F, H, and J highlights the potential physiological mechanisms to maintain the stable perfusion index shown in Fig. 5D. As shown in Fig. 5F, when pulse rates were between 43 and 53 bmp, the respiration rate was negatively correlated with pulse rate, and a significant reduction was evident in 2020. When the pulse rate was over 65 bmp, the respiration rate was positively correlated with the pulse rate. In 2016, the correlation between the respiration rate and pulse rate was a reversed bell shape and had significantly more volatility when the pulse rate was over 65 bmp. As shown in Fig. 5H and J, a pulse rate over 65 bmp was a critical turning point for the regulation of the perfusion index and blood oxygen saturation. When the pulse rate was over 65 bmp, the perfusion index was decreased dramatically, and the SpO_2 was highly variable. In 2020, the turning point of the sharp drop in the perfusion index was shifted to a higher pulse rate (about 2e3 bmp), and the amplitudes of the variabilities of SpO_2 and pulse rate curves were smaller, indicating the adaptations of long-term training. Fig. 5L shows the downward shift of the correlation curve between SpO_2 and the perfusion index during Qi Gong meditation practice in 2020, which suggests that the same vascular tone could tolerate lower levels of SpO_2 in 2020 than in 2016 during Qi Gong meditation. To illustrate the progression of these changes, the data from 2016 to 2020 were plotted in Supplemental Fig. 1. These changes were achieved gradually over the years of practice. Therefore, they could be true training effects. According to the existing knowledge of human physiology, these correlated changes indicate the training effects of Qi Gong meditation on the reduction of response amplitudes to moderate physiological hypoxia.

Training adaptation was also demonstrated in Fig. 6. With a total of 1047 recorded pulse rates from the Microsoft Band or Apple

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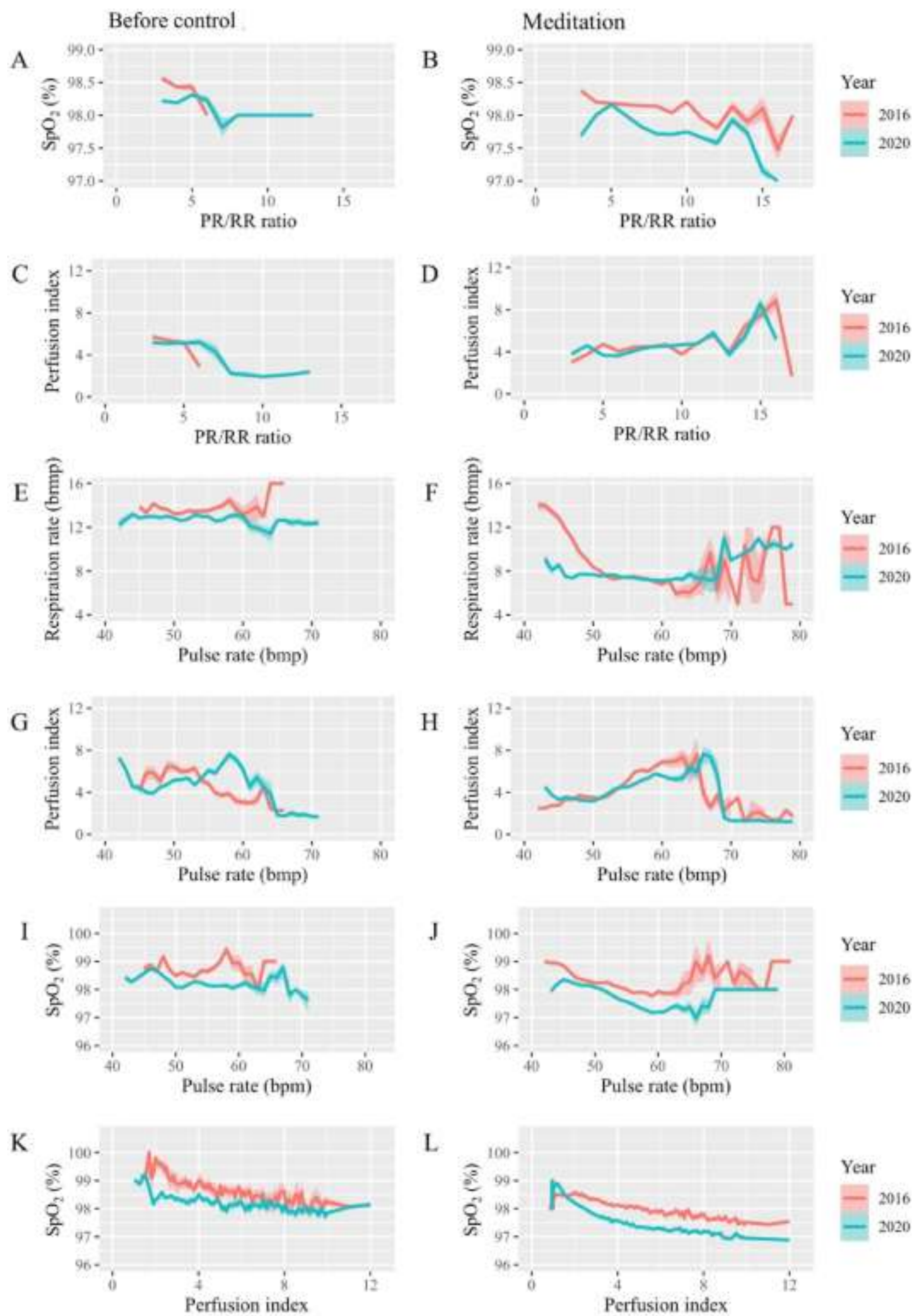

Fig. 5. Correlations among pulse rate, respiration rate, perfusion index, SpO_2, and PR/RR ratio before-meditation control and meditation conditions.
Notes: Mean values of the instantaneous pulse rate, respiration rate, perfusion index, SpO_2, and PR/RR ratio collected in 2016 and 2020 are represented by the solid lines. The data of the before-meditation control are plotted in A, C, E, G, I, and K, indicating correlations among vital signs during the baseline and adaption states achieved by long-term Qi Gong meditation practice. The data of Qi Gong meditation are graphed in B, D, F, H, J, and L, indicating correlations among vital signs during Qi Gong meditation practice. SpO_2: oxygen saturation; PVI: pleth variability index; PR/RR: pulse-respiration rate ratio.

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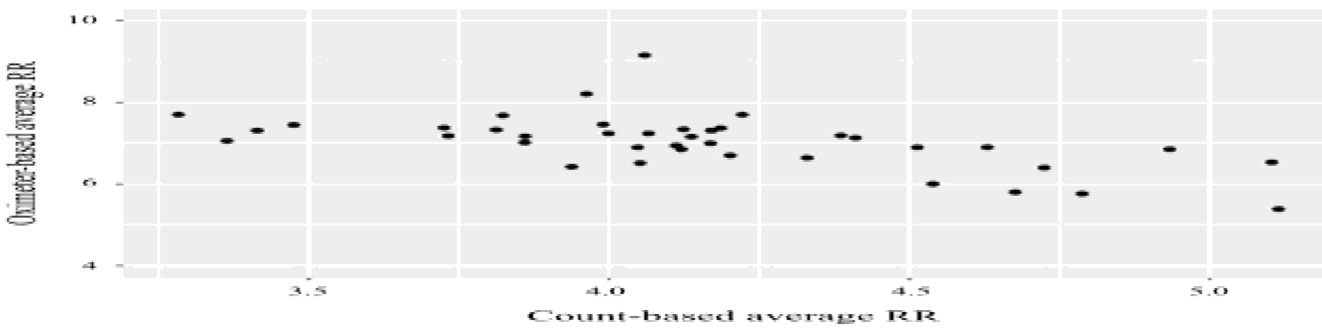

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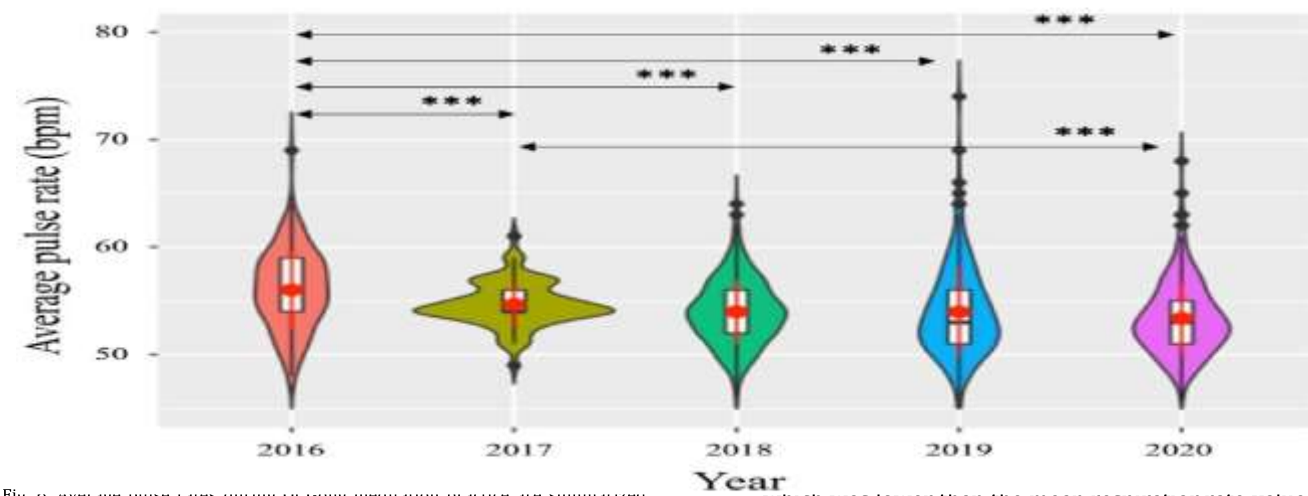

Fig. 6. Average pulse rates during Qi Gong meditation practice are summarized over time.

Notes: Violin plots demonstrate the distributions of average pulse rates of meditation practice. The box plot indicates the median value and first and third quartiles. Red dots and lines indicate the means ± SDs. Black arrow lines indicate the t test comparisons.

***$P < .001$. Years of Qi Gong meditation training decreased the average pulse rate from 56 ± 3.6 bpm in 2016 to 53 ± 3.3 bpm in 2020.

Watch during Qi Gong meditation practices (*n* ¼82) and calculated from MightySat data (*n* ¼65), the average pulse rates of Qi Gong meditation practices dropped significantly ($P < .001$) from
56.0 ± 3.6 bpm in 2016 to 53.0 ± 3.3 bpm in 2020. The violin plots in Fig. 6 demonstrate the distributions of average pulse rates. The boxplots indicate the summary statistics, where red dots and lines indicated the means ± SDs of average pulse rates grouped by years. Mean and SD data supporting Fig. 6 are shown in Supplemental Table 2.

2.6. Limitation of algorithm-based respiration rate prediction by MightySat

It was reported that the respiration rate extracted from plethysmographic waveform has its limitation beyond the range of 12e20 brpm.[20] This limitation was also observed in the MightySat oximeter data reported in this study. Among the 138 recorded practices, 40 of them (29%) also had the total breath counts during meditation detailed. Fig. 7 presents the correlation of average respiration rates between algorithm-based and mentally counted rates. The average respiration rates of 40 counted practices had a mean of 4.1 ± 0.4 brpm, which was lower than the mean respiration rate value of 7.5 ± 2.5 brpm reported from the MightySat oximeter shown in Supplemental Table 1. The average PR/RR ratios calculated by dividing average pulse rates reported with the Apple Watch by the count-based respiration rates had a mean of 13.2 ± 1.5, which was much higher than algorithm-based results of 7.9 ± 2.4. In recent years, the bias of respiration rate extracted through algo- rithms has been corrected in other wearable devices. For example, a newer model of Garmin watch Vivoactive 4S reported average respiration rates centered around 4 brpm in Qi Gong meditation practices (based on 95 practice recordings since November 2021), which matched count-based average respiration rates.

3. Discussion

Long ago, in the Yellow Emperor's Classic of Internal Medicine (Huang Di Nei Jing), the health advantages of practicing Qi Gong meditation were first outlined.1 While a large body of recent research on the therapeutic effects of meditation and Qi Gong has revealed

beneficial impacts on well-being,2,3 One thing that makes it hard to evaluate this ancient

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intervention is the fact that there are no objective ways to quantify the quality of Qi Gong practice.21 In this regard, the potential for changes in vital signs during Qi Gong meditation practice to serve as biomarkers in future clinical research of Qi Gong is encouraging. The MightySat fingertip pulse oximeter, Apple Watch, and Microsoft Band were used in this one-subject five-year longitudinal study. Commercially available wearables include the Apple Watch and the Microsoft Band, while the MightySat is a medical gadget that gives clinical-grade measurements of vital signs and has been authorised by the FDA.13 The MightySat stood out from the competition in 2016 when the author was looking for an oximeter due to its algorithm-based respiration rate.22 With this function, all three vital signs—heart rate, respiration rate, and blood oxygen saturation—could be recorded simultaneously on the same device. While breathing rate remained constant, vital sign measures taken before, during, and after Qi Gong meditation sessions demonstrated physiological adaptability and resilience in the dynamically controlled SpO2, pulse rate, and perfusion index. While Qi Gong meditation exercise included a naturally longer exhale, a little drop in SpO2 level caused the heart rate to rise (Fig. 1). Under the Qi Gong meditation, the average SpO2 level declined by 0.4% and the average pulse rate rose by 2 bpm, despite the fact that the instantaneous SpO2 levels and pulse rates fluctuated dynamically.

condition, shown in Figure 4. Also in 2017, Bernardi et al. showed that acute meditation practice reduced SpO2.23 Not only did long-term Qi Gong meditation training have this acute effect, but it also reduced resting SpO2, perfusion index, and pulse rate (Figs. 5 and 6). This is probably due to physiological adaptations brought about by years of LSBZQYXF meditation training. In a comprehensive study of endurance and yoga training, Reimers et al. also found that participants' resting heart rates decreased.24 The review paper did not assess the relationship between the decrease in resting heart rate and the change in blood oxygen saturation. Here, variations in SpO2 level were shown to correspond with the immediate dynamic control and adaptation of heart rate fluctuations.

Moreover, the elevation of PR/RR ratios greater than 4 and 5 is observed as a unique feature in the LSBZQYXF meditation state, which has not been reported before. The 4:1 or 5:1 pulse-

4. Long ago, in the Yellow Emperor's Classic of Internal Medicine (Huang Di Nei Jing), the respiration ratio was included as a measure for assessing health.25 In contrast to the resting before and after control circumstances, the distribution of instantaneous PR/RR ratio during Qi Gong meditation settings centred on values significantly larger than 4 or 5, according to the early preliminary data analysis in 2016. The author repeated tests using the MightySat oximeter in both resting and active states to have a better grasp of this phenomena. The MightySat oximeter had trouble recording the rate of breathing during riding until fatigue set in. The respiration rate signal remained unaffected by mild cycling, as seen in Figure 3. The distributions of the instantaneous PR/RR ratios centred around 4 were preserved throughout both light cycling and sleep.
In their December 2019 human investigation, Scholkmann et al. noted the same thing with the resting PR/RR ratio centred around 4.26 In a review, the same authors synthesised this cardiorespiratory coupling phenomena and coined the term "Pulse-Respiration Quotient" (PRQ) to describe the PR/RR ratio of 4.27 April 2019 marked the publication of this review. Although the statement in the Yellow Emperor's Classic of Internal Medicine (Huang Di Nei Jing) was made thousands of years ago, the authors state that the initial PRQ research was carried out in the 1920s. It was the Austrian scientist Rudolf Steiner who first highlighted the potential of the

PRQ 4:1 in understanding human physiology. In the years after Steiner's groundbreaking research, a number of German scientists have contributed to journals published in German since 1953. The work of Scholkmann et al. brought back German research into English literature. Age, gender, circadian rhythm, body posture, and exercise intensity were shown to have an effect on the PR/RR ratio. One participant in the present research sat quietly throughout the meditation condition, and data was taken at predetermined intervals. We have eliminated potential sources of data variance by avoiding the use of several individuals of various ages and genders, recording in different practice times, and subjecting them to diverse settings. This is the PR/RR ratio.

while exercising was also recorded with the use of a Garmin watch.28 This finding demonstrated that three distinct forms of exercise—strength training, running, and elliptical training—exhibited average PR/RR ratios ranging from 3.5 to 4.7. The findings presented in this investigation were likewise in agreement with the observations made with the Garmin watch. According to Scholkmann et al.'s review, the PRQ may be defined in two ways: first, using measurements of PR and RR taken at the same moment; and second, using data taken at a longer interval, say 1 minute, to calculate the PR/RR ratio.27 The PR/RR ratio was calculated instantly in this research using data from the oximeter. Furthermore, this study revealed the first-ever simultaneous measurement of the blood SpO2 level and the instantaneous PR/RR ratio. In Figure 5B, we can see that there is a negative correlation between the instantaneous SpO2 level and the PR/RR ratio. This is due to the fact that, when the pulse rate is between 48 and 65 bpm, there is also a negative correlation between the instantaneous SpO2 level and the instantaneous pulse rate (Fig. 5J). This five-year follow-up study found that assessing blood oxygen saturation level in conjunction with the PR/RR ratio may have an effect. In order to better understand the physiological processes by which Qi Gong meditation imparts its health benefits, may an enhanced PR/RR ratio serve as a quantifiable biomarker? When the cardiorespiratory coupling changes, how does it control the autonomic nervous system to make us more resilient? While these problems remain unanswered, Russo et al. (29), and Boyadzhieva et al. (30) addressed the physiological and neurological views on the benefits of slow breathing and its probable causes. Consistent with previous research, the present study found that LSBZQYXF meditation included breathing at a cadence of 0.1 Hz, or 6 breaths per minute, while simultaneously promoting physiological and psychological calm.31 According to the research, this breathing rhythm improves the synchronisation of the heart and lungs. As a consequence of practicing LSBZQYXF Qi Gong meditation for an extended period of time, one may reduce their resting blood oxygen saturation (SpO2), heart rate (HR), and perfusion index (PI)—all of which contribute to better energy conservation. Some research suggests that physiological hypoxia might have positive effects on health by triggering adaptations in the body.32 By influencing lipid metabolism and redox homeostasis, intermittent hypoxia may have positive health effects.33 According to a mouse in vitro and in vivo investigation, cardiac regeneration may be facilitated by a moderate drop of heart rate (10%e20%) caused by anti-arrhythmic medications via stimulating the metabolic pattern switch.34 Human pluripotent stem cell-induced cardiomyocytes (hPSC-CMs) cells also demonstrated heart regeneration caused by anti-arrhythmic drugs.34 In this research, participants who practiced Qi Gong meditation for 5 years had a decrease of 3 beats per minute (5.4%). Could the impact shown in animal research and cell culture be

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replicated in people by reducing the pulse rate, which promotes heart regeneration? In the current research on the benefits of meditation, the effects on the nervous system, in addition to the heart, have emerged as major themes.35 In this case, a decrease in resting SpO2 was associated with long-term Qi Gong meditation practice, according to a longitudinal observation. The advantages of this non-pharmaceutical treatment for controlling whole-body metabolism are brought to light by this discovery. These results require more investigation in order to confirm the significance of vital indicators during Qi Gong meditation.

A handy tool for keeping tabs on your Qi Gong meditation sessions, the MightySat oximeter isn't without its drawbacks. To begin with, it does not capture heart rate variability (HRV) data often enough (one record per second). Secondly, while the device could show the plethysmographic waveforms, it couldn't export them for further analysis. This meant that the data collected couldn't be used for a thorough assessment of the cardio-respiratory coupling and vascular tension. Numerous studies have linked stress and ageing to HRV and cardio-respiratory coupling.eleven, thirty-seven, We can delve deeply into the physiological mechanics of Qi Gong meditation using more frequent data points and the waveform. This longitudinal data is analysed retrospectively and compares an individual's moods before, during, and after meditation. Seasonal changes were minimised in the analysis by directly comparing the control and meditation conditions in each recording. Nevertheless, the present investigation is not without its caveats. First of all, this was not an attempt to recreate a laboratory environment; rather, it was an attempt to observe Qi Gong meditation in its own habitat. The duration of each exercise varied somewhat according to practical considerations. I think it's important to approach the findings with an inquisitive mindset. Secondly, the summary statistics of average values do not clearly reflect numerous dynamic elements of physiological regulations among the vital signs, which only happened in a limited duration during therapy. Additional quantitative measures of physiological resilience may be revealed in future analysis of time series with data captured more often. These results must be confirmed in a larger-scale randomised controlled trial that accounts for demographic variables such as age, gender, race/ethnicity, and medical history.

5. Conclusions

6. It was shown in this early retrospective analysis research that meditation may drop the blood SpO2 level, raise the pulse rate, and elevate the PR/RR ratio. The participants wore wearable devices that recorded critical vital signs throughout 5 years of Qi Gong meditation practice. A decrease in blood SpO2, pulse rate, and perfusion index was seen in the resting state after long-term LSBZQYXF training. Meditating causes a distinct physiological state distinct from sleeping, resting, and light cycling activity, characterised by an increase of the PR/RR ratio larger than 4 or 5. This paper details the results of a longitudinal study that tracked a healthy individual's vital signs as they progressed through LSBZQYXF meditation instruction and practice. These results have important implications for the development of future mechanistic studies of meditation intervention and for the evaluation of Qi Gong practice adherence. They suggest the possibility of objective metrics for evaluating the quality of meditation practice.

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