

# Adherence to virtual Qigong practice and its relationship with sleep and mental health: A large cross-sectional global study of middle-aged and older Asian adults

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## ABSTRACT

**Background:** Adherence to mind-body exercise practices such as Qigong has been positively associated with mental health indicators, but the underlying mechanism remains unclear. We aim to explore whether the association between adherence to virtual Qigong exercise and mental health indicators is partially accounted by sleep quality among middle-aged and older Asian adults participating in a global home-based virtual Qigong program.

**Method:** A total of 1393 Asian adults ( $M_{age} = 52.67$  years, 86% female) who practiced home-based virtual Qigong both individually and in group settings were recruited as study participants. Exercise adherence was measured using the Exercise Adherence Rating Scale (EARS). Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Mental health indicators included depressive symptoms, assessed using the Beck Depression Inventory (BDI-SF), and mental sub-health status, assessed using the Mental Sub-Health Scale from the Sub-Health Measurement Scale version 1.0 (SHMS v1.0). Cross-sectional data were collected from November to December 2022. A total of 1374 participants with complete data on all model variables were included in the mediation analyses.

**Results:** Exercise adherence was significant associated with sleep quality, depressive symptoms, and mental sub-health (all  $p < .001$ ). Cross-sectional mediation analyses showed that sleep quality partially accounted for the association between exercise adherence and mental health indicators. For depressive symptoms, exercise adherence was negatively associated with PSQI,  $B = -0.244$ ,  $p < .001$ , and PSQI was positively associated with BDI-SF,  $B = 0.453$ ,  $p < .001$ . The indirect effect was significant,  $B = -0.110$ , 95% bootstrap CI [-0.143, -0.082], while the direct effect remained significant,  $B = -0.246$ ,  $p < .001$ . For mental sub-health, PSQI was negatively associated with MS,  $B = -0.020$ ,  $p < .001$ . The indirect effect was significant,  $B = 0.005$ , 95% bootstrap CI [0.004, 0.006], while the direct effect remained significant,  $B = 0.011$ ,  $p < .001$ .

**Conclusion:** Adherence to mind-body exercise practices such as Qigong was associated with better sleep and mental health. Sleep quality partially accounted for the association between exercise adherence and mental health indicators. Home-based virtual Qigong may represent an accessible format for supporting sleep and mental health, yet causal effects require confirmation in longitudinal or intervention studies.

## 1. Introduction

Mental health issues, such as depression, have been increasingly viewed as public health concerns (Arends et al., 2022), which results in significant personal distress for affected individuals and families as well

as imposing a considerable burden on society. Beyond clinically diagnosable mental disorders, researchers have also recognized intermediate states of psychological well-being that fall between optimal mental health and mental illness. One such concept is mental sub-health, which has been widely discussed in Asian public health literature. Mental

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sub-health refers to a transitional or subclinical state characterized by psychological discomfort, reduced vitality, emotional instability, or mild psychological symptoms that do not meet diagnostic criteria for mental disorders (Miao et al., 2021). Studying mental sub-health is particularly relevant in community populations because it reflects early or mild psychological difficulties that may precede more severe mental health problems. Modifiable factors, such as lifestyle choices, play a crucial role in influencing mental health and offer opportunities for intervention (Firth et al., 2020). It is thus essential to thoroughly examine the interconnected factors related to mental health challenges to develop effective targeted programs (Worrall et al., 2020).

Among various interventions, exercise is widely acknowledged as a cost-effective method for improving mental health. Cross-sectional studies consistently associate regular exercise with improved mental well-being (Chekroud et al., 2018; Hallgren, Kandola, et al., 2020), and longitudinal studies further reinforced its protective effects across all age groups, including adolescents (Chiang et al., 2024), adults (Schuch et al., 2018), and older adults with physical disabilities (Battalio et al., 2020). Regular exercise has been linked to elevated mood and reduced symptoms of depression and anxiety (Ligeza et al., 2023), improved cognitive function and reduced stress levels (Arida & Teixeira-Machado, 2020; Ashdown-Franks et al., 2020).

One accessible form of mind-body exercise is Qigong, a traditional Chinese practice that integrates physical movement, breathing techniques, and focused intention. Qigong is particularly well-suited for aging populations due to its low-impact nature and documented psychological benefits, including emotional regulation and stress reduction (Cheng, 2015; Liu, Yang, et al., 2023). Taken together, the current evidence suggests that exercise may provide a holistic approach to enhancing mental health, supporting its role as a valuable modifiable factor for intervention.

A crucial factor in maximizing the benefits of exercise is exercise adherence, defined by American Psychological Association (APA) as the extent to which individuals consistently attend and engage with a prescribed exercise regimen. High adherence is essential to sustain the long-term mental health benefits of exercises (Rivera-Torres et al., 2019).

Exercise has been consistently associated with improved sleep quality and duration (Kredlow et al., 2015; Rosa et al., 2021; Y. Xie, Liu, et al., 2021). Mind-body exercises like Qigong may provide similar benefits (He et al., 2019; Liu, Yang, et al., 2024). Mechanistically, exercise may enhance sleep through homeostatic regulation, circadian phase shifts, or by altering REM and NREM sleep patterns (Ezati et al., 2020; Suppiah & Chia, 2015).

Sleep quality is also deeply intertwined with mental health symptoms. Approximately 75% of individuals with depression display symptoms of insomnia, excessive daytime sleepiness, and hypersomnia (Nutt et al., 2008), highlighting the strong connection between sleep disturbances and mental health. Longitudinal studies reveal that disrupted sleep patterns serve as precursors to mental health disorders, with insufficient sleep implicated in the onset and exacerbation of conditions such as anxiety and depression (Li et al., 2017; Roberts & Duong, 2014). Insufficient or poor-quality sleep contributes to impaired emotional regulation, heightened stress sensitivity, and worsened symptoms of mental disorders (Du et al., 2021; Gruber & Cassoff, 2014; Reid et al., 2023; Serrano et al., 2023).

Emerging research suggests that sleep may mediate the relationship between exercise and mental health. Individuals with greater physical activity and better sleep tend to report fewer depressive symptoms (Barham et al., 2022). However, several gaps remain. Most prior studies focus on exercise frequency or duration rather than adherence. Measuring adherence helps identify barriers to continued participation and supports the development of strategies to maintain long-term behavioral change. Additionally, few studies have examined these relationships within the context of home-based virtual exercise, despite the post-pandemic growth of online physical activity programs (Fearnbach et al., 2021; Im et al., 2021).

This study aims to address these gaps by examining exercise adherence, sleep quality, and mental health (including depressive symptoms and mental sub-health) in a large sample of middle-aged Asian adults who regularly practice Qigong virtually, both individually and in group settings. By focusing on adherence rather than frequency alone, and leveraging a culturally relevant, low-cost, and scalable virtual mind-body practice, this study offers insights into sustainable strategies for mental health promotion in aging populations.

We hypothesize that higher exercise adherence will be associated with better sleep quality, fewer depressive symptoms, and higher mental sub-health scores. Specifically, we further test whether sleep quality partially accounts for the associations between exercise adherence and mental health indicators in cross-sectional mediation models.

## 2. Methods

### 2.1. Participants and procedure

Between January and December 2022, global Asian adults attending a home-based, virtual Qigong exercise program in a specific social network were invited to participate in this study; this virtual format was initially adopted due to pandemic restrictions and continued to be sustained in the post-pandemic period (Liu & Liu, 2024; Liu, Liu, et al., 2024). A total of 1393 participants were recruited from Taiwan, Malaysia, Singapore, Hong Kong, and other regions. The inclusion criteria were as follows: a) being 18 years of age or older, b) having actively engaged in virtual Qigong courses within the specific social network, c) not having significant physical limitations, and d) possessing the cognitive capacity to complete questionnaires. Individuals with current diagnoses of major acute illnesses or psychotic disorders were excluded from the study. Of these, 1374 participants had complete data on all variables entered in the mediation models and constituted the analytic sample for the inferential analyses (see Statistical analysis).

The recruitment process involved the distribution of recruitment posters online and the identification of suitable participants through convenient sampling. To incentivize participation, we offered a chance to win free Qigong courses through a random draw. After reaching out to participants, information about the study was provided including the purposes, benefits, and potential risks associated with participation.

The data collection of this study was conducted in November–December 2022. Participants used electronic questionnaires to complete a battery of assessments, including demographic information such as age, gender, marital status, and education level, as well as data on exercise behaviors, mental health indicators, and sleep quality. The recruitment materials and electronic questionnaires were administered in Chinese. Participants from all regions, including Taiwan, Hong Kong, Singapore, Malaysia, North America, Europe, and other locations, were Chinese-speaking and completed the same Chinese-language survey. No other versions of the questionnaire were administered.

### 2.2. Home-based virtual Qigong program

Qigong is a mind-body exercise that incorporates mindfulness-based meditation, breathing, and physical movements to increase energy balance and enables healing (Zou et al., 2018). In this study, the Qigong exercise consisted of 60-min instructor-led large group sessions, smaller group sessions, and individual practice sessions over a twelve-month period, from January to December 2022. All sessions were delivered virtually through a social media platform called Dingtalk. To ensure a structured and progressive curriculum, participants were grouped on Dingtalk according to their skill levels, ranging from novice to advanced. Each group was assigned a dedicated supervisor responsible for coordinating session schedules and sending participation reminders. In addition to participating in the virtual exercises, participants also frequently updated their activity status, followed others' progress, and interacted with the larger global virtual community, all of which helped

promote sustained participation.

### 2.3. Ethical considerations

This study adhered to ethical guidelines to protect participants' rights and well-being. Informed consent was obtained from all participants. Data were kept confidential and anonymized to ensure privacy. The study was approved by the Ethics Board of Qigong for Life Association (E2021002), the ethics review committee of the nonprofit association that oversees research. The board reviewed the study protocol, recruitment procedures, informed consent process, questionnaire content, participant confidentiality protections, and potential risks and benefits before data collection. The review process was guided by standard human-subjects research principles, including voluntary participation, informed consent, confidentiality, minimization of risk, and the right to withdraw. The research team was not involved in the ethics review decision. All participants provided informed consent before completing the electronic questionnaire, and all data were anonymized before analysis. Participants were not exposed to significant risks. All procedures were culturally sensitive and appropriate for the target population.

### 2.4. Measures

We disseminated a post Qigong program cross-sectional survey to assess whether exercise adherence was associated with sleep quality and mental health outcomes. The specific measurements are listed below. All measurements were administered in Chinese. The same Chinese-language instruments were used across geographic regions, and participants completed the questionnaire electronically.

#### 2.4.1. Demographic variables

Demographic data were collected via a self-report questionnaire, including sex, age, marital status, education level, and geographical location. Additionally, based on previous literature (Hallgren, Vancampfort, et al., 2020; Pavey & Brown, 2019; Vaingankar et al., 2020), health-related variables were also incorporated such as number of underlying diseases, specifically diabetes, hypertension, coronary heart disease, kidney disease, chronic pain, cancer, and others. We also examined participants' body mass index (BMI) and their drinking and smoking habits, which were categorized as follows: none, 1-2 times per week, 3-4 times per week, and 5 or more times per week.

#### 2.4.2. Exercise adherence

Since participants consistently engaged in the Qigong exercises over a period of twelve months, it was crucial to monitor their adherence. Consequently, exercise adherence was selected as the independent variable of interest rather than solely focusing on exercise frequency or intensity because it provides a more accurate measure of participants' commitment to and consistency in performing the Qigong exercises.

Exercise Adherence Rating Scale (EARS) was used to assess participants' exercise adherence. The 6-item scale was designed to measure the adherence to prescribed home exercise. Participants were asked to rate their exercise adherence on a 5-point Likert scale, ranging from 0 (strongly disagree) to 4 (strongly agree). The EARS generates a composite score that can vary from 0 to 24, with higher scores indicating a higher level of exercise adherence. The scale demonstrated good internal consistency, with a Cronbach's alpha coefficient of 0.81 (Newman-Beinart et al., 2017). EARS is validated in Chinese populations; the Cronbach's  $\alpha$  of the Chinese version of the EARS was previously reported to be 0.94 (Yuxuan et al., 2024).

#### 2.4.3. Sleep quality

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Subjective sleep quality, sleep latency, sleep duration, sleep efficiency (the proportion of sleep time spent in bed), sleep disturbances

(nighttime waking), use of sleep medications, and daytime dysfunction (distressed and impaired daytime functioning) are the seven categories covered by this tool. Answers were graded on a scale of 0 to 3 for a final score of 21. According to Buysse et al. (1989), higher values suggest lower sleep quality, with a total score greater than 5 suggesting significant sleep difficulties. PSQI is validated in Chinese populations; the Cronbach's  $\alpha$  of the Chinese version of the PSQI was previously reported to be 0.82-0.83 (Tsai et al., 2005). The Cronbach alpha of PSQI in this study is 0.806.

#### 2.4.4. Depressive symptoms

The BDI-SF, a short form of the Beck Depression Inventory, was used to evaluate the participants' depressive symptoms. It has 13 questions and asks participants to score each one on a scale of 0 to 3, depending on the intensity of their own symptoms. Higher scores on the BDI-SF indicate a greater level of depressive symptoms, with a commonly recommended cutoff for screening at 10 (Beck et al., 1961). This well-established instrument has demonstrated strong reliability and validity in assessing depressive symptoms and has been widely used in both clinical and research settings to effectively evaluate depressive symptoms (Furlanetto et al., 2005). BDI is validated in Chinese populations; the Cronbach's  $\alpha$  of the Chinese version of BDI was previously reported to be 0.85-0.94 (Wang et al., 2011, 2020; Yang et al., 2012). The Cronbach alpha of BDI in this study is 0.868.

#### 2.4.5. Mental sub-health status

Mental sub-health status was assessed using the Sub-Health Measurement Scale version 1.0 (SHMS v1.0). The instrument contains a mental sub-health subscale consisting of 14 items. It employs the Likert five-point scoring system, where higher scores reflect better health conditions. In order to make things clear and comparable, the original raw scores were converted into a percentage scale for statistical analysis. SHMS is validated in Chinese populations; the Cronbach's  $\alpha$  coefficient for internal consistency is 0.92, and the split-half reliability is 0.83, affirming its reliability and validity for sub-health evaluation (Xu et al., 2011). The Cronbach alpha of SHMS in this study is 0.792.

### 2.5. Statistical analysis

Mean and standard deviation, and frequencies and percentages were used to describe the distribution of continuous variables and categorical variables, as appropriate. Descriptive statistics are based on all participants who completed the survey ( $N = 1393$ ). Because a small number of participants had missing values on individual model variables, the mediation analyses used listwise deletion, yielding an analytic sample of  $N = 1374$  (19 participants excluded: 17 with missing PSQI scores and 2 with missing age). Pearson correlation analyses were conducted to explore bivariate relationships among the study variables. PROCESS v4.0 macro-program developed by Hayes (2017) was utilized to investigate the hypothesized mediation models. Because all variables were measured during the same survey window, the mediation analyses were interpreted as tests of indirect statistical associations rather than evidence of temporal or causal mechanisms. The assumed ordering among exercise adherence, sleep quality, and mental health outcomes was theory-driven but not directly observed; therefore, alternative directions, such as mental health influencing sleep quality or exercise adherence, cannot be ruled out. Accordingly, the terms "direct," "indirect," and "mediated" refer to model-estimated statistical associations rather than causal effects. The statistical significance of the indirect effect was determined by assessing bias-corrected confidence intervals generated from 5000 bootstrap samples. An effect was considered statistically significant if its 95% bootstrap confidence interval did not encompass zero (Hayes, 2017). The significance level was set at 0.05 (two-tailed). The analysis was executed using IBM SPSS v25.0 software (SPSS Inc., Chicago, IL, USA). As a sensitivity analysis, mediation models were re-estimated with weekly Qigong frequency added as an additional

covariate to evaluate whether the associations of exercise adherence with sleep quality and mental health were independent of practice frequency.

### 3. Results

#### 3.1. Descriptive analyses

Table 1 provides an overview of participants' demographic and health-related characteristics. The average age of participants is 52.67 years ( $SD = 8.21$ ). Among the participants, 1.9% fall within the 18-35 age group, 36.3% belong to the 36-50 age group, 56% fall within the 51-65 age group, and 5.8% are aged over 65. Notably, the sex ratio is imbalanced, with 1198 female participants (86%) and 195 male participants (14%). This skewed distribution is primarily due to the predominant presence of middle-aged and older women within the Qigong

group exercise community.

Regarding health-related variables, participants have a BMI of 22.73 on average ( $SD = 3.58$ ). A total of 56.3% of respondents report no underlying disease, while 34.8% report having one. A much lower percentage, 7.6%, reported two underlying disorders, and just 1.1% reported three. Notably, 98.9% of participants did not smoke and 86.8% did not consume alcohol. In terms of physical activity, most participants reported engaging in Qigong at least five times per week (94.4%), whereas exercise other than Qigong was more evenly distributed. 26.1% reported no exercise other than Qigong, 27.7% reported 1-2 times per week, 21.4% reported 3-4 times per week, and 24.8% reported at least five times per week.

Table 2 presents the descriptive statistics for the key study variables. The mean PSQI score was 5.75 ( $SD = 3.21$ ). Using the established cutoff of 5, 56.3% of participants were classified as having good sleep quality ( $PSQI \leq 5$ ) and 43.7% as having poor sleep quality ( $PSQI > 5$ ). The mean BDI-SF score was 2.88 ( $SD = 3.78$ ). Using the recommended screening cutoff of 10, 92.0% of participants scored below the threshold ( $\leq 9$ ) and 8.0% scored at or above it ( $\geq 10$ ), indicating that most participants had minimal depressive symptoms. In contrast to the low prevalence of clinically significant depression, the mean mental sub-health score (MS) was 68.0% ( $SD = 15.0\%$ ) on the transformed percentage scale, where higher scores indicate better mental health.

#### 3.2. Associations between exercise adherence, mental health, and sleep quality

**Pearson correlation:** As shown in Table 3, EARS demonstrates a significant negative association with PSQI ( $r = -0.27, p < .001$ ) and BDI-SF ( $r = -0.32, p < .001$ ), indicating that higher exercise adherence was linked to better sleep quality and fewer depressive symptoms. EARS was positively associated with MS ( $r = 0.36, p < .001$ ), indicating that higher exercise adherence was associated with higher mental sub-health scores, which reflect better mental health status. PSQI exhibited a positive association with BDI-SF ( $r = 0.46, p < .001$ ) and negatively associated with MS ( $r = -0.50, p < .001$ ).

**Mediation model:** Covariates for the mediation models were selected based on theoretical relevance and empirical associations with both the exercise adherence and outcome variables. The number of underlying diseases was included because it was significantly associated with EARS ( $r = -0.09, p = .001$ ), PSQI ( $r = 0.16, p < .001$ ), BDI-SF ( $r = 0.12, p < .001$ ), and MS ( $r = -0.10, p < .001$ ). Chronic illness may simultaneously reduce exercise engagement and worsen sleep quality and mental health, making it a plausible confounder. Age was included because it was significantly associated with both outcomes (BDI-SF:  $r = -0.16, p < .001$ ; MS:  $r = 0.18, p < .001$ ) and weakly with EARS ( $r = 0.07, p = .011$ ). Although its association with PSQI was not significant, age may still confound the direct pathways from exercise adherence to the outcomes. Exercise other than Qigong was also included, as total physical activity volume may independently influence both exercise adherence and mental health outcomes. Exercise other than Qigong was significantly associated with EARS ( $r = 0.08, p = .005$ ), PSQI ( $r = -0.06, p = .042$ ), BDI-SF ( $r = -0.10, p < .001$ ), and MS

**Table 1**  
Demographic characteristics.

|                                   | N = 1393     |
|-----------------------------------|--------------|
| Age, mean (SD)                    | 52.67 (8.21) |
| BMI, mean (SD)                    | 22.73 (3.58) |
| Underlying disease, mean (SD)     | 0.53 (0.70)  |
| Sex, N (%)                        |              |
| Female                            | 1198 (86.0%) |
| Male                              | 195 (14.0%)  |
| Marital status, N (%)             |              |
| Unmarried                         | 343 (24.6%)  |
| Married                           | 974 (70.0%)  |
| Divorced                          | 45 (3.2%)    |
| Widowed                           | 26 (1.9%)    |
| Separated                         | 5 (0.4%)     |
| Educational level, N (%)          |              |
| Primary school                    | 11 (0.8%)    |
| Junior high school                | 75 (5.4%)    |
| High school                       | 281 (20.2%)  |
| College                           | 1026 (73.7%) |
| Location, N (%)                   |              |
| Taiwan                            | 662 (47.5%)  |
| Hongkong                          | 137 (9.8%)   |
| Singapore                         | 306 (22.0%)  |
| Malaysia                          | 228 (16.4%)  |
| USA                               | 22 (1.6%)    |
| Canada                            | 9 (0.6%)     |
| Europe                            | 8 (0.6%)     |
| Other                             | 21 (1.5%)    |
| Drinking habit, N (%)             |              |
| None                              | 1206 (86.6%) |
| 1-2 times/week                    | 176 (12.6%)  |
| 3-4 times/week                    | 7 (0.5%)     |
| 5-7 times/week                    | 4 (0.3%)     |
| Smoking habit, N (%)              |              |
| None                              | 1378 (98.9%) |
| 1-2 times/week                    | 6 (0.4%)     |
| 3-4 times/week                    | 1 (0.1%)     |
| 5-7 times/week                    | 8 (0.5%)     |
| Weekly Qigong sessions, N (%)     |              |
| None                              | 14 (1.0%)    |
| 1-2 times/week                    | 13 (0.9%)    |
| 3-4 times/week                    | 51 (3.7%)    |
| $\geq 5$ times/week               | 1315 (94.4%) |
| Exercise other than Qigong, N (%) |              |
| None                              | 363 (26.1%)  |
| 1-2 times/week                    | 386 (27.7%)  |
| 3-4 times/week                    | 298 (21.4%)  |
| $\geq 5$ times/week               | 346 (24.8%)  |

*Note.* Percentages are based on the total sample who completed the survey ( $N = 1393$ ). Categorical variables had complete data (valid  $N = 1393$ ). Valid  $N$  differed only for age ( $n = 1391$ ) and BMI ( $n = 1389$ ) because of missing values. The analytic sample for the mediation models was  $N = 1374$  after listwise deletion of participants with missing data on any model variable (17 missing PSQI scores and 2 missing age).

**Table 2**  
Mean scores (SD) of study variables and gender difference.

| Variables | Total sample | Female       | Male         | Welch's <i>t</i> | <i>p</i> |
|-----------|--------------|--------------|--------------|------------------|----------|
| EARS      | 17.00 (3.25) | 17.00 (3.25) | 16.98 (3.25) | 0.09             | 0.926    |
| PSQI      | 5.75 (3.21)  | 5.83 (3.27)  | 5.25 (2.84)  | 2.55             | 0.011    |
| BDI-SF    | 2.88 (3.78)  | 2.94 (3.70)  | 2.52 (4.25)  | 1.30             | 0.195    |
| MS        | 68% (15%)    | 68% (15%)    | 69% (15%)    | -1.31            | 0.192    |

*Note.* EARS: Exercise Adherence Rating Scale; PSQI: Pittsburgh Sleep Quality Index; BDI-SF: Beck Depression Inventory-Short Form; MS: mental sub-health score from the Sub-Health Measurement Scale. Group comparisons used Welch's *t*-test (independent-samples *t*-test not assuming equal variances).

**Table 3**  
Correlation matrix of study variables.

|        |          | EARS    | PSQI    | BDI-SF  | MS      | Age     | BMI     | UD    | QG      | NQG |
|--------|----------|---------|---------|---------|---------|---------|---------|-------|---------|-----|
| EARS   |          |         |         |         |         |         |         |       |         |     |
| PSQI   | <i>r</i> | −0.27   |         |         |         |         |         |       |         |     |
|        | <i>p</i> | < 0.001 |         |         |         |         |         |       |         |     |
| BDI-SF | <i>r</i> | −0.32   | 0.46    |         |         |         |         |       |         |     |
|        | <i>p</i> | < 0.001 | < 0.001 |         |         |         |         |       |         |     |
| MS     | <i>r</i> | 0.36    | −0.50   | −0.68   |         |         |         |       |         |     |
|        | <i>p</i> | < 0.001 | < 0.001 | < 0.001 |         |         |         |       |         |     |
| Age    | <i>r</i> | 0.07    | −0.04   | −0.16   | 0.18    |         |         |       |         |     |
|        | <i>p</i> | 0.011   | 0.113   | < 0.001 | < 0.001 |         |         |       |         |     |
| BMI    | <i>r</i> | −0.09   | 0.05    | −0.01   | 0.04    | 0.06    |         |       |         |     |
|        | <i>p</i> | 0.002   | 0.071   | 0.838   | 0.176   | 0.020   |         |       |         |     |
| UD     | <i>r</i> | −0.09   | 0.16    | 0.12    | −0.10   | 0.20    | 0.12    |       |         |     |
|        | <i>p</i> | 0.001   | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |       |         |     |
| QG     | <i>r</i> | 0.47    | −0.12   | −0.15   | 0.21    | 0.18    | −0.01   | 0.01  |         |     |
|        | <i>p</i> | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | 0.653   | 0.725 |         |     |
| NQG    | <i>r</i> | 0.08    | −0.06   | −0.10   | 0.11    | 0.12    | −0.01   | −0.03 | 0.13    |     |
|        | <i>p</i> | 0.005   | 0.042   | < 0.001 | < 0.001 | < 0.001 | 0.664   | 0.225 | < 0.001 |     |

Note. EARS: Exercise adherence; PSQI: Pittsburgh Sleep Quality Index; BDI-SF: Beck Depression Inventory-Short Form; MS: mental sub-health score from the Sub-Health Measurement Scale; BMI: Body Mass Index; UD: underlying disease; QG: weekly Qigong sessions; NQG: exercise other than Qigong.

( $r = 0.11$ ,  $p < .001$ ).

Several candidate covariates were examined but not retained. BMI was excluded because it was not significantly associated with the primary outcomes. Smoking and alcohol consumption were not included due to extremely limited variability (98.9% non-smokers, 86.6% non-drinkers). Weekly Qigong sessions were not included as a covariate because Qigong practice frequency was substantially correlated with exercise adherence ( $r = 0.47$ ,  $p < .001$ ). Controlling for Qigong frequency would partial out variance central to the variable of interest. To confirm that this decision did not distort the findings, a sensitivity analysis that added weekly Qigong frequency as a covariate is reported below. The adherence effects remained significant and were negligibly altered, and weekly Qigong frequency was not independently associated with any outcome once adherence was included (PSQI:  $p = .825$ ; BDI-SF:  $p = .200$ ; MS:  $p = .322$ ). Practice frequency therefore did not confound the observed associations, and exercise adherence remained associated with the outcomes beyond practice frequency. Other potentially relevant confounders, such as medication use, baseline mental health status, and social support, were not comprehensively assessed for inclusion in the current analysis.

Two cross-sectional mediation models were tested using the PROCESS framework (Hayes, 2017) to examine whether sleep quality (PSQI) statistically accounted for part of the association between exercise adherence (EARS) and two mental health outcomes: depressive symptoms (BDI-SF, Model A) and mental sub-health (MS, Model B). Because all variables were assessed at the same time point, these models were interpreted as evidence of indirect statistical associations, not as evidence of temporal or causal pathways. The models controlled for age, underlying diseases, and exercise other than Qigong. All mediation coefficients are reported as unstandardized estimates to preserve interpretability in original scale units (Table 4). Standardized coefficients are presented on the path diagrams (Figs. 1 and 2) as supplementary effect-size indices. Indirect effects were tested using 5000 bias-corrected bootstrap resamples with percentile 95% confidence intervals.

### 3.2.1. Mediation model A: EARS → PSQI → BDI-SF

Higher exercise adherence was associated with lower PSQI scores after adjustment for covariates,  $a = -0.244$ ,  $p < .001$ , 95% CI [−0.294, −0.193]. The mediator model explained 9.1% of the variance in PSQI,  $R^2 = 0.091$ ,  $F(4, 1369) = 34.43$ ,  $p < .001$ .

In the outcome model, PSQI was positively associated with BDI-SF after controlling for EARS and covariates,  $b = 0.453$ ,  $p < .001$ , 95% CI [0.398, 0.509]. Higher exercise adherence remained significantly associated with lower BDI-SF scores after accounting for PSQI,  $c' = -0.246$ ,  $p < .001$ , 95% CI [−0.301, −0.191]. The outcome model explained

27.8% of the variance in BDI-SF,  $R^2 = 0.278$ ,  $F(5, 1368) = 105.32$ ,  $p < .001$ .

The total effect of EARS on BDI-SF was significant,  $c = -0.356$ ,  $p < .001$ , 95% CI [−0.414, −0.298]. The indirect effect through PSQI was also significant,  $ab = -0.110$ , bootstrapped 95% CI [−0.143, −0.082]. PSQI statistically accounted for approximately 30.9% of the total association between EARS and BDI-SF. Greater exercise adherence was associated with fewer depressive symptoms both directly and indirectly through better sleep quality; however, this cross-sectional model does not establish causal mediation.

These coefficients indicate that the individual-level associations were modest in magnitude: a one-standard-deviation higher EARS score, equivalent to approximately 3.25 points, was associated with approximately 0.79 points lower PSQI and 0.80 points lower BDI-SF after adjustment. The total association with BDI-SF was approximately 1.16 points lower.

### 3.2.2. Mediation model B: EARS → PSQI → MS

The association between exercise adherence and PSQI was identical to Model A. In the outcome model, PSQI was negatively associated with MS after controlling for EARS and covariates,  $b = -0.020$ ,  $p < .001$ , 95% CI [−0.022, −0.018]. Higher exercise adherence remained significantly associated with higher MS scores after accounting for PSQI,  $c' = 0.011$ ,  $p < .001$ , 95% CI [0.009, 0.013]. The outcome model explained 32.8% of the variance in MS,  $R^2 = 0.328$ ,  $F(5, 1368) = 133.72$ ,  $p < .001$ .

The total effect of EARS on MS was significant,  $c = 0.016$ ,  $p < .001$ , 95% CI [0.014, 0.018]. The indirect effect through PSQI was significant,  $ab = 0.005$ , bootstrapped 95% CI [0.004, 0.006]. PSQI statistically accounted for approximately 31.2% of the total association between EARS and MS. Greater exercise adherence was associated with better mental sub-health both directly and indirectly through better sleep quality; however, this cross-sectional model does not establish causal mediation.

For mental sub-health, a one-standard-deviation higher EARS score was associated with approximately 3.6 percentage points higher MS after accounting for PSQI and covariates. The total association with MS was approximately 5.2 percentage points higher.

### 3.2.3. Sensitivity analysis: adjustment for weekly Qigong frequency

To address the possibility that weekly Qigong frequency confounded the association between exercise adherence and the outcomes, both mediation models were re-estimated with weekly Qigong frequency added as a covariate (Table 5). In Model A, the direct effect of EARS on BDI-SF remained significant ( $c' = -0.264$ ,  $p < .001$ ) and the indirect effect through PSQI remained significant ( $ab = -0.112$ , 95% bootstrap

**Table 4**

Mediation analyses: exercise adherence, sleep quality, depressive symptoms, and mental sub-health.

|                                                                          | B      | SE      | t      | p     | 95% CI                        |
|--------------------------------------------------------------------------|--------|---------|--------|-------|-------------------------------|
| <b>Model A: EARS → PSQI → BDI-SF</b>                                     |        |         |        |       |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>)</i>                   |        |         |        |       |                               |
| EARS → PSQI                                                              | -0.244 | 0.026   | -9.40  | <     | [-0.294, -0.193]              |
| (a)                                                                      |        |         |        | 0.001 |                               |
| Age                                                                      | -0.020 | 0.010   | -1.95  | 0.052 | [-0.041, 0.000]               |
| UD                                                                       | 0.679  | 0.122   | 5.58   | <     | [0.441, 0.918]                |
|                                                                          |        |         |        | 0.001 |                               |
| NQG                                                                      | -0.028 | 0.032   | -0.88  | 0.378 | [-0.091, 0.035]               |
| <i>Outcome model: BDI-SF (<math>R^2 = 0.278</math>)</i>                  |        |         |        |       |                               |
| PSQI → BDI-SF                                                            | 0.453  | 0.028   | 15.96  | <     | [0.398, 0.509]                |
| (b)                                                                      |        |         |        | 0.001 |                               |
| EARS → BDI-SF                                                            | -0.246 | 0.028   | -8.74  | <     | [-0.301, -0.191]              |
| (c')                                                                     |        |         |        | 0.001 |                               |
| Age                                                                      | -0.063 | 0.011   | -5.74  | <     | [-0.084, -0.041]              |
|                                                                          |        |         |        | 0.001 |                               |
| UD                                                                       | 0.357  | 0.129   | 2.76   | 0.006 | [0.103, 0.610]                |
| NQG                                                                      | -0.051 | 0.033   | -1.54  | 0.124 | [-0.116, 0.014]               |
| <i>Effects summary</i>                                                   |        |         |        |       |                               |
| Total effect (c)                                                         | -0.356 | 0.030   | -12.00 | <     | [-0.414, -0.298]              |
|                                                                          |        |         |        | 0.001 |                               |
| Direct effect (c')                                                       | -0.246 | 0.028   | -8.74  | <     | [-0.301, -0.191]              |
|                                                                          |        |         |        | 0.001 |                               |
| Indirect effect                                                          | -0.110 | 0.015   | —      | —     | [-0.143, -0.082] <sup>b</sup> |
| (ab)                                                                     |        |         |        |       |                               |
| <b>Model B: EARS → PSQI → MS</b>                                         |        |         |        |       |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>) — same as Model A</i> |        |         |        |       |                               |
| <i>Outcome model: MS (<math>R^2 = 0.328</math>)</i>                      |        |         |        |       |                               |
| PSQI → MS (b)                                                            | -0.020 | 0.001   | -18.25 | <     | [-0.023, -0.018]              |
|                                                                          |        |         |        | 0.001 |                               |
| EARS → MS (c')                                                           | 0.011  | 0.001   | 9.97   | <     | [0.009, 0.013]                |
|                                                                          |        |         |        | 0.001 |                               |
| Age                                                                      | 0.003  | < 0.001 | 6.10   | <     | [0.002, 0.003]                |
|                                                                          |        |         |        | 0.001 |                               |
| UD                                                                       | -0.008 | 0.005   | -1.59  | 0.112 | [-0.018, 0.002]               |
| NQG                                                                      | 0.003  | 0.001   | 2.22   | 0.026 | [-0.001, 0.005]               |
| <i>Effects summary</i>                                                   |        |         |        |       |                               |
| Total effect (c)                                                         | 0.016  | 0.001   | 13.39  | <     | [0.014, 0.018]                |
|                                                                          |        |         |        | 0.001 |                               |
| Direct effect (c')                                                       | 0.011  | 0.001   | 9.97   | <     | [0.009, 0.013]                |
|                                                                          |        |         |        | 0.001 |                               |
| Indirect effect                                                          | 0.005  | 0.001   | —      | —     | [0.004, 0.006] <sup>a</sup>   |
| (ab)                                                                     |        |         |        |       |                               |

Note. EARS: Exercise adherence; PSQI: Pittsburgh Sleep Quality Index; BDI-SF: Beck Depression Inventory-Short Form; MS: mental sub-health score (percentage scale); UD: underlying disease; NQG: exercise other than Qigong. All coefficients are unstandardized.

<sup>a</sup> Bias-corrected bootstrap confidence interval based on 5000 resamples.

CI [-0.145, -0.081]). In Model B, the direct effect of EARS on MS remained significant ( $c' = 0.010$ ,  $p < .001$ ), as did the indirect effect through PSQI ( $ab = 0.005$ , 95% bootstrap CI [0.004, 0.006]). Since the coefficients did not shift appreciably, practice frequency did not confound the observed associations. These findings support that the conclusions do not depend on whether practice frequency is included as a covariate.

### 3.2.4. Female-only subsample analysis

Given that the sample was predominantly female (86%), supplementary analyses were conducted using only female participants to assess the robustness of the mediation findings (Table 6). Welch's  $t$ -test indicated no significant gender differences in exercise adherence, depressive symptoms, or mental sub-health. However, females reported significantly higher PSQI scores than males ( $t = 2.55$ ,  $p = .011$ ), indicating poorer sleep quality.

In the female subsample, exercise adherence was significantly associated with lower PSQI scores after adjustment for covariates,  $B = -0.239$ ,  $p < .001$ . In Model A, higher PSQI scores were significantly

associated with higher BDI-SF scores,  $B = 0.428$ ,  $p < .001$ . The direct effect of exercise adherence on BDI-SF remained significant after accounting for PSQI,  $B = -0.240$ ,  $p < .001$ . The indirect effect through PSQI was significant,  $ab = -0.102$ , 95% bootstrap CI [-0.136, -0.072], indicating that poorer sleep quality partially mediated the association between lower exercise adherence and greater depressive symptoms.

In Model B, higher PSQI scores were significantly associated with lower mental sub-health scores,  $B = -0.019$ ,  $p < .001$ . The direct effect of exercise adherence on MS remained significant after accounting for PSQI,  $B = 0.011$ ,  $p < .001$ . The indirect effect through PSQI was significant,  $ab = 0.005$ , 95% bootstrap CI [0.003, 0.006], indicating that better sleep quality partially mediated the association between higher exercise adherence and better mental sub-health. These results closely mirror the full-sample findings, indicating that the observed indirect statistical associations are similar in the female subsample and not driven by the small male subsample.

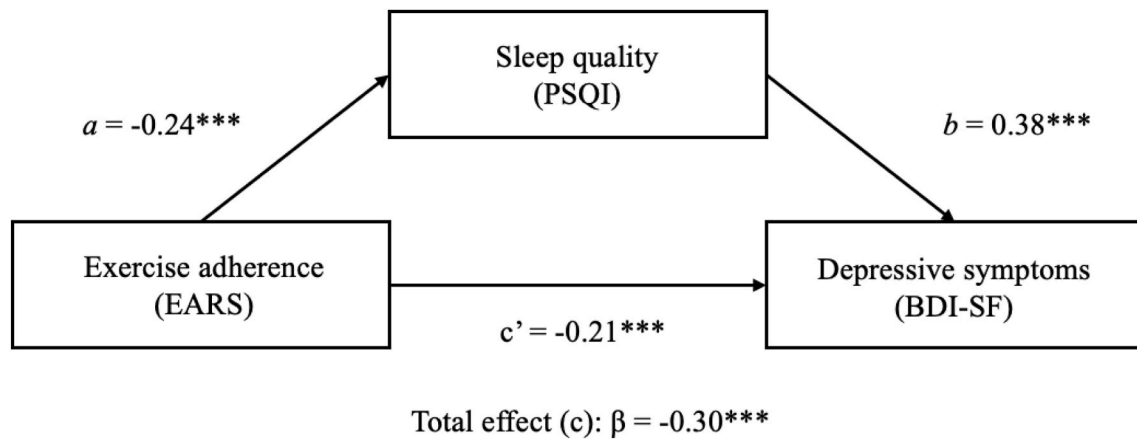
## 4. Discussion

In this home-based, virtual Qigong study involving middle-aged and older Asian adults, who regularly participated in Qigong exercise over the twelve-month period, we found that greater adherence to Qigong was associated with lower levels of depressive symptoms and more favorable mental sub-health indicators. Notably, sleep quality statistically accounted for part of these associations in cross-sectional mediation models. These findings suggest that even low-to-moderate intensity exercise, when practiced regularly at home, is associated with better psychological well-being in aging populations, although causal effects cannot be inferred.

Although statistically significant, the associations were small to modest in magnitude. A one-standard-deviation higher EARS score, or approximately 3.25 points, was associated with about 0.79 points lower PSQI, 0.80 points lower BDI-SF, and 3.6 percentage points higher MS after adjustment. The total associations were approximately 1.16 points lower for BDI-SF and 5.2 percentage points higher for MS. These modest individual-level differences should be evaluated for clinical significance in future studies, particularly in samples with higher depressive symptom burden.

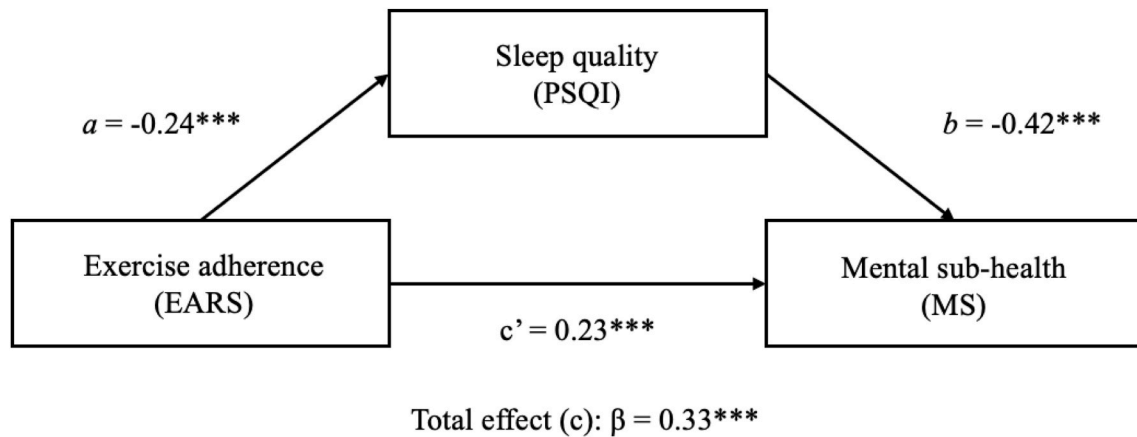
The observed association between exercise adherence and both depressive symptoms and mental sub-health in our study reveals a promising relationship between sustained exercise and mental well-being, even when the exercise modality, such as Qigong, is not particularly intensive. In our study, participants who reported greater adherence to Qigong also reported fewer depressive symptoms and better mental health. The findings align with existing literature suggesting that exercise serves as a protective factor against depression and contributes to psychological resilience (Harvey et al., 2018). In the specific case of Qigong, its mind-body connection and integration of gentle movements, breathing, and meditation may further enhance its psychological impact (Klein et al., 2017). According to Jahnke et al. (2010), Qigong may enhance emotional regulation, reduce physiological stress responses, and promote a sense of inner calm, all of which may help contextualize the associations observed in the present study.

Sleep quality partially explained the association between exercise adherence and mental health indicators in the cross-sectional mediation models. The contribution of the present study lies in examining these associations in the context of a home-based virtual Qigong program for middle-aged and older adults, with a focus on exercise adherence rather than exercise frequency alone, and with both depressive symptoms and mental sub-health included as mental health indicators. While prior studies have considered sleep as a mediator in lifestyle-health relationships, few have specifically focused on its interaction with exercise adherence in aging Asian populations. Existing evidence does support the mediating role of sleep quality in various lifestyle factors. For example, Barham et al. (2022) found that sleep quality mediated the association between exercise levels and depressive symptoms in



**Fig. 1.** Mediation model: exercise adherence, sleep quality, and depressive symptoms.

*Note.* Path coefficients are standardized. The corresponding unstandardized coefficients are reported in Table 4. The standardized indirect effect of exercise adherence on depressive symptoms through sleep quality (EARS→PSQI→BDI-SF) was  $-0.094$ , 95% bootstrap CI  $[-0.121, -0.069]$ .  $***p < .001$ .



**Fig. 2.** Mediation model: exercise adherence, sleep quality, and mental sub-health.

*Note.* Path coefficients are standardized. The corresponding unstandardized coefficients are reported in Table 4. The standardized indirect effect of exercise adherence on mental sub-health through sleep quality (EARS→PSQI→MS) was  $0.104$ , 95% bootstrap CI  $[0.078, 0.131]$ .  $***p < .001$ .

middle-aged adults, while Shi et al. (2024) demonstrated a similar pathway between dietary behavior and depressive symptoms in Chinese populations. Building on this foundation, our study extends the discussion to the broader middle-aged Asian population, a group that has not been closely examined yet, offering insight into how behavioral health programs may function similarly or differently across cultural and demographic groups.

Several physiological and neurological mechanisms may help explain the associations observed among exercise adherence, sleep quality, and mental health. From a physiological perspective, exercise may influence sleep through mechanisms such as homeostatic sleep regulation and circadian rhythm adjustments (Suppiah & Chia, 2015). Furthermore, exercise may exert antidepressant effects mediated by increases in non-rapid eye movement (NREM) sleep and decreases in rapid eye movement (REM) sleep, as well as alterations in slow-wave sleep via temperature elevation (Ezati et al., 2020). In turn, sleep could support recovery and emotional regulation following exercises. Kline (2014) pointed out the importance of sleep in muscle recovery and restoration of energy levels between exercise sessions, which can enhance one's capacity to engage and maintain regular exercise. Similarly, post-exercise thermoregulation processes, such as vasodilation and increased blood flow, may also facilitate sleep initiation and quality (Ezati et al., 2020). Thus, exercise participation may be associated with improved sleep, which may in turn relate to better mental health

outcomes. However, these relationships may also operate in the opposite direction, as poor sleep may reduce energy levels and hinder engagement in regular exercise. On a neurological level, sleep and mental health share common regulatory structures. The brainstem and thalamus, both of which are areas implicated in affective arousal and sleep regulation, may explain the high comorbidity of sleep disturbances and depression (Thase, 2006). Supporting this link, Zhao et al. (2021) found that better sleep quality was associated with improved mental health in older Chinese adults. These findings are consistent with our mediation results: individuals who consistently engage in exercise may also report improved sleep, which is associated with reduced depressive symptoms and better mental well-being. Taken together, these insights suggest that integrated programs targeting both exercise adherence and sleep quality may warrant testing in longitudinal or intervention studies as potential strategies for supporting psychological well-being in aging populations.

Importantly, while sleep quality played a meaningful mediating role, the direct effects of exercise adherence on mental health were consistently stronger. This pattern suggests that the mental health benefits of regular exercise, particularly in reducing depressive symptoms, are not solely dependent on improved sleep. Nonetheless, the indirect effects observed through sleep quality remain clinically and theoretically important. Inadequate sleep has been shown to impair daytime energy levels, reduce exercise capacity, and lower muscle strength (Dolezal et al., 2017), potentially undermining the health benefits of exercises.

Table 5

Sensitivity analysis: mediation models with weekly Qigong frequency added as a covariate.

|                                                                          | B      | SE      | t      | p       | 95% CI                        |
|--------------------------------------------------------------------------|--------|---------|--------|---------|-------------------------------|
| <b>Model A: EARS → PSQI → BDI-SF</b>                                     |        |         |        |         |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>)</i>                   |        |         |        |         |                               |
| EARS → PSQI (a)                                                          | −0.247 | 0.029   | −8.42  | < 0.001 | [−0.304, −0.189]              |
| Weekly Qigong sessions                                                   | 0.004  | 0.018   | 0.22   | 0.825   | [−0.031, 0.039]               |
| Age                                                                      | −0.021 | 0.011   | −1.96  | 0.050   | [−0.041, 0.000]               |
| UD                                                                       | 0.679  | 0.122   | 5.57   | < 0.001 | [0.440, 0.918]                |
| NQG                                                                      | −0.029 | 0.032   | −0.90  | 0.369   | [−0.091, 0.034]               |
| <i>Outcome model: BDI-SF (<math>R^2 = 0.279</math>)</i>                  |        |         |        |         |                               |
| PSQI → BDI-SF (b)                                                        | 0.453  | 0.028   | 15.95  | < 0.001 | [0.397, 0.509]                |
| EARS → BDI-SF (c')                                                       | −0.264 | 0.032   | −8.37  | < 0.001 | [−0.326, −0.202]              |
| Weekly Qigong sessions                                                   | 0.024  | 0.019   | 1.28   | 0.200   | [−0.013, 0.062]               |
| Age                                                                      | −0.065 | 0.011   | −5.87  | < 0.001 | [−0.087, −0.043]              |
| UD                                                                       | 0.352  | 0.129   | 2.72   | 0.007   | [0.098, 0.606]                |
| NQG                                                                      | −0.055 | 0.033   | −1.65  | 0.098   | [−0.121, 0.010]               |
| <i>Effects summary</i>                                                   |        |         |        |         |                               |
| Total effect (c)                                                         | −0.376 | 0.033   | −11.22 | < 0.001 | [−0.442, −0.310]              |
| Direct effect (c')                                                       | −0.264 | 0.032   | −8.37  | < 0.001 | [−0.326, −0.202]              |
| Indirect effect (ab)                                                     | −0.112 | 0.017   | —      | —       | [−0.145, −0.081] <sup>b</sup> |
| <b>Model B: EARS → PSQI → MS</b>                                         |        |         |        |         |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>) — same as Model A</i> |        |         |        |         |                               |
| <i>Outcome model: MS (<math>R^2 = 0.329</math>)</i>                      |        |         |        |         |                               |
| PSQI → MS (b)                                                            | −0.020 | 0.001   | −18.26 | < 0.001 | [−0.022, −0.018]              |
| EARS → MS (c')                                                           | 0.010  | 0.001   | 8.44   | < 0.001 | [0.008, 0.013]                |
| Weekly Qigong sessions                                                   | 0.001  | 0.001   | 0.99   | 0.322   | [−0.001, 0.002]               |
| Age                                                                      | 0.003  | < 0.001 | 5.89   | < 0.001 | [0.002, 0.003]                |
| UD                                                                       | −0.008 | 0.005   | −1.62  | 0.106   | [−0.018, 0.002]               |
| NQG                                                                      | 0.003  | 0.001   | 2.12   | 0.034   | [0.000, 0.005]                |
| <i>Effects summary</i>                                                   |        |         |        |         |                               |
| Total effect (c)                                                         | 0.015  | 0.001   | 11.49  | < 0.001 | [0.013, 0.018]                |
| Direct effect (c')                                                       | 0.010  | 0.001   | 8.44   | < 0.001 | [0.008, 0.013]                |
| Indirect effect (ab)                                                     | 0.005  | 0.001   | —      | —       | [0.004, 0.006] <sup>a</sup>   |

Note. EARS: Exercise adherence; PSQI: Pittsburgh Sleep Quality Index; BDI-SF: Beck Depression Inventory-Short Form; MS: mental sub-health score (percentage scale); UD: underlying disease; NQG: exercise other than Qigong. All coefficients are unstandardized. Weekly Qigong frequency was not independently associated with any outcome once exercise adherence was included in the model.

<sup>a</sup> Bias-corrected bootstrap confidence interval based on 5000 resamples.

Given these close associations, exercise adherence and sleep quality may both play important roles in mental health (Rajkumar, 2021), particularly in the context of depressive symptoms. Our findings thus reinforce the importance of comprehensive behavioral health programs that do not target these factors in isolation.

Finally, the demographic and health profiles of our participants offer important context for interpreting the findings. The sample was predominantly female (86%) and middle-aged to older in age, reflecting the gendered and age-specific appeal of Qigong in community settings (Liu, Kowal, et al., 2023). Prior research suggests that women may be more engaged in health-promoting behaviors, and may report higher participation in group or community-based programs, which could influence adherence levels. Similar pattern was also shown in complementary and alternative medicine (CAM) and mind-body practices, where women are

Table 6

Mediation models in the female subsample.

|                                                                          | B      | SE      | t      | p       | 95% CI                        |
|--------------------------------------------------------------------------|--------|---------|--------|---------|-------------------------------|
| <b>Model A: EARS → PSQI → BDI-SF</b>                                     |        |         |        |         |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>)</i>                   |        |         |        |         |                               |
| EARS → PSQI (a)                                                          | −0.239 | 0.028   | −8.44  | < 0.001 | [−0.295, −0.184]              |
| Age                                                                      | −0.028 | 0.012   | −2.39  | 0.017   | [−0.051, −0.005]              |
| UD                                                                       | 0.717  | 0.133   | 5.39   | < 0.001 | [0.456, 0.978]                |
| NQG                                                                      | −0.018 | 0.034   | −0.52  | 0.603   | [−0.086, 0.050]               |
| <i>Outcome model: BDI-SF (<math>R^2 = 0.274</math>)</i>                  |        |         |        |         |                               |
| PSQI → BDI-SF (b)                                                        | 0.428  | 0.030   | 14.50  | < 0.001 | [0.370, 0.486]                |
| EARS → BDI-SF (c')                                                       | −0.240 | 0.030   | −8.10  | < 0.001 | [−0.298, −0.182]              |
| Age                                                                      | −0.070 | 0.012   | −5.89  | < 0.001 | [−0.093, −0.046]              |
| UD                                                                       | 0.291  | 0.137   | 2.13   | 0.033   | [0.023, 0.559]                |
| NQG                                                                      | −0.051 | 0.035   | −1.46  | 0.146   | [−0.119, 0.018]               |
| <i>Effects summary</i>                                                   |        |         |        |         |                               |
| Total effect (c)                                                         | −0.342 | 0.031   | −10.97 | < 0.001 | [−0.403, −0.281]              |
| Direct effect (c')                                                       | −0.240 | 0.030   | −8.10  | < 0.001 | [−0.298, −0.182]              |
| Indirect effect (ab)                                                     | −0.102 | 0.016   | —      | —       | [−0.136, −0.072] <sup>a</sup> |
| <b>Model B: EARS → PSQI → MS</b>                                         |        |         |        |         |                               |
| <i>Mediator model: PSQI (<math>R^2 = 0.091</math>) — same as Model A</i> |        |         |        |         |                               |
| <i>Outcome model: MS (<math>R^2 = 0.323</math>)</i>                      |        |         |        |         |                               |
| PSQI → MS (b)                                                            | −0.019 | 0.001   | −16.40 | < 0.001 | [−0.022, −0.017]              |
| EARS → MS (c')                                                           | 0.011  | 0.001   | 9.59   | < 0.001 | [0.009, 0.014]                |
| Age                                                                      | 0.003  | < 0.001 | 5.72   | < 0.001 | [0.002, 0.004]                |
| UD                                                                       | −0.007 | 0.005   | −1.25  | 0.213   | [−0.018, 0.004]               |
| NQG                                                                      | 0.003  | 0.001   | 2.21   | 0.027   | [< 0.001, 0.006]              |
| <i>Effects summary</i>                                                   |        |         |        |         |                               |
| Total effect (c)                                                         | 0.016  | 0.001   | 12.56  | < 0.001 | [0.014, 0.019]                |
| Direct effect (c')                                                       | 0.011  | 0.001   | 9.59   | < 0.001 | [0.009, 0.014]                |
| Indirect effect (ab)                                                     | 0.005  | 0.001   | —      | —       | [0.003, 0.006] <sup>a</sup>   |

Note. EARS: Exercise adherence; PSQI: Pittsburgh Sleep Quality Index; BDI-SF: Beck Depression Inventory-Short Form; MS: mental sub-health score (percentage scale); UD: underlying disease; NQG: exercise other than Qigong. All coefficients are unstandardized.

<sup>a</sup> Bias-corrected bootstrap confidence interval based on 5000 resamples.

often more likely than men to participate (Keshet & Simchai, 2014). In our study, participants were recruited from a virtual Qigong community, which similarly attracted more female members. Therefore, the findings may primarily reflect patterns among middle-aged and older women who engage in CAM-based exercise practices. The gender imbalance may influence study outcomes, as gender differences have been documented in both sleep patterns (Zuo et al., 2022) and the prevalence of depressive symptoms (Cheung & Mui, 2023). Older participants generally reported greater exercise adherence, better mental sub-health, and fewer depressive symptoms, aligning with prior work suggesting that emotional stability and health-conscious behaviors increase with age (Burr et al., 2021; Scheibe & Carstensen, 2010). Additionally, the number of underlying diseases was significantly associated with poorer sleep, higher depression, and lower exercise adherence, which highlights the physical and psychological burden of chronic illness in aging adults (Huang et al., 2010). It should also be noted that higher BMI was associated with both more underlying disease and lower exercise adherence, further emphasizing how physical and psychological health factors are closely intertwined in this population (Camilo et al., 2024;

Rivera-Torres et al., 2019). In summary, the current findings may primarily reflect patterns among middle-aged and older women and should be interpreted with caution when generalizing to other populations.

## 5. Implications, limitations, and conclusion

This study's findings carry substantial implications for individuals and society, particularly in the context of addressing the escalating issue of mental health in contemporary society. At an individual level, the findings suggest that participants who reported more consistent Qigong adherence also tended to report better sleep quality and more favorable mental health indicators. The exercise plan need not be overly strenuous or challenging; rather, consistency in adherence is key. This knowledge empowers individuals to proactively manage their mental health. Additionally, the emphasis on exercise adherence serves as a crucial indicator for healthcare professionals and therapists. Monitoring exercise adherence and understanding potential obstacles is important in ensuring the effectiveness of medical plans (Collado-Mateo et al., 2021). Importantly, the home-based, virtual Qigong engagement highlights the accessibility and scalability of digital exercise programs. Such virtual formats can help overcome common barriers to participation, such as time constraints, mobility limitations, geographic isolation, or public health restrictions. Virtual programs also allow for flexible scheduling and broader reach, making them especially beneficial for middle-aged and older adults who may prefer low-impact, convenient exercise options. Finally, on a broader societal scale, promoting exercise adherence, both as prevention and therapy, can ease the strain on healthcare systems and enhance societal mental resilience (Hogan, 2014). The integration of exercise into comprehensive mental health interventions can be a valuable approach for policymakers, healthcare providers, and advocates working to tackle the increasing burden of mental health issues (Xie et al., 2021).

While the study's findings offer valuable insights into the relationship between exercise adherence, sleep quality, and mental health, it is important to acknowledge certain limitations. Firstly, given the cross-sectional nature of the current analysis, which captures data at a single point in time, our findings reflect associations only and do not support causal inferences. The relationships observed among exercise adherence, sleep quality, and mental health may also be bidirectional; for example, while exercise participation may be associated with better sleep, poor sleep may also reduce energy levels and motivation for maintaining regular exercise. Future longitudinal and randomized controlled studies are needed to examine whether Qigong adherence improves sleep and mental health, and to establish causal relationships. Secondly, the participant sample in our study was predominantly composed of women because the data were drawn from a virtual exercise community that primarily attracted female members. This distribution likely reflects the greater participation of women in community-based Qigong programs; however, it may limit the generalizability of the findings to other genders. Future studies could benefit from efforts to include a more balanced representation of all genders, and consider the use of propensity score matching to create comparable groups. They could also consider delving deeper into distinct age groups, as individuals face varying challenges at different stages of life, such as menopause, which could influence exercise adherence and mental health differently (Fausto et al., 2023). Thirdly, the relationship between sleep, exercise, and mental health is complex, and the exact nature of the links among these variables remains to be clarified in further studies. Semplonius and Willoughby (2018) investigated the long-term relationship between sleep and exercise, with a particular emphasis on the direction of these effects. They highlighted a two-way connection between sleep and exercise, which prompts consideration in future research designs to explore whether enhancing sleep quality can lead to improved mental health through more effective exercise. Fourth, the study focused only on depressive symptoms and mental sub-health, which represent important but limited dimensions of mental health.

Other psychological outcomes, such as anxiety, perceived stress, positive well-being, and psychological resilience, are also highly relevant. Future research should incorporate a broader range of mental health indicators to provide a more comprehensive understanding of the potential psychological effects of exercise adherence and sleep quality. Fifth, the sample appeared relatively healthy and reported low levels of depressive symptoms. This restricted symptom range may have introduced floor effects, limiting the ability to detect clinically meaningful variation in depressive symptoms. Therefore, although the associations involving BDI-SF were statistically significant, they should be interpreted as associations with depressive symptom levels in a generally low-symptom community sample rather than as evidence concerning clinically diagnosed depression. Given the large sample size, statistically significant findings may reflect small differences that require further evaluation for clinical significance in samples with higher baseline symptom burden. Sixth, although the analyses adjusted for the number of underlying diseases, other potentially important confounders, such as medication use (e.g., antidepressants or sleep aids), baseline mental health status, and social support, may also be associated with outcomes. The absence of these variables raises the possibility of residual confounding, and the observed associations should therefore be interpreted with caution. A related consideration is that most participants practiced Qigong at least five times per week (94.4%), so variability in practice frequency was limited and the sample likely reflects highly engaged individuals. This restricted range may reduce generalizability to people who practice Qigong more casually or intermittently, and could attenuate estimates involving frequency-related measures. Furthermore, we acknowledge that we did not collect data on attendance by practice format (e.g., large-group, small-group, or individual practice) or the level of peer interaction. These unmeasured factors may have contributed to the observed associations between exercise adherence and improvements in mental health outcomes. Future studies should assess format-specific participation and social interaction to better distinguish the effects of the intervention itself from those of group support. And finally, although validated Chinese versions of the measurements were used in this study, the present sample included participants from diverse Asian backgrounds, so cultural and linguistic differences may influence how individuals interpret questionnaire items. Future studies should further examine the cross-cultural measurement equivalence of these instruments in more diverse Asian populations.

In conclusion, the study finds that exercise adherence was associated with better mental health indicators among middle-aged and older Asian adults participating in a home-based virtual Qigong program, and sleep quality statistically accounted for part of these associations, albeit with a smaller effect. These findings suggest that both adherence and sleep quality may be relevant behavioral markers in virtual mind-body exercise programs. However, because the study used a cross-sectional, self-report design, the results do not establish temporal ordering or causal effects. Comprehensive mental health programs could consider incorporating both exercise adherence and efforts to improve sleep quality as complementary strategies. The home-based, virtual Qigong format may provide a highly accessible and scalable model, particularly beneficial for individuals with mobility challenges or limited access to in-person programs. Given its cultural adaptability and ease of implementation, this approach may be relevant for promoting mental well-being in geographically dispersed or underserved populations worldwide, and its causal impact should be confirmed in future longitudinal and randomized controlled studies.

## CRedit authorship contribution statement

**Yi Yang:** Writing – review & editing, Writing – original draft, Validation. **Yuxin Huang:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Validation. **Se Hee Min:** Writing – review & editing, Writing – original draft, Validation. **Yuanfei Liu:** Writing – review & editing, Writing – original draft, Investigation,

Validation, Data curation. **Ying Dai**: Writing – review & editing, Writing – original draft, Investigation, Validation. **Vienna Chen**: Writing – review & editing, Project administration, Investigation. **Yin Quan**: Writing – review & editing, Project administration, Resources, Investigation. **Bai Yin**: Writing – review & editing, Project administration, Resources, Investigation. **Jianghong Liu**: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

## Ethics declaration

Written informed consent to take part in the study and to publish the article has been obtained from all participants or their legal representatives. The privacy rights of participants have been observed.

This study was performed in compliance with relevant laws, regulatory frameworks and guidelines where the research took place. This study was approved by the Ethics Board of Qigong for Life Association. (Approval No. E2021002)

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

Data will be made available on request.

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