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Effects of Qigong combined with Wai Khru Muay Thai on cardiopulmonary responses in sedentary older adults: A randomized control trial

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Abstract

This study investigated the acute and training effects of Khon Kaen Qigong (KKQ), which combines Qigong and Muay Thai, on the cardiopulmonary responses in older adults. There were two experiments: 1) acute effect: a 30-minute KKQ session (control group performed reading) at pre-intervention and, 2) training effect (post-intervention compared with pre-intervention): composed of two conditions: the single session of KKQ/reading and two tests of cardiorespiratory fitness and respiratory muscle strength. Training intervention consisted of a 60-minute KKQ/day, three days a week (the control group had a sedentary life) for 12 weeks. At pre-intervention, there were three days of the experiment: 1) familiarization with the KKQ session, 2) heart rate, blood pressure, pulmonary function, and expired gas collection in response to KKQ/reading, and, 3) the six-minute walk distance and respiratory muscle strength. Post-intervention, participants repeated the pre-intervention except familiarization day. We found that the training contributed to a greater six-minute walk distance compared to the control group (mean difference [95%CI]; 7.04 [-14.94, 29.02], $p < 0.05$). Compared to the reading, it increased oxygen consumption ($p < 0.05$) and decreased ventilatory efficiency ($p < 0.05$) during and after the 30-minute KKQ session. The acute KKQ session produced cardiopulmonary responses to a very low level. An improvement of walking distance and ventilatory efficiency were previously shown to be negatively associated with cardiovascular risk and mortality. Thus, KKQ could be an alternative exercise that should be promoted to enhance a healthy long life for the older participants.

Keywords: Aerobic exercise, Ageing, Cardiorespiratory fitness, Respiratory muscle strength, Ventilatory efficiency

1. Introduction

This article results from a multi-disciplinary investigation in which the acute and chronic effects of a novel exercise (Qigong combined with Muay Thai; Khon Kaen Qigong (KKQ)) on many body systems including neurological, cardiopulmonary responses, musculoskeletal, and physical performance were explored in sedentary older adults. In earlier studies, its exercise intensity [1] and acute effects on heart rate variability [2], and cardiopulmonary [1] responses and training effects on psychological responses and physical fitness [3] were reported. Herein, the influences of acute and training of KKQ on the cardiopulmonary responses in the same participants which have not been investigated, are described.

The proportion of the aging population is expected to reach 21% by 2050 [4]. Hence, cardiopulmonary diseases among the elderly have become a serious health issue. To improve age-related impairments in cardiopulmonary function, mind-body exercises that focus on breathing, concentration, and gentle movement have been increasingly promoted [5].

Recently, we developed KKQ by combining Muay Thai (Wai Khru Muay Thai session) with traditional Qigong (Baduanjin and Wuqinxi), as posture will be described in the Methods section. The modification is that Wai Khru Muay Thai has neck, thoracic spine, and upper limb extensions that allow more lung expansion. Thus, adding Wai Khru Muay Thai to Qigong which has been reported to improve cardiopulmonary functions may promote the increase of both functions. Previously, it was found that a single session of KKQ increased cardiopulmonary responses to a very low level in older adults [1]. However, according to the available literature, no research has proven the acute and training effects of KKQ on these responses in the same participants.

To the best of our knowledge, Baduanjin Qigong has been reported to improve resting heart rate (HR), blood pressure (BP), and physical function in the elderly [5]. This year, Muay Thai training has been shown to reduce diastolic BP in older adults [6]. However, no research has investigated the effects of Wuqinxi on cardiopulmonary responses in the healthy elderly. In a review of patients with cardiopulmonary diseases, Baduanjin [7,8] and Wuqinxi [8,9] improved the 6-minute walk distance (6MWD), BP, and dynamic lung function. The 6 MWD measures cardiorespiratory fitness (CRF) in various age groups, including older adults [10].Hence, training in our novel exercise mode may show significant results in cardiopulmonary variables in older adults.

The training effect of KKQ on CRF determined was primarily explored by the 6 MWD in sedentary older participants. The secondary objective was to investigate the training effects of KKQ on hemodynamics (HR and BP) and pulmonary responses (expired gas data, dynamic pulmonary function, and respiratory muscle strength). Furthermore, the acute effect was examined on hemodynamics and expired gas data. It was hypothesized that a single session of KKQ increased cardiopulmonary responses to a very low level while the training improved all outcomes in sedentary older adults.

2. Materials and methods

2.1 Study design and setting

This was a pre-and post-test parallel Randomized Controlled Trial (RCT) conducted based on RCT guidelines [11]. The Consort checklist is shown in Supplementary Table 1. This study was conducted in Khon Kaen Province, Thailand between June 2021 and February 2022. It was registered in the Thai Clinical Trials Registry (TCTR20211228001) on 02 June 2021. All participants lived in four similar communities in terms of socioeconomic and other demographic factors. The names of these communities were each put inside a sealed similar opaque envelope and randomly selected by participants. The first two communities to be drawn were assigned to be the Control Group (CG) and the second two communities to be the Exercise Group (KKG). The sample size was calculated using G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) based on a previous study [12] which reported the role of Qigong in increasing the 6-MWD. Power was set at 80%, alpha at 5%, and Cohen effect size at 0.50. The sample size for each group was 30 participants, with a 20% dropout rate.

Participants aged 60–75 years and with no diseases that would limit exercise were included. Participants with diabetes type 2, hypertension, and dyslipidemia who discussed it with their doctor and intended to maintain medication throughout the experiment were recruited. The participants included signed the participants' declaration before being recruited. Furthermore, those who had regular (longer than 1 hour/week) longer than 2 years' experience with Qigong, meditation, or other types of exercise during the past 6 months were excluded.

Participants underwent screening involving physical examinations, health questionnaires, anthropometry, body composition, electrocardiography, and blood chemistry. Recruitment was performed through hard copy flyers, direct contact, and an email address. Before signing up to participate, they were informed verbally and in writing about the study details including the right to withdraw from this study. Participants in CG were offered the KKQ training, albeit without recording of outcome measures, after completion of the study.

An open-blinded, two-block randomized allocation sequence in a 1:1 design was performed using computer-generated random numbers. Codes were kept in sequentially numbered, opaque, and sealed envelopes. The researcher who provided the envelope to the participants for group allocation in the enrollment was not the one who prepared the envelope. Outcomes adjudicators and data analysts were blinded to the participants' codes.

2.2 Data collection

The participants were randomly allocated to one of two groups: KKG and CG (Supplementary Figure 1). The KKG was scheduled for five visits. The 2nd visit (pre-intervention) had an acute effect and the last two compared with the 2nd and 3rd visits showed the training effects. Firstly, the participants performed a 30-minute KKQ session

(Supplementary Figure 2) (Supplementary Table 2) [2] to familiarize themselves with the exercise. They performed a 5 m warmup (by stretching the upper and lower limbs and trunk) followed by a 30-minute KKQ session of two 15 m sets comprising 12 motions. During the 2nd visit, they lay down for 30 minutes, then performed a pulmonary function test followed by a 30-minute KKQ session and a 30 m. lying down (recovery).

The HR and BP were recorded immediately before and after the KKQ / reading and recovery sessions. The expired gas was collected throughout the experiment to determine respiratory rate (RR), ventilation rate (VE), oxygen consumption rate (VO2), and carbon dioxide production rate (VCO2). Ventilatory efficiency, a ratio between $\dot{V}_E$ and $\dot{V}O_2$ or $\dot{V}CO_2$ was also assessed because it reflects the cardiopulmonary function during exercise [13]. During the 3rd visit, they underwent respiratory muscle strength tests followed by measuring 6 MWD. During the next 12 weeks, they performed a 60-minute KKQ/day, 3 days/week for 12 weeks. They received diaries to record their KKQ practice (Supplementary Tables 3) throughout the training which were submitted to the researcher on the last visit. During all the exercise sessions, the participants were asked about any discomfort. They were told that they could stop their participation at any time. At the end of 12 weeks (the 4th and 5th visits), they performed the same experiment as in the 2nd and 3rd visits, respectively. For 12 weeks, they did not do other exercises except KKQ.

The CG participated in the experiment over four visits (2nd-5th) except that they read Buddhist books instead of undergoing the KKQ session. Twelve weeks after the 3rd visit, they maintained a sedentary lifestyle. A week before the 2nd and 5th visits, they recorded their physical activity for 3 days (2 weekdays and 1 weekend day) and sent what they had recorded to the investigator at the visits (Supplementary Table 4).

2.3 Outcome measurements

2.3.1 Cardiorespiratory fitness (CRF)

CRF was assessed by distance in 6MWT and followed by the American Thoracic Society (ATS) [14] to control for quality.

2.3.2 Cardiopulmonary responses

The measurements and quality control of participants' cardiopulmonary responses including hemodynamics and expired air analysis were shown in our previous article [1]. In addition, dynamic lung volumes were measured using a Vyntus® spirometer (CareFusion, Yorba Linda, CA, USA) following the standardization of spirometry according to the ATS/European Respiratory Society (ERS) guidelines [15]. The equipment was calibrated using a 3-L syringe connected to the transducer. The subjects performed full inspiration, followed by a quick and full expiration, for at least six seconds. Data was collected from the highest values of the three recorded measurements. The best lung function value was chosen to measure forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1).

2.3.3 Exercise intensity

Exercise intensity was determined by the percentage of HR immediately after the KKQ session from HRmax (HRmax calculated from 220-age) and $\%\dot{V}O_{2,peak}$ (calculated from 6MWD).

2.3.4 Respiratory muscle strength

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured by microRPM™ (CareFusion, Yorba Linda, CA, USA), following the ATS/ERS statement which is a standard testing protocol (ATS/ERS, 2002) [16]. The equipment was calibrated within 3% of a pressure manometer reading. During the test, the participants were instructed to use a nose clip and mouthpiece while seated. For the MIP test, they exhaled as much as possible followed by a maximum inhalation of at least 2 seconds. For the MEP test, they inhaled as much as possible followed by a maximum exhalation for at least 2 seconds. The assessor checked for any air leaks during the test. At least five MIP and MEP assessments with a one-minute rest period were conducted until three acceptable and reproducible measurements were obtained. The highest value of the three maneuvers was recorded, with less than a 10% difference.

2.4 Control during KKQ Intervention

During the KKQ practice, the participants were asked to concentrate on every motion with pursed lip breathing. Professional coaches checked each participant's correct movements and breathing. All participants wore comfortable sportswear and flat shoes. The KKQ leader during acute and training sessions was a Certified KKQ instructor and taught the KKQ session to other co-investigators who each led groups of 5-10 participants.

2.5 Statistical analysis

All statistical analysis was performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). The data normality was tested using the Kolmogorov-Smirnov test. Repeated measures of the ANOVA were used to compare continuous variables with a normal distribution within and between groups. The Bonferroni test was used as a post hoc test. The Mann-Whitney U test was used for ordinal data and unpaired samples that were not normally distributed. Data is presented as mean ± SD except when stated elsewhere for normal distributed data and median (interquartile range) for non-normal distributed data. Mean difference and 95% confidence interval [95% CI] are also presented in the Table. Differences were considered statistically significant if the p-value was < 0.05.

3. Results

3.1 Participants

Of 90 screened participants, 56 (CG = 28; 26 women and 2 men; KKG = 28; 27 women and 1 man) completed the experiment (Supplementary Figure 3). Supplementary Table 5 shows good matching between the two groups because the baseline demographic, anthropometric, body composition, hemodynamics, and blood chemistry of participants were similar in both groups. The ratio of participants' underlying diseases in both groups was comparable (Supplementary Table 6) and they could maintain their treatment throughout the experiment. The self-reported proportion of participants adhering to the exercise training was > 93%. Energy expenditure favors the exercise over the control group but does not reach a statistical difference (1,204.9 ±416.3 and 1,310.9 ±620.7 vs 1,271.8 ±419.8 and 1,258.8 ±522.8 kcal/day, for KKG and CG respectively). No participants had discomfort or injury throughout the experiment. The data on acute and training effects were aimed at being collected from the same participants who completed this study. Therefore, the number of participants at pre- and post-intervention is 28.

3.2 Primary outcome: six-minute walk distance

Training effect

Twelve-week KKQ training produced significant interaction between groups and time for the 6 MWD which was significantly increased from pre-intervention and was higher in the KKG than the CG (Table 1). There was no significantly different change within the CG and no difference at pre-intervention between the groups.

3.3 Secondary outcomes

3.3.1 Hemodynamics

Acute effect

At pre-intervention, the KKQ session increased, whereas the reading decreased (both were $p<0.01$) HR from baseline immediately after the KKQ/reading session with a greater value in KKG ($p<0.01$) (Figure 1A). In addition, both groups had a lower HR than baseline after recovery ($p<0.05$ and $p<0.01$), without any significant differences between the groups. Surprisingly, like the KKG, the CG had increased SBP from baseline immediately after reading ($p<0.05$ and $p<0.01$, respectively) (Figure 1B). However, only the CG had a greater SBP than the baseline after recovery ($p<0.01$). The CG had greater DBP than that of the baseline only after recovery at pre-intervention ($p<0.05$) (Figure 1B).

Training effect

Post-intervention, both groups showed no changes in HR and SBP at rest or in response to exercise compared with pre-intervention (Figure 1A-B). In comparison, only KKG showed increases in DBP in response to exercise. Furthermore, at post-intervention, the KKQ session increased (both $p<0.01$), whereas the reading decreased ($p<0.05$ and $p<0.01$, respectively) HR from baseline immediately after the KKQ/reading session with a greater KKG value ($p<0.01$) (Figure 1A). In addition, both groups had a lower HR than that at baseline after recovery, without any significant differences between the groups ($p<0.01$). Surprisingly, like the KKG, the CG had increased SBP from baseline immediately after reading (both $p<0.01$) (Figure 1B). However, only the CG had a greater SBP than that of the baseline after recovery for pre- and post-intervention ($p<0.01$). Furthermore, the KKG had greater DBP than that of the baseline immediately after the KKQ session and recovery at post-intervention ($p<0.05$) (Figure 1B).

Table 1 Cardiorespiratory fitness, pulmonary functions, and respiratory muscle strength of participants in both groups at pre- and post-interventions.

	CG		KKG		MD [95% CI]	*p*-value
	Pre (n=28)	Post (n=28)	Pre (n=28)	Post (n=28)		
6MWD (m)	491.9±47.7	498.7±41.8	480.6±66.0	526.4±54.6$^{\delta\ \beta}$	7.04[-14.94,29.02]	0.03
FEV_1 (L)	1.8±0.45	1.79±0.43	1.86(1.62-2.07)	1.79±0.37	0.02[-0.173,0.214]	0.95
FVC (L)	2.25(1.78-2.44)	2.3(1.81-2.45)	2.42(1.95-2.71)	2.32(2.01-2.63)	0.11[-0.15, 0.36]	0.50
FEV_1/FVC (%)	79.4±5.63	78.0±6.87	77.4±7.06	77.0±7.35	-2.23 [-5.80, 1.34]	0.94
MIP (cmH_2O)	59.4±23.7	65.4±24.2	30.7±16.5$^{\#}$	62.8±24.1$^{\delta\delta}$	-5.37[-18.29, 7.55]	0.84
MEP (cmH_2O)	42.0(19.7-66.0)	56.9±33.8$^{\delta}$	48.8(14.7-75.0)	67.9(31.0-109.2)$^{\delta\delta}$	-12.14[30.17,5.89]	0.30

All the data is represented as mean ± SD or median (interquartile range, IQR) based on the normal distribution.
Data is expressed as mean ± SD (MD [95% CI]) and median (interquartile range) (MD [95% CI]). CG = control group, KKG = Khon Kaen Qigong group, MD = mean difference, CI = confidence interval, Pre = pre-intervention, Post = post-intervention, FEV_1 = forced expiratory volume in the first second, FVC, forced vital capacity, MIP = maximal inspiratory pressure, MEP = maximal expiratory pressure, and 6MWD = 6-minute walk distance. $^{\delta,\delta\delta}$ difference from pre-intervention within the group ($p < 0.05, 0.01$), difference from CG at pre-intervention ($p < 0.05$), $^{\beta}$ difference from CG at post-intervention ($p < 0.05$).

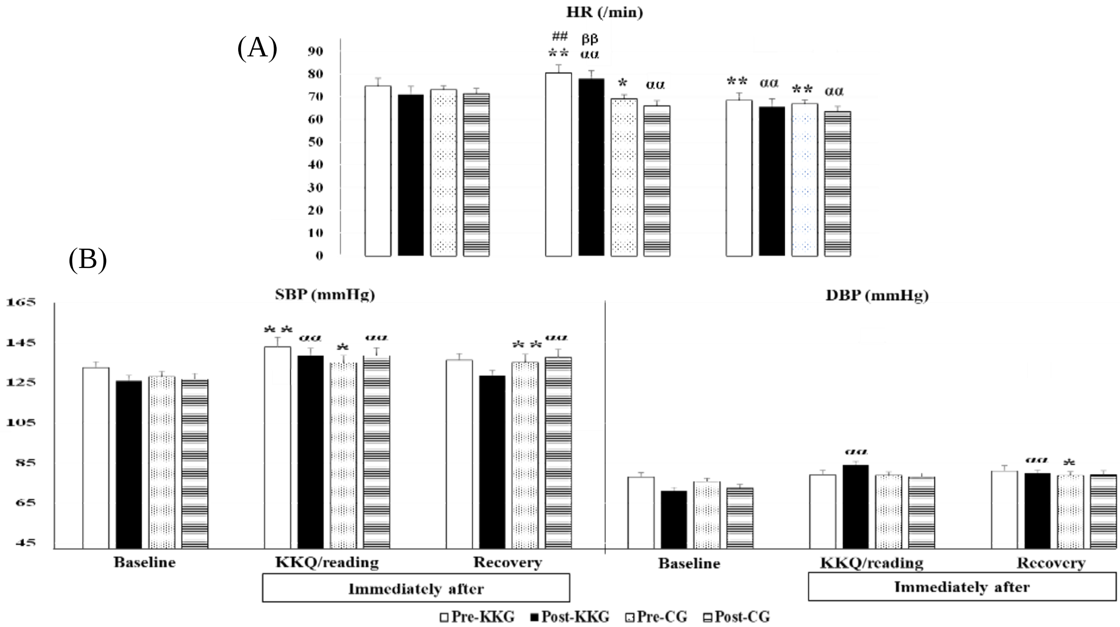

Figure 1 HR (A), SBP, and DBP (B) at baseline, immediately after KKQ/reading session and recovery in both groups. Data is expressed as mean ± SE (n=28 for each group). CG = control group, KKG = Khon Kaen Qigong group, HR = heart rate, SBP = systolic blood pressure, and DBP = diastolic blood pressure. ** difference from baseline within the group at pre-intervention ($p < 0.01$), $^{\#\#}$ difference from CG at the same time point at pre-intervention ($p < 0.01$), $^{\alpha\alpha}$ difference from baseline within the group at post-intervention ($p < 0.01$), $^{\beta\beta}$ difference from CG at the same time point at post-intervention ($p < 0.01$).

3.3.2 Pulmonary responses

There were no significant changes in any gas variables throughout the control group's single session at pre- and post-intervention (Figures 2-3 and Supplementary Figures 4-5).

Acute effect

At pre-intervention in KKG, compared with that of the baseline, absolute values of RR were higher from 10 minutes of exercise to 5 minutes of recovery with significantly higher than CG (all p<0.01). They returned to baseline after that with considerably lower than during exercise (all p<0.05) (Figure 2A). Like RR, $\dot{V}_E$, $\dot{V}O_2$, and $\dot{V}CO_2$ had similar responses to exercise, but had significant differences to the baseline and between groups at the first 5 minutes of KKQ/reading session and recovery (all p<0.01) (Figure 2B-D). The absolute values of $\dot{V}_E/\dot{V}O_2$ were decreased during the first 20 minutes of exercise and returned to the baseline during recovery (all p<0.01) (Figure 3A). Moreover, they were higher during recovery than during exercise (all p<0.01). $\dot{V}_E/\dot{V}O_2$ were lower in the KKG than the CG at the 10-minute KKQ/reading session and during the first 20-minute recovery. $\dot{V}_E/\dot{V}CO_2$ were decreased throughout the exercise and returned to baseline during recovery with significantly lower values during the exercise than reading (all p<0.01) (Figure 3B). $\dot{V}_E/\dot{V}CO_2$ were higher than during the KKQ session throughout recovery (all p<0.01).

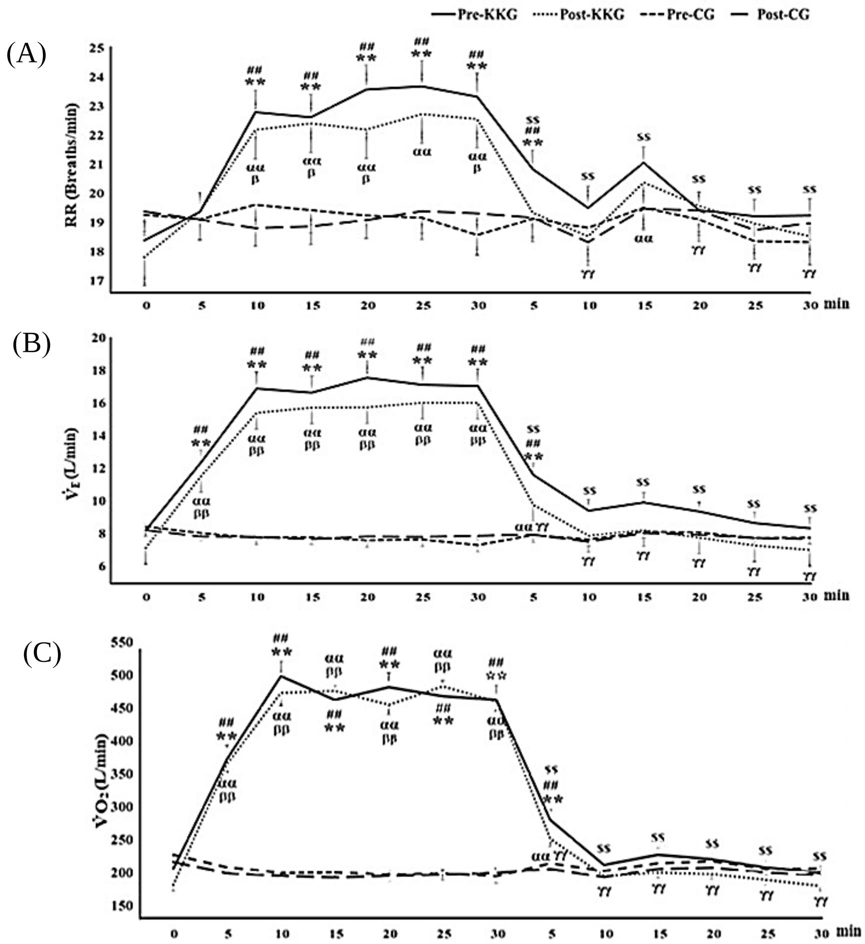

Figure 2 RR (A), $\dot{V}_E$ (B), $\dot{V}O_2$ (C), $\dot{V}CO_2$ (D), at baseline, during KKQ/reading part, and recovery in both groups. Data are expressed as mean ± SE (n = 28 for each group). CG, Control Group; KKG, Khon Kaen Qigong group; KKQ, Khon Kaen Qigong; RR, respiratory rate, $\dot{V}_E$, ventilation rate; $\dot{V}O_2$, oxygen consumption rate; $\dot{V}CO_2$, carbon dioxide production rate. ** difference from baseline within the group at pre-intervention (p < 0.01), $^{\$\$}$ difference from during KKQ section in KKG at pre-intervention (p < 0.01), $^{\#\#}$ difference from CG at the same time point and pre-intervention (p < 0.01), $^{\alpha,\alpha\alpha}$ difference from baseline within the group at post-intervention (p < 0.05, 0.01), $^{\gamma\gamma}$ difference from during KKQ section in KKG and at post-intervention (p < 0.01), $^{\beta,\beta\beta}$ difference from CG at the same time point and post-intervention (p < 0.05, 0.01).decreased throughout the exercise and returned to baseline during recovery with significantly lower values during the exercise than reading (all p<0.01) (Figure 3B). $\dot{V}_E/\dot{V}CO_2$ were higher than during the KKQ section throughout recovery (all p<0.01).

(D)

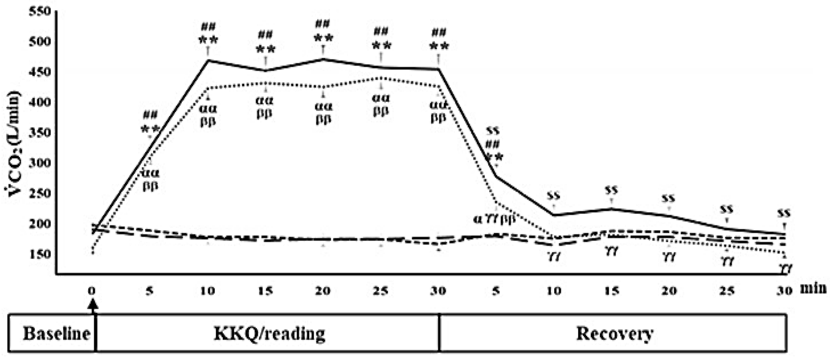

Figure 2 (CONT.) RR (A), $\dot{V}_E$ (B), $\dot{V}O_2$ (C), $\dot{V}CO_2$ (D), at baseline, during KKQ/reading part, and recovery in both groups. Data are expressed as mean ± SE (n = 28 for each group). CG, Control Group; KKG, Khon Kaen Qigong group; KKQ, Khon Kaen Qigong; RR, respiratory rate, $\dot{V}_E$, ventilation rate; $\dot{V}O_2$, oxygen consumption rate; $\dot{V}CO_2$, carbon dioxide production rate. ** difference from baseline within the group at pre-intervention (p < 0.01), $^{\$\$}$ difference from during KKQ section in KKG at pre-intervention (p < 0.01), $^{\#\#}$ difference from CG at the same time point and pre-intervention (p < 0.01), $^{\alpha,\alpha\alpha}$ difference from baseline within the group at post-intervention (p < 0.05, 0.01), $^{\gamma\gamma}$ difference from during KKQ section in KKG and at post-intervention (p < 0.01), $^{\beta,\beta\beta}$ difference from CG at the same time point and post-intervention (p < 0.05, 0.01).decreased throughout the exercise and returned to baseline during recovery with significantly lower values during the exercise than reading (all p<0.01) (Figure 3B). $\dot{V}_E/\dot{V}CO_2$ were higher than during the KKQ section throughout recovery (all p<0.01).

Training effect

Post-intervention, the KKG showed no significant changes in expired gas variables either at rest or in response to exercise compared with pre-intervention (Figures 2 and 3). Compared with that of the baseline, at post-intervention, the absolute values of RR were higher from 10 minutes of exercise to 5 minutes of recovery. They returned to baseline after that (all p<0.01), with significantly lower values than during exercise (Figure 2 (A)). Like RR, $\dot{V}_E$, $\dot{V}O_2$, and $\dot{V}CO_2$ had similar responses to exercise but had significant differences to the baseline and between groups at the first 5 minutes of KKQ/reading session and recovery (all p<0.01) (Supplementary Figure 4 (B-D)). Although there were no significant differences in the absolute values of RR and $\dot{V}O_2$ between pre-and post-intervention after 12 weeks, the KKG had a greater decrease in RR than the CG at 5-minute recovery (Supplementary Figure 4 (A)) and greater increases in $\dot{V}O_2$ than CG at 5- and 15-minute KKQ/reading session (Supplementary Figure 4 (C)). No significant difference in changes between the groups in $\dot{V}_E$ and $\dot{V}CO_2$ after 12 weeks was noted (Supplementary Figure 4 (B-D)). $\dot{V}_E/\dot{V}O_2$ were decreased throughout the 20-minute KKQ session and returned to baseline during recovery with significantly lower values during the KKQ session than reading (all p<0.01) (Figure 3 (A)). Like $\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$ were decreased throughout the KKQ session and returned to baseline during recovery with significantly lower values during the KKQ session than reading (all p<0.01) (Figure 3 (B)). Although absolute values of $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ were not different between pre-and post-intervention they were more decreased at post-intervention than at pre-intervention of the KKQ session than reading at most time points (all p<0.05) for $\dot{V}_E/\dot{V}O_2$ (Supplementary Figure 5 (A)) and at 5- and 20-minute KKQ/reading session and 5-, 10-, and 25-minutes recovery (all p<0.05) for $\dot{V}_E/\dot{V}CO_2$ (Supplementary Figure 5 (B)).

3.3.3 Dynamic pulmonary function and respiratory muscle strength

Training effect

Both groups did not change dynamic pulmonary function (Table 1). At pre-intervention, some participants had low MIP [17]). It was lower in the KKG than in the CG (p <0.05) but was significantly higher post-intervention in the KKG (p <0.01), without any change in the CG. The MEP was higher at post-intervention than at pre-intervention in the KKG (p<0.01) and CG (p<0.05). At post-intervention, no significant differences existed between the groups in the MIP and MEP (Table 1).

3.3.4 Exercise intensity

The data of %HRmax (HRmax calculated from 220-age) and $\%\dot{V}O_{2,peak}$ (calculated from 6MWT) showed that a KKQ session is a very light-intensity activity [18] (Supplementary Table 7).

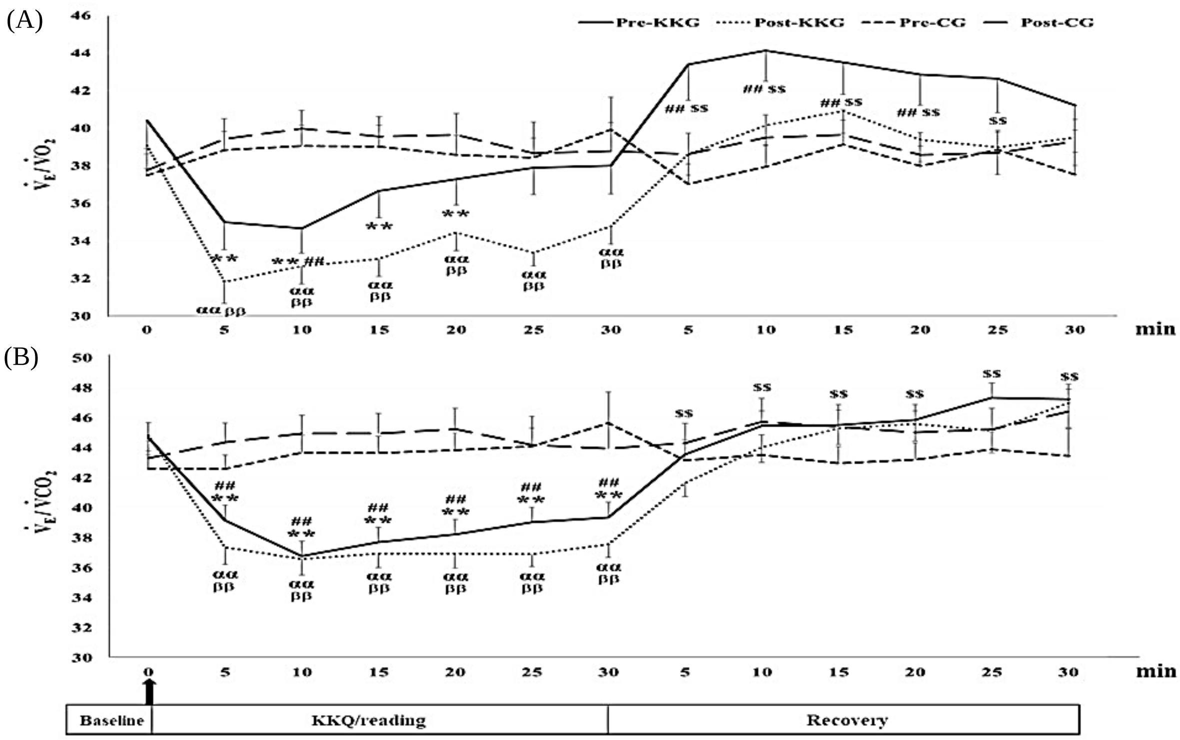

Figure 3 $\dot{V}_E/\dot{V}O_2$ (A), $\dot{V}_E/\dot{V}CO_2$ (B) at baseline, during KKQ/reading part, and recovery in both groups. Data are presented as mean ± SE (n = 28 for each group). CG, control Group; KKG, Khon Kaen Qigong group, KKQ, Khon Kaen Qigong; $\dot{V}_E/\dot{V}O_2$, ventilatory efficiency relative to $\dot{V}O_2$; $\dot{V}_E/\dot{V}CO_2$, ventilatory efficiency relative to $\dot{V}CO_2$ ** difference from baseline within group at pre-intervention ($p < 0.01$), $^{\$\$}$ difference from during KKQ section in KKG at pre-intervention ($p < 0.01$), $^{\#\#}$ difference from CG at the same time point and at pre-intervention ($p < 0.01$), $^{\alpha,\alpha\alpha}$ difference from baseline within group at post-intervention ($p < 0.05$, 0.01), $^{\gamma\gamma}$ difference from during KKQ section in KKG at post-intervention ($p < 0.01$), $^{\beta,\beta\beta}$ difference from CG at the same time point and post-intervention ($p < 0.05$, 0.01).

4. Discussions

The main findings of this study are that the beneficial effects of the 12-week KKQ training produced significant interaction between the groups and time for the CRF indicated by the 6MWD of sedentary older participants. The training increased $\dot{V}O_2$ and decreased ventilatory efficiency relative to $\dot{V}O_2$ and $\dot{V}CO_2$ during the single session. The improvement of ventilatory efficiency and RR existed during recovery. However, hemodynamics was not affected by the training. Additionally, this study confirmed that a single session of KKQ (an acute effect) increased cardiopulmonary responses to a very low level.

As hypothesized, the 12-week KKQ improved CRF calculated from the 6MWD compared to the control group, who maintained a sedentary life. No previous studies on KKQ or Wai Khru Muay Thai training reported this beneficial effect on walking distance in sedentary older adults. This potential effect has been reported for the Baduanjin [7,8] and Wuqinxi [8,9] in many reviews of participants with cardiopulmonary disease. The improved CRF indicates the improved oxygen consumption capacity comparable with the increased oxygen consumption in this study. The increased oxygen consumption seems to be due to increased inspiratory air volumes resulting from KKQ-enhanced thoracic cage flexibility [19]. KKQ training improves cage flexibility by providing good stretching in all parts of the body, especially the chest with breathing exercises. Another mechanism explaining the increased oxygen consumption is increased skeletal muscle mitochondria respiration yielding energy production for physical activity [20]. However, we did not measure it leading to no data on muscle oxidation. Thus, this study has a limitation which should be further explored. In addition, the increased walk distance is comparable with the decreased ventilatory efficiency in this study. This is consistent with an article that reported a negative correlation between the 6MWD and ventilatory efficiency [21]. Importantly, CRF [22] and ventilatory efficiency [23], particularly $\dot{V}_E$ relative to $\dot{V}CO_2$ were demonstrated to be negatively associated with cardiovascular risk and mortality. Therefore, KKQ could be an alternative exercise that should be promoted to improve a healthy long life.

Changes in HR or BP according to the KKQ training were not observed. This contrasts with an original and two review articles reporting that practicing Baduanjin improved SBP and DBP in the healthy elderly population and patients [5,24-26]. The discrepancy may be due to the use of different protocols. Although the session duration was similar (40–60 m.) and the training period ranged from 3 months, those previous studies employed a higher frequency (5 sessions/week) and longer duration (6 months) than ours (3 sessions/week, 3 months). A higher frequency and longer duration may partly result in a greater decrease in BP after training. Furthermore, normal hemodynamics in most participants in both groups may attenuate the changes according to training. In addition, KKQ training did not change dynamic lung function. This may be due to the normality of participants' lung function.

After 12 weeks, the mean respiratory muscle strength tended to slightly favor the exercise group compared to the control group but failed to reach statistical significance. The lack of improvement in MIP and MEP after KKQ training compared to the control group does not support our hypothesis. Based on a literature review, no training results for Baduanjin, Wuqinxi, or Wai Khru Muay Thai on MIP and MEP have been reported. Furthermore, one might argue that the exercise group had significantly lower MIP at pre-training than the control group. There is no explanation for this. Of note, respiratory muscle strength is not in our inclusion criteria leading to no measurements of MIP and MEP in the screening. However, we excluded those who had a diagnosis of pulmonary disease. Hence, the respiratory muscle strength of both groups was assumed to be within normal ranges. It is noted that some participants in both groups had lower MIP and MEP than normal values [17,27], classified as respiratory muscle weakness. This can be a symptom found in older adults [17,27]. Previously, 5 times/week Liuzijue Qigong emphasized that breathing demonstrated improved MIP and MEP in patients at an early recovery stage from stroke [24]. The patients with stroke mostly had respiratory muscle weakness. Therefore, setting the respiratory muscle weakness as the inclusion criteria may yield significant benefits to the pulmonary response.

The very light exercise level of KKQ supports our hypothesis. The level is indicated by a gold standard indicator i.e. %HRmax and $\%\dot{V}O_{2,peak}$ [18]. The former indicated very light to light while the latter which is more valid indicates very light. Therefore, KKQ is a very light-level exercise. This study confirms the result of the recent article [1]. The strength of this study is that all participants in the exercise group performed both acute and training sessions. Hence, no participant bias was found in this study. Furthermore, this intensity was confirmed by no within and group differences in energy expenditure although it favors the exercise group to the control group without any significant difference. In addition, the intensity is comparable with the absence of discomfort and injury.

Importantly, the quality of the measurement process throughout was controlled. Firstly, this study is RCT, a research design that yields reliable data [11]. The rules of RCT were followed including planning, conducting, analyzing, and reporting methodologically sound and appropriate to the question being asked. As aforementioned, the 6-MWT is a safe, simple, less costly, and standard method of measuring CRF [10]. Its activity is more representative of daily life than other walking tests and it measures CRF in various age ranges including older adults [10]. Secondly, standardized procedures were used involving accurate measuring equipment, and measurements controlled by calibration before data collection or quality assessment during the analysis as described in Methods. Furthermore, their matched demographic characteristics including education level and career between groups lead to a lack of bias. Finally, the ratio of participants' underlying diseases was homogenizing (5 and 3 participants with diabetes mellitus type 2, and 18 and 17 participants with hypertension, in the CG and KKG, respectively). Therefore, this data was valid to confirm the results of this study. Additionally, the group exercises in their communities are advantageous because they encourage participants to adhere (based on a high adherence rate (93%) to the training due to the enjoyment and convenience.

To obtain clear results, for the response to a session of KKQ, reading a neutral book was selected as the control activity because reading was not reported to increase cardiopulmonary responses [2]. Thus, compared to reading, the effect of KKQ on cardiopulmonary responses should be observed. For KKQ training, participants in the control group continued their regular sedentary life which has been shown to impair physical function in older adults [28]. Thus, an observation may be conducted on a beneficial cardiopulmonary response according to the KKQ training compared with the sedentary lifestyle in older participants.

Limitations of this study

This study has limitations. Exercise-induced changes in HR and BP were not continuously recorded throughout and after a single session of the exercise/reading. Therefore, recent data may not represent the changes in all sessions. Additionally, the researchers did not measure ventilation efficiency using cardiopulmonary exercise testing [29] because this test may be invasive for older participants. Thus, efficiency was assessed during the KKQ session instead. This protocol was previously published in articles of Qigong [13,30]. Therefore, this outcome is valid enough to present the effect of KKQ on these participants. Furthermore, the intensity, frequency, or duration of the training may be inadequate to yield significant differences for the non-significant variables after the training. Another limitation is the sex distribution because there were more female than male participants in both groups (26 females and 2 males in the CG and 27 females and 1 male in the KKG). Although the sex ratio was not different between groups resulting in no sex bias, sex has been reported to affect HR and $\dot{V}O_2$ during exercise at various intensities [31]. Therefore, this study should not apply to the male population. Finally, muscle oxygen consumption, autonomic nervous system activity, or stress hormone levels were not measured. Therefore, the mechanisms underlying the training effects of KKQ could not be determined.

Recommendations for future research

To receive more efficiency from the KKQ training using the progressive training principle, further study with a more advanced KKQ program such as progressively adding more weight resistance and increasing frequency (5-6 times/week), or duration (6-12 months) is warranted. More mechanisms such as muscle oxygen consumption, and endocrinal and autonomic nervous system activity should be studied. In addition, KKQ training in other populations, such as male participants and patients with cardiopulmonary diseases such as patients with hypertension, COPD, or respiratory muscle weakness is needed to explore further knowledge of health care. Finally, regarding the reduction in cardiovascular risk implied by improved CRF and ventilatory efficiency [32-34], there is a need to explore the training effects of KKQ on cardiovascular risk.

5. Conclusions

The training effects on improving CRF determined by the 6MWD and improving $\dot{V}O_2$, and ventilatory efficiency during a session of KKQ in sedentary older participants make KKQ a particularly potent form of exercise. The cardiopulmonary responses to the acute KKQ session confirm that it is a very light-intensity exercise. Without injury or symptoms, the improved CRF and ventilatory efficiency implied decreased cardiovascular risk and mortality. Therefore, KKQ could be an alternative exercise that should be promoted to enhance a healthy long life. A progressive resistance to higher depth of breathing, frequency, or longer duration of training to confirm the results of this study. A further study is planned to investigate the mechanisms by which the practice of KKQ has produced the benefits documented.

6. Ethical declarations

Ethical approval was obtained from the Ethics Committee of Khon Kaen University (HE641163)

7. References

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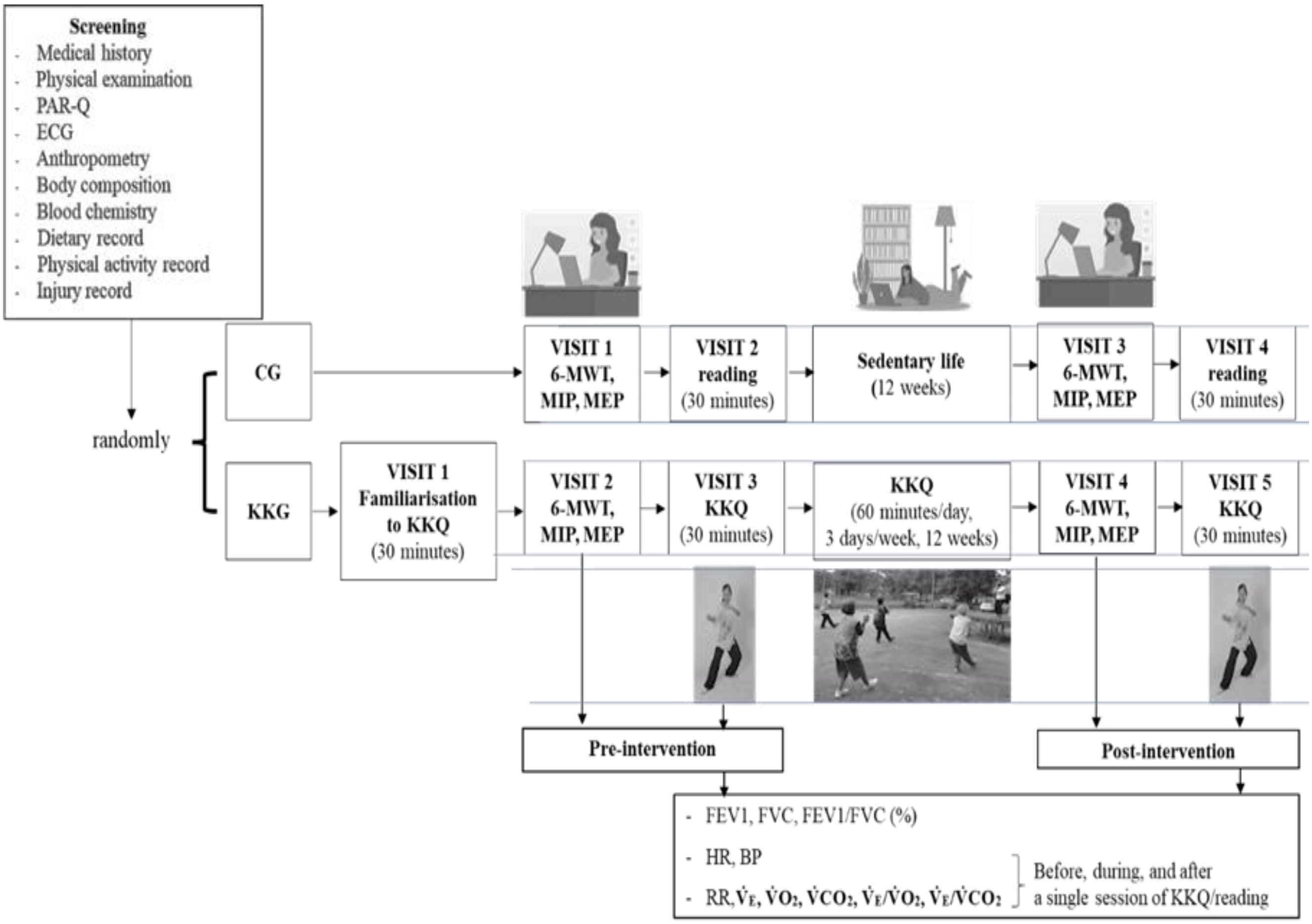
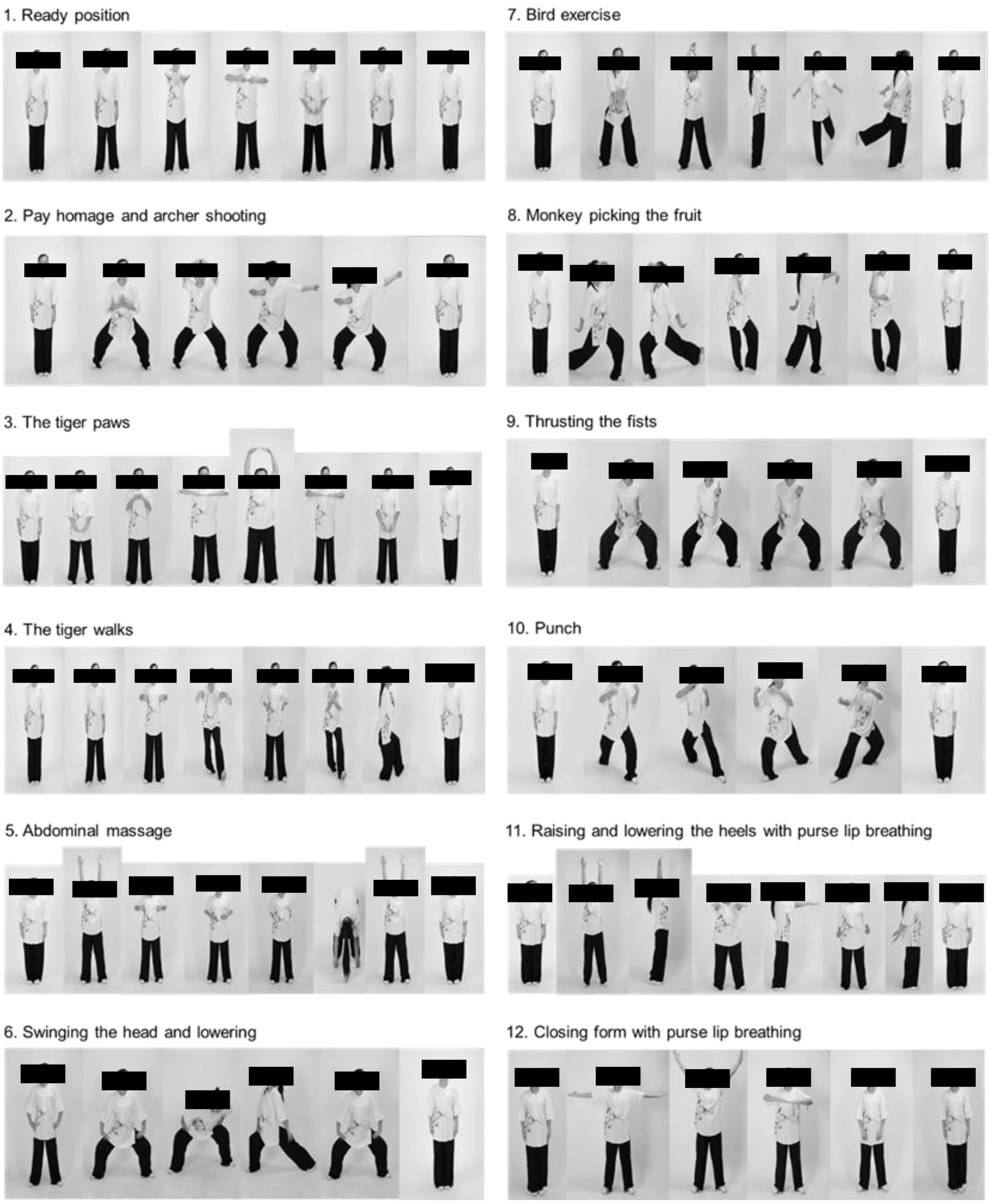
Appendices (Supplementary)



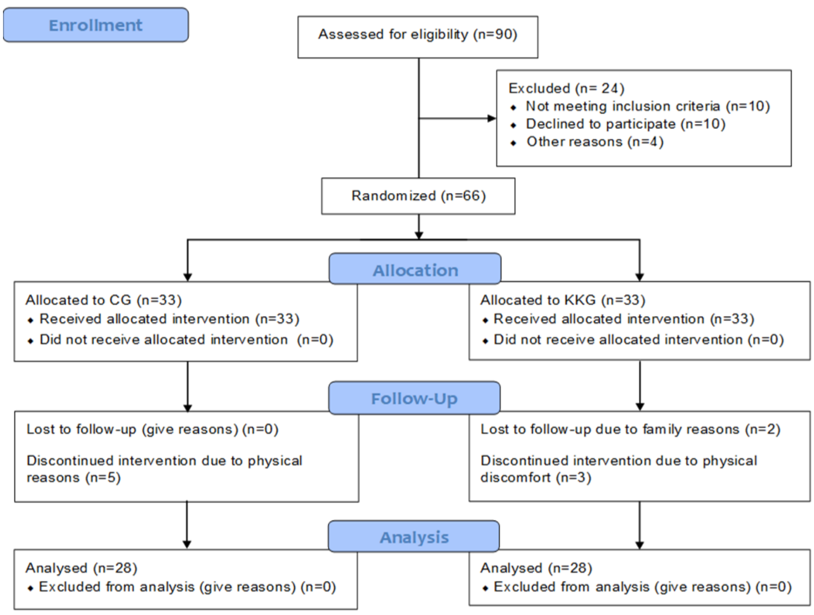
Supplementary Figure 1 Protocol of this study.

PAR-Q, Physical Activity Readiness Questionnaire; ECG, electrocardiogram; CG, control Group; KKG, Khon Kaen Qigong group; KKQ, Khon Kaen Qigong; 6MWD, 6-minute walk distance; HR, heart rate; BP, blood pressure; RR, respiratory rate, $\dot{V}_E$, ventilation rate; $\dot{V}O_2$, oxygen consumption rate; $\dot{V}CO_2$, carbon dioxide production rate; $\dot{V}_E/\dot{V}O_2$, ventilatory efficiency relative to $\dot{V}O_2$; $\dot{V}_E/\dot{V}CO_2$, ventilatory efficiency relative to $\dot{V}CO_2$; FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure.

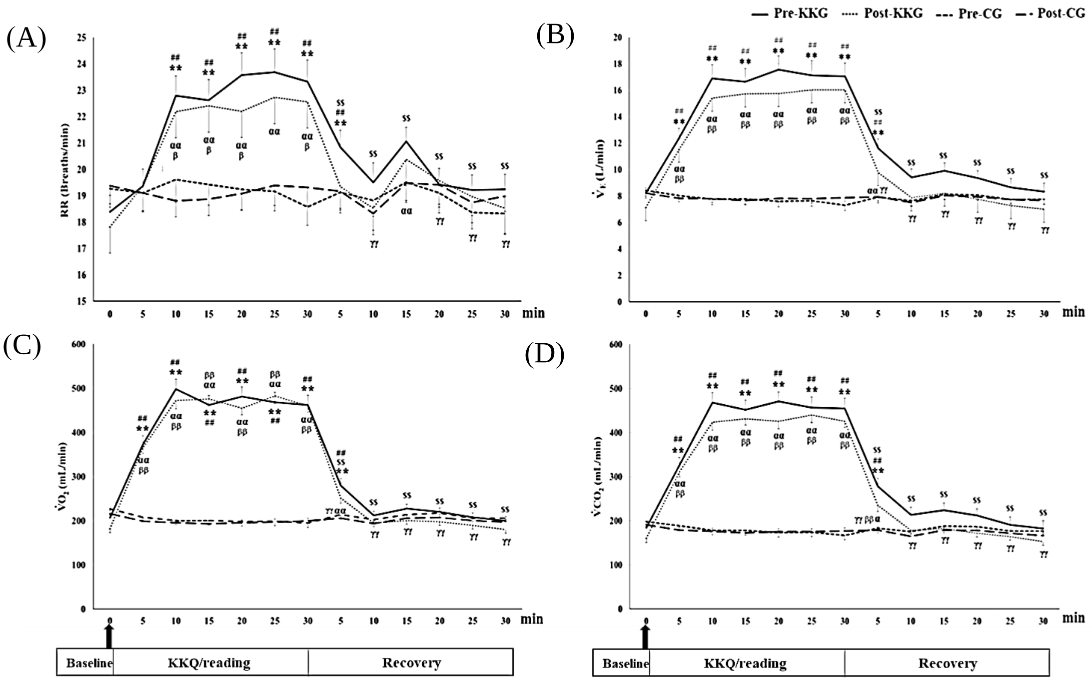


Supplementary Figure 2 Khon Kaen Qigong motions (Figure reproduced with permission from Liu et al, 2022) [2].

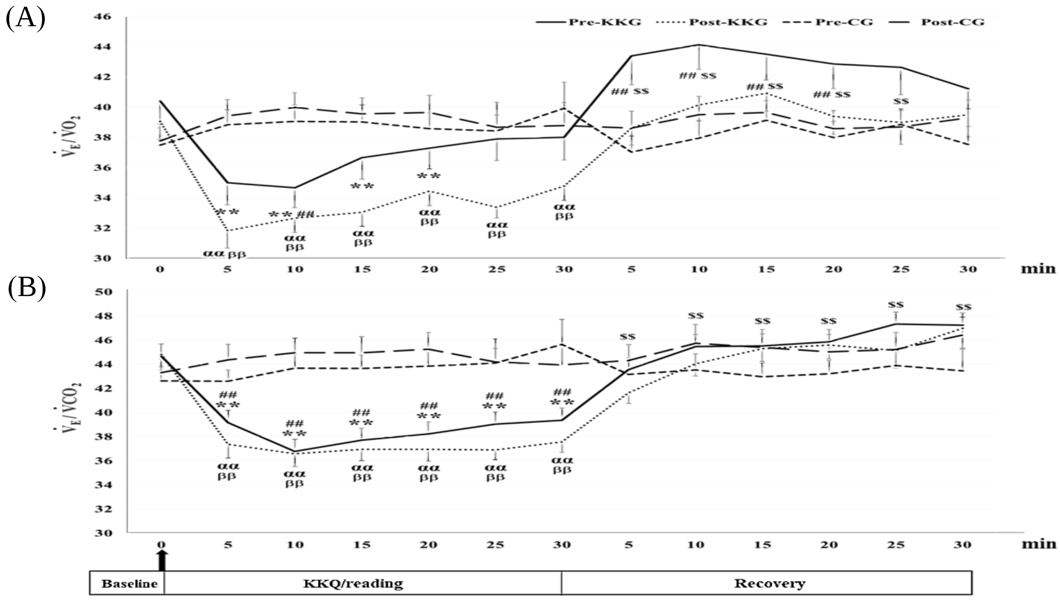
CONSORT 2010 Flow Diagram



Supplementary Figure 3 Consort flow diagram of this study. CG, control Group; KKG, Khon Kaen Qigong g



Supplementary Figure 4 RR (breaths/min) (A), $\dot{V}_E$ (L/min) (B), $\dot{V}O_2$ (mL/min) (C), $\dot{V}CO_2$ (mL/min) (D), at baseline, during KKQ/reading, and recovery in both groups. Data are expressed as mean±SE (n = 56, CG = 28, KKG = 28). CG, Control Group; KKG, Khon Kaen Qigong group; KKQ, Khon Kaen Qigong; RR, respiratory rate, $\dot{V}_E$, ventilation rate; $\dot{V}O_2$, oxygen consumption rate; $\dot{V}CO_2$, carbon dioxide production rate. ** difference from baseline within group at pre-intervention ($p < 0.01$), $^{\$\$}$ difference from during KKQ in KKG at pre-intervention ($p < 0.01$), $^{\#\#}$ difference from CG at the same time point and at pre-intervention ($p < 0.01$), $^{\alpha,\alpha\alpha}$ difference from baseline within group at post-intervention ($p < 0.05$, 0.01),$^{\gamma\gamma}$ difference from during KKQ in KKG and at post-intervention ($p < 0.01$), $^{\beta,\beta\beta}$ difference from CG at the same time point and at post-intervention ($p < 0.05$, 0.01).



Supplementary Figure 5 $\dot{V}_E/\dot{V}O_2$ (A), $\dot{V}_E/\dot{V}CO_2$ (B) at baseline, during KKQ/reading, and recovery in both groups. Data are presented as mean±SE (n = 56, CG = 28, KKG = 28). CG, control Group; KKG, Khon Kaen Qigong group, KKQ, Khon Kaen Qigong; $\dot{V}_E/\dot{V}O_2$, ventilatory efficiency relative to $\dot{V}O_2$; $\dot{V}_E/\dot{V}CO_2$, ventilatory efficiency relative to $\dot{V}CO_2$.

** difference from baseline within group at pre-intervention ($p < 0.01$), $^{\$\$}$ difference from during KKQ in KKG at pre-intervention ($p < 0.01$), $^{\#\#}$ difference from CG at the same time point and at pre-intervention ($p < 0.01$), $^{\alpha,\alpha\alpha}$ difference from baseline within group at post-intervention ($p < 0.05, 0.01$), $^{\gamma\gamma}$ difference from during KKQ in KKG at post-intervention ($p < 0.01$), $^{\beta,\beta\beta}$ difference from CG at the same time point and at post-intervention ($p < 0.05, 0.01$).

Supplementary Table 1 Motions of Khon Kaen Qigong

	Title of motion	Modified from	Additional movement
1	Ready position: adjusting the breath	Wuqinxi	
2	Paying homage and archer shooting	Baduanjin and Wai-Khru	increased neck and trunk extension
3	The tiger's paws	Wuqinxi and Wai Khru	
4	The tiger's walk 1	Wuqinxi	
5	The tiger's walk 2	Wuqinxi	
6	Swinging the head and lowering	Baduanjin	
7	Bird exercise	Wuqinxi	
8	Monkey picking the fruit	Wuqinxi	increased 3 steps diagonal walking
9	Thrusting the fists	Baduanjin	
10	Punching	Wai Khru	
11	Raising and lowering the heels with purse lip breathing	Baduanjin	increased arm swing
12	Closing form	Wuqinxi	

Supplementary Table 2 Baseline demographic, anthropometric, body composition, hemodynamics, and blood chemistry of participants in both groups

	CG (n=28)	KKG (n=28)
Age (yr) [a]	65±3.34	67±5.1
Sex (male/female) [b]	2/26	1/27
Highest education level		
- Primary school	20	19
- Secondary school	6	7
- Bachelor's degree	1	2
- Master's degree	1	-
Career		
- Farmer	9	14
- Maid	8	1
- Housewife	-	2
- Selling goods	-	5
- Medical staff	-	1
- Retired person	5	2
- General employee	5	2
- No career	1	1
BMI (kg/m^2) [a]	26.7±8.55	25.4±3.07
W (cm) [a]	86.5±10.6	87.2±8.16
H (cm) [a]	98.4±7.5	99±6.5
W/H [a]	0.88±0.06	0.87±0.06
HR (/min) [a]	66±8.5	64±8.89
SBP (mmHg) [a]	132±19.8	136±15.7
DBP (mmHg) [a]	77±10.3	77±7.70
FBG (mg/dL) [a]	103.5±28.2	118.3±50.1
TC (mg/dL) [a]	200.6±41.5	224.7±39.9
TG (mg/dL) [a]	141.3±64.0	156.456±145.2
HDL-C (mg/dL) [a]	52.2±13.9	55.8±27.8
LDL-C (mg/dL) [a]	129.1±39.0	142.2±38.9
Cr (mg/dL) [a]	0.85±0.21	0.81±0.19
SGPT (U/L) [a]	16.5±5.66	23.328±28.5

The data are presented by mean ± SD. [a]The independent t-test was used to compare continuous variables with a normal distribution between groups. [b]The Mann-Whitney U test was used for ordinal data.BMI, body mass index; W, waist circumference; H, hip circumference; FBG, fasting blood glucose; TC, total cholesterol; TG, triacylglycerol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Cr, creatinine; SGPT, serum glutamate pyruvate transaminase.