



Effects of tai chi on physical performance, sleep, and quality of life in older adults with mild to moderate cognitive impairment

高, 冉

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博士論文

Effects of tai chi on physical performance, sleep, and quality of life in older adults
with mild to moderate cognitive impairment
(太極拳が認知症高齢者の睡眠や心身の状態に及ぼす効果)

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神戸大学大学院保健学研究科保健学専攻

Ran Gao
(高 冉)

Abstract

Background Exercise is a promising non-pharmacological intervention to delay the progression of cognitive impairment and improve physical function and sleep quality in patients, but the evidence remains inconclusive.

Aims To compare the therapeutic efficacy of an exercise intervention on physical performance, sleep efficiency, and quality of life in older adults with cognitive impairment.

Design A three-arm randomized controlled trial.

Methods This study recruited 81 older adults with mild to moderate cognitive impairment at a nursing home from December 2020 to July 2021. Participants were screened and randomized into three groups: a tai chi intervention group ($n = 27$), a conventional exercise intervention group ($n = 27$), and a waitlist control group with no intervention ($n = 27$). The intervention groups underwent 12 weeks of exercise intervention. Participants were assessed at weeks 0, 6, and 12. The primary outcome was the Short Physical Performance Battery score, and the secondary outcomes were sleep efficiency and quality of life. Statistical analysis was conducted with generalized estimating equations (GEEs).

Results The mean age of the participants was 81.0 ± 7.4 years. The GEE analysis revealed that the Short Physical Performance Battery score, sleep efficiency, and quality of life were significantly higher in both intervention groups than in the control group at week 12, and physical performance improved significantly more in the tai chi group than in the conventional exercise group.

Conclusions Both exercise interventions improved physical performance, sleep efficiency, and quality of life in older adults with mild to moderate cognitive impairment. According to our results,

tai chi may be a more effective therapeutic approach for cognitive impairment than conventional exercise.

Keywords Cognitive impairment, tai chi, Physical functional performance, Quality of life, Nursing intervention

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1. INTRODUCTION

1.1. Epidemiology of cognitive impairment

According to the World Health Organization (WHO, 2021), approximately 55 million people worldwide have cognitive impairment, and this number is expected to grow to 78 million by 2030 and 139 million by 2050 [1]. The inevitable increase in the aging population results in an increase in the number of people with cognitive impairment. The prevalence of cognitive impairment in China—the country with the highest number of people with cognitive impairment worldwide—is 4.3%–6.3%, imposing a heavy burden on the public and the health care system [2]. In nursing homes, the prevalence of cognitive impairment ranges from 50% to 84%, and most residents have extensive physical performance impairments [3].

1.2. Physical and mental problems faced by people with cognitive impairment

Cognitive and physical performance impairments often co-occur in older adults; people with cognitive impairment exhibit a greater decline in physical functional performance than cognitively healthy adults, and their physical performance progressively deteriorates with disease severity [4,5]. Nursing home residents tend to experience a decline in physical functional performance over time [6]. Physical functional performance is a prerequisite for mobility and the successful completion of activities of daily living [7]. Cognitive impairment can significantly influence quality of life and increase the risk of disability, dependency, and mortality.

In addition to experiencing impairments in physical functional performance, most people with cognitive impairment also face sleep problems [4]. Furthermore, they often spend less time in slow-wave sleep and rapid eye movement (REM) sleep (dream sleep), and they have difficulty falling asleep [5]. Sleep disorders are reported in 55.9% of people with cognitive impairment, and this incidence is believed to be even higher among those living in nursing homes [8]. Previous

studies have demonstrated that sleep problems contribute to cognitive decline and may also increase the risk of cognitive impairment by increasing β -amyloid levels [9]. In addition, disturbed sleep is considered a consequence of cognitive impairment, and substantial evidence demonstrates a bidirectional relationship between them [10]. Poor sleep quality was also verified to decrease the quality of life of people with cognitive impairment [11].

1.3. Possible solutions---- tai chi

There are multiple theoretical targets for sleep enhancement in people with cognitive impairment. Different with disadvantages of pharmacological interventions, interest in non-pharmacological sleep-modifiers especially tai chi is intensifying with technological advances permitting exploration of novel approaches [12]. Tai chi as a kind of non-pharmacological interventions that offer a holistic approach by targeting sleep, physical and mental health of cognitive impairment require rigorous investigation. The evidence-based benefits of physical activity for this field in cognitive impairment have been observed [13]. Structured limbs exercise program for mild Alzheimer patients achieved statistically significant improvements in the Pittsburgh Sleep Quality Index (PSQI) with one study reporting co-existent improved actigraphy variables [12]. Studies also explored the effects of tai chi interventions in people with dementia, and that intervention might improve their quality of sleep and life, even for cognitive function [14].

2. LITERATURE REVIEW

To clarify suitable strategies that solve the challenges faced with cognitive impairment, identification of potentially modifiable interventions especially exercise interventions that stimulate physical and mental problems faced by people with cognitive impairment is imperative. International literature was reviewed in accordance with the guidelines for Systematic Reviews

[15] that ensure quality through a standard list of 27 items. Two investigators (RG and YM), doctoral students in nursing science for dementia, independently searched the literature in Eight databases (PubMed/MEDLINE, Cochrane Library, Embase, CINAHL, Web of Science, China National Knowledge Infrastructure, Wanfang, China Science and Technology Journal Database). Terms from the Medical Subject Headings (MESH) or keywords such as cognitive impairment, dementia, Alzheimer's dementia, tai chi were used. The lists of articles included were studied in order to identify the research related to the subject at hand.

2.1. Research progress of exercise

Currently, the only evidence-based behavioral intervention that has shown to provide some improvement is that of physical activity [16]. Many studies have shown that exercise can improve the lower limb muscle strength, balance, and coordination of patients with impaired cognitive function [5,6]. Physical activity and conventional exercise have been proposed as non-pharmacological strategies for disease prevention and management. Carvalho et al. suggested that an exercise intervention combining aerobic, strength, balance, and postural exercises might be effective in improving the functional capacity of people with cognitive impairment [12].

In addition, extensive evidence suggests that physical activity can slow the progression of cognitive impairment [17]. Furthermore, group-based moderate-intensity aerobic exercise programs can significantly improve health-related quality of life and cognitive function in people with mild cognitive impairment [18].

2.2. Research progress of tai chi

Tai chi, an ancient form of Chinese mind–body exercise that has become increasingly popular in the West, consists of a series of gentle movements aiming to strengthen and relax the body and

mind. It is a whole-body exercise that integrates breathing with harmonious movement of body training. It is designed to loosen the joints, promote deep, relaxed breathing, and cure many medical ailments. The Tai chi movements are used to aid the Qi in its journey (meridians), dissolve blockages that can lead to sickness and disease, and increase general energy level. The meditation component of Tai chi may have direct benefits by enhancing attention and executive functions. Engaging in a group setting may have further benefits for cognition by improving mood and coping skills through social interaction and support [19, 20].

A previous study exploring the effects of tai chi interventions on various outcomes in people with cognitive impairment revealed that these interventions might improve the quality of life and sleep of these individuals, as well as their cognitive function [21]. These movements are accompanied by deep breathing techniques, which may eliminate tension, depression, anxiety, and melancholic psychological states while improving immunity, enhancing physical fitness, and promoting a long and healthy life [22]. Tai chi can be considered equivalent to moderate-intensity exercise and meditation [23]. Most research on tai chi has focused on physical and mental health in healthy older adults. In addition, several systematic reviews and meta-analyses have reported that tai chi may promote balance and prevent falls [24] as well as enhance motor and non-motor function, sleep, and quality of life in older adults with Parkinson's disease [25] and stroke [26].

2.3. Summary on exercise especially for tai chi

Based on the literature, it is not difficult to draw the benefits of exercise for patients with cognitive impairment. Nevertheless, the previous studies on exercise in people with cognitive impairment have been limited by methodological flaws, such as insufficient statistical power, inadequate controls, and the absence of control groups. Moreover, additional research is needed regarding the

extent to which people with cognitive impairment can retain improvements after an exercise intervention. In addition, multiple targets for sleep enhancement in people with cognitive impairment must be examined. Thus, non-pharmacological interventions that offer a holistic approach by targeting physical function and sleep require rigorous investigation. Thus far, few studies have investigated tai chi's effects on outcomes in people with cognitive impairment.

3. PURPOSE

The purpose of this study was to investigate the feasibility and effects of a tai chi intervention on physical functional performance (primary outcome) and sleep efficiency, and quality of life (secondary outcomes) among people with cognitive impairment in China. The effects of the tai chi intervention were compared with those of a conventional exercise intervention.

4.METHODS

4.1. Study design and duration

This study employed a three-arm, double-blind RCT design. The trial was registered at <http://www.umin.ac.jp/ctr/index.htm> (ID no. UMIN000042051, first posted October 8, 2019) and was preceded by a pilot intervention phase. It was conducted at the cognitive impairment unit of a nursing home in Hainan province, China, between December 2020 and July 2021.

4.2. Setting and data collection

After screening and collecting baseline data, participants who met the inclusion criteria were assigned numbers from 1–81, and a random number table was produced by random number generation software. A block-randomization distribution was adopted to ensure that the number of participants in each group was equal and to control for potential confounders. An independent researcher who was not involved in the study placed the random computer-generated numbers into

opaque, sealed envelopes according to the chronological order of the participants' recruitment.

The two interventions were conducted on different days of the week to prevent the participants from knowing other participants' group assignments or comparing themselves with participants in other groups. The professional instructors and research assistants were informed about the study protocols before the interventions. Research assistants involved in the collection of post-test data were blinded to the group assignments.

4.3. Participants

Potential participants were recruited from the cognitive impairment unit of a nursing home in Hainan province, China. The inclusion criteria were as follows: (a) age of ≥ 65 years; (b) the ability to speak and understand Chinese; (c) a confirmed diagnosis of cognitive impairment and a score of 10–23 points on the mini-mental state examination (MMSE, a test widely used to diagnose cognitive impairment; <10 points indicates severe cognitive impairment and >24 points indicates no cognitive impairment [27,28]); (d) the ability to see the body movement demonstrations clearly and hear the coach's instructions clearly (both of which were tested before the intervention); (e) a physical condition that allowed the completion of the prescribed exercise plan (as assessed before the intervention); (f) stable condition and medication doses for at least 30 days before the intervention; and (g) agreement to participate in the study and sign the informed consent form. The exclusion criteria were as follows: (a) a diagnosis of severe illness or pain that would prevent full participation in the exercise interventions (e.g., metastatic cancer or musculoskeletal disorders) and (b) regular exercise over the past year (≥ 30 min, 3 times per week for over 3 months).

4.4. Intervention

A pilot study was conducted before the formal intervention to ensure the safety and feasibility of our protocol. Six potential participants were randomly selected and allocated to a tai chi (TC) group, a conventional exercise (CE) group, and a waitlist control group with no intervention, and the pilot interventions were implemented for 1 week. The feedback obtained from participants was discussed with the research team and a conventional exercise physiotherapist to modify the program. After conducting the pilot study and finalizing the intervention programs, participants in the TC and CE intervention groups attended three 50-minute intervention sessions per week for 12 weeks. The sessions were guided by a physiotherapist with more than 5 years of teaching experience and appropriate qualifications. All physical therapists held a national advanced tai chi coach certificate. Research assistants monitored participants during the intervention sessions to ensure their safety.

Previous research has shown that eight-form tai chi is easy to learn and suitable for patients with mild to moderate cognitive impairment [29]. Accordingly, we selected the eight-form tai chi method created by China's Physical General Office. The training was performed on Mondays, Wednesdays, and Fridays, and the details of the intervention are summarized in **Table 1**. Each session included a warm-up and cool-down, and the participants were instructed to slowly stretch at a comfortable intensity rather than forcing themselves to perform the movements. They were also advised to focus on their lower body while fully extending their upper body.

The conventional exercise intervention was based on relevant literature and was developed through consultation with an exercise physiotherapist [30]. The intervention sessions took place on Tuesdays, Thursdays, and Saturdays. The conventional exercise sessions included the same warm-up and cool-down exercises as the tai chi intervention (**Table 1**).

The waitlist controls maintained their normal daily routine care and were given the option to participate in either a tai chi or conventional exercise program after the 12-week assessment.

4.5. Sample size

A sample size of 81 was calculated with a power analysis using the F-test (one-way analysis of variance [ANOVA], fixed effects, omnibus) with the G*power program [31]. Following the methods of previous research, the participants were divided into three groups according to the presence of multiple independent variables and multiple regression modeling with a medium effect size (f^2) of 0.36 [32], in which α was set to 0.05 and the power was set to 0.80. The results indicated that each group required 26 participants. The reported turnover rate of older adults participating in a similar study was 14% [33]; thus, the target number of participants in each group was 30 (90 in total).

4.6. Outcome measures

Outcomes were assessed at three time points: at baseline before randomization (week 0), during the intervention (week 6), and after the intervention (week 12). All outcomes were compared between assessment points and between groups. The primary outcome was physical performance, which was measured with the Short Physical Performance Battery (SPPB). The secondary outcomes were sleep efficiency, measured by an ActiGraph GT9X+ (ActiGraph in America) device, and quality of life, measured with the Quality of Life in Alzheimer's Disease (QOL-AD) questionnaire. An objective method was selected to measure sleep quality because people with cognitive impairment typically have different degrees of cognitive impairment, and subjective scales, such as the Pittsburgh Sleep Quality Index (PSQI), cannot reflect the real sleep conditions of patients.

The Short Physical Performance Battery (SPPB)

SPPB is one of the most commonly used assessment tools to measure comprehensive physical ability and can effectively quantify mobility among older adults, including their daily living ability, degree of physical weakness, prediction of fall risk, and sports ability [34]. The evaluation includes three sections: balance testing (in a parallel, semi-tandem, and tandem position for 10 s), walking speed (4 m), and standing up from a chair (sit-to-stand five times). Each test is evaluated separately. The overall SPPB score ranges from 0 to 12, and a higher score implies a greater physical functional performance.

ActiGraph

ActiGraph is a wearable device used to record physical activity and sleep data. The device leverages recent advancements in science and technology to measure sleep with high sensitivity, comprehensive recording parameters, and a long monitoring time. Changes in sleep stages are accompanied by alterations in body movements, allowing the patient's sleep state to be indirectly calculated by analyzing the activity parameters. Therefore, ActiGraph is a useful tool for measuring sleep quality. As early as 2007, the American Academy of Sleep Medicine (AASM) recommended using wearable devices as an auxiliary method for sleep evaluation [35]. Recently, more studies have utilized wearable devices to track sleep, verifying their use for the collection of objective sleep data in older adults with cognitive disorders [36].

This study used the ActiGraph GT9X+, which features a three-axis accelerometer, a gyroscope, a magnetometer, data filtering technology, and Bluetooth Smart technology to provide information on sleep latency, total sleep time, and sleep efficiency, as well as real-time participant data

feedback. When collecting data, the sampling interval of the accelerometer was set to 60 s, and the sampling frequency was set to 30 Hz. ActiLife 6 software was used to analyze the data.

Quality of Life in Alzheimer's Disease (QOL-AD)

The QOL-AD was developed by Logsdon and colleagues at the University of Washington, United States [37], and Hu et al. translated and revised the scale to Chinese [38]. The scale includes 13 items, and each item is scored with a 4-point Likert scale, with 1 indicating 'poor' and 4 indicating 'excellent'. The total score ranges from 13 to 52 points, and a higher score indicates a better quality of life. The scale can be evaluated by patients or caregivers; regardless of the evaluation method, the scale has good reliability and validity, with a Cronbach's alpha ranging from 0.83 to 0.90. Many studies have used this tool to evaluate the quality of life of patients with cognitive impairment.

4.7. Data collection

The research team contacted the director of the nursing home and obtained permission to conduct the study after explaining the details of the protocol. The participants who met the eligibility criteria provided informed consent. Finally, participants were randomly divided into (i) a TC group, (ii) a CE group, or (iii) a waitlist control group with no intervention. All participants provided demographic data at baseline. They completed the SPPB and QOL-AD and wore an ActiGraph device for 72 hours at three time points (0, 6, and 12 weeks).

4.8. Ethical considerations

The Institutional Review Board of Kobe University approved this study (approval number: 940), which was registered in the University Hospital Medical Information Network (UMIN) Center (registration number: UMIN000042051). Informed written consent was obtained from all

participants. Codes were used to replace real names to ensure privacy. The data were locked and will be destroyed 3 years after the end of the study.

4.9. Data analysis

The data were entered and checked in two ways. For missing data, if the missing data accounted for less than one-third of the total data, the average of the available data was used to replace the missing data; if the missing data accounted for over one-third of the total data, they were omitted. Data were analyzed with SPSS version 26.0 (IBM Corporation). Baseline socio-demographic and clinical characteristics are presented with descriptive statistics. The feasibility measures were compared between the groups with one-way ANOVA, t-test, and Chi-square or Fisher's exact tests. To account for missing values and correlation between repeated measurements, generalized estimating equations (GEEs) were used to compare the primary and secondary outcomes. The baseline measurement, time (the number of weeks from baseline), group (control group, TC group, or CE group), and group-by-time interaction were used as covariates. The group interaction, indicating the difference in a given outcome between interventions over time, was the primary measure of the intervention effect.

Missing values of quantitative data were not replaced because GEE analysis accommodates missing data under the assumption that they are missing at random [39]. Missing values for the SPPB, sleep efficiency, and the QOL-AD were managed by multiple imputations (SPSS PROC), given that these observations would otherwise be omitted from the logistic regression analysis.

This study used valid questionnaires and exercise interventions validated by international organizations. The study protocol was standardized, and the physiotherapist, research assistants, and assessors were trained to ensure consistency. Furthermore, the measurement instruments were

valid and reliable, and all data were carefully checked immediately after collection. Finally, throughout the study, the research team regularly met to assess the study's progress and ensure that it strictly followed the protocol.

5.RESULTS

Of the 91 patients in the cognitive impairment unit at the selected nursing home in Hainan province, China, 10 (11.0%) were not eligible to participate. Among the remaining 81 patients, 6 were lost to follow-up (7.5%); however, their baseline characteristics and outcomes were similar to those of the remaining participants. By the end of the study, 75 participants remained, with 26 in the TC group, 24 in the CE group, and 25 in the control group (**Fig. 1**). The attendance rate for the TC group was 93.28%, and that for the CE group was 90.02%, with no statistical difference between the two.

The descriptive characteristics of the participants are provided in **Table 2**. Most participants were female (74.1%), and the mean age was 81.0 (SD: 7.4) years. The most common education level was primary school (29.6%), and most of the participants were widowed (69.1%). The mean MMSE score was 16.8 (SD: 3.3), the mean SPPB score was 7.8 (SD: 1.9), the mean sleep efficiency was 72.2% (SD: 11.9%), and the mean QOL-AD score was 31.9 (SD: 4.7). At baseline, the study groups had similar demographic and clinical characteristics.

According to the results of the paired t-test, the TC group had a higher SPPB score at week 12 than at baseline ($P < 0.001$). Furthermore, the TC group had higher SPPB scores than the control group at weeks 6 and 12, although these differences were modest; the adjusted mean differences in SPPB scores between these groups were 0.7 at week 6 (95% CI, 0.4–1.0; $P < 0.001$) and 1.5 at week 12 (95% CI, 1.1–1.9; $P < 0.001$). The CE group also had a slightly higher mean SPPB score

at week 12 than at baseline, although the difference was not significant ($P = 0.083$). The CE group had a modestly higher score than the control group only at week 12; the adjusted mean difference between the two groups was 0.8 (95% CI, 0.4–1.2; $P < 0.001$). Finally, the TC group had a significantly higher SPPB score than the CE group at week 12 (95% CI, 0.3–1.1; $P = 0.001$). The SPPB score was lower at week 12 relative to baseline in the control group; however, the difference was not significant ($P = 0.083$). After the intervention, the GEE analysis indicated that the mean SPPB score differed significantly between the three groups ($P_{group} < 0.001$); the detailed results are presented in **Table 3**.

The mean sleep efficiency significantly increased in the TC group from 72.9% at baseline to 90.2% at week 6 and 93.9% at week 12 ($P < 0.001$). The TC group had a higher sleep efficiency than the control group at week 12 (adjusted mean difference, 7.6%; 95% CI, 4.0%–11.3%, $P < 0.001$). In addition, the mean sleep efficiency increased significantly in the CE group from 70.6% at baseline to 90.0% at week 6 and 92.0% at week 12 ($P < 0.001$), and the CE group had a higher sleep efficiency than the control group at week 12 (adjusted mean difference, 5.8%; 95% CI, 1.6%–10.0%; $P = 0.007$). No significant difference in sleep efficiency was observed between the TC and CE groups at week 6 or 12. Although all three groups showed significant changes in sleep efficiency from baseline to week 12, the GEE analysis still revealed significant differences between these three groups after the intervention ($P = 0.004$).

The mean QOL-AD score increased significantly in the TC group from 33.0 at baseline to 36.4 at week 12 ($P = 0.009$). The adjusted mean difference in the QOL-AD score between the TC group and the control group was 4.1 at week 12 (95% CI, 2.1–6.1; $P < 0.001$). The mean QOL-AD score increased significantly in the CE group from baseline to week 12 ($P < 0.001$). The adjusted mean

difference in the QOL-AD score between the CE and the control group was 4.9 at week 12 (95% CI, 2.7–7.2; $P < 0.001$). No significant differences were observed between the TC and CE groups during the intervention. The control group had a slightly higher QOL-AD score at week 12 relative to baseline, but this difference was not significant ($P = 0.548$). Furthermore, both the TC and CE groups showed significantly increased QOL-AD scores compared with the control group at week 12 in the group interaction effect ($P_{group} = 0.001$).

6.ADVERSE EVENTS

No adverse events were reported during the study period.

7.DISCUSSION

To the best of our knowledge, this is the first study to compare the effects of tai chi and conventional exercise interventions in older adults with mild to moderate cognitive impairment living in a nursing home in China. Our findings demonstrated that compared with no intervention, both eight-form tai chi and conventional exercise significantly improved physical function, as measured by the SPPB. The practice of tai chi can induce relaxation in the body, leading to the release of endorphins and reducing the production of stress hormones such as cortisol [40]. In addition, the slow, flowing movements and deep breathing in tai chi help activate the parasympathetic nervous system, which is responsible for the body's rest-and-digest response [41]. By activating this relaxation response, tai chi can effectively counteract the body's stress response system, allowing individuals to achieve the calm state necessary for quality sleep. Moreover, the results suggest that tai chi may be more effective than conventional exercise to manage physical function in older adults with mild to moderate cognitive impairment. The interventions adopted in this study also improved sleep efficiency and quality of life in people with cognitive impairment.

Our results showed that a 12-week tai chi or a conventional exercise intervention significantly improved physical function in older adults with mild to moderate cognitive impairment, in line with previous studies [40,41]. Furthermore, eight-form tai chi, a form of non-pharmaceutical therapy and mind-body exercise, could be a more suitable and effective approach to managing physical function than conventional exercise.

However, studies on the effects of physical exercise in older adults with cognitive impairment have reported inconsistent results [42]; this may be due to the types of tai chi exercises, as previous studies have investigated 10- or 24-form tai chi. Although 24-form tai chi is the most common form, it may be too complex for people with cognitive impairment, considering that this population often experiences different degrees of cognitive impairment. Accordingly, eight-form tai chi could be more feasible for this population.

Moreover, the participation rate has a large impact on the effectiveness of exercise interventions. Previous research suggested that a higher participation rate and stronger exercise adherence lead to better exercise-related effects [43]. In the present study, the attendance rate was 89.5% (SD: 11.5%). Other studies have implemented interventions for community-dwelling people with cognitive impairment, reporting that home-based training is associated with lower attendance, greater chances of missing sessions, and insufficient levels of exercise required for effective treatment [44,45].

Prior research has shown that older adults are more prone to sleep problems. Cognitive dysfunction, along with changes in the pineal region, the production of melatonin, receptor activity, the loss of cholinergic neurons, and other mechanisms, can cause sleep disorders in older adults. In this study, we observed a significant increase in sleep efficiency in all three groups after

the 12-week intervention. However, sleep efficiency improved more in the TC and CE groups than in the control group. These findings align with those of previous studies that have reported an improvement in sleep quality with exercise interventions, including tai chi [46,47].

Although no consensus has been reached on the effect of exercise on outcomes in people with cognitive impairment [48,49], our findings on the beneficial effects of tai chi and conventional exercise on sleep efficiency are consistent with those of previous studies [50,51]. However, other studies comparing tai chi with similar forms of low- to moderate-intensity exercise have reported that the outcomes did not differ significantly between groups. Thus, the current evidence is not sufficient to conclude that tai chi has more beneficial effects on cognitive impairment outcomes than conventional exercise (or vice versa); additional rigorous RCTs are needed for more in-depth analysis.

This study was initiated at the beginning of 2020 when nursing homes carried out a month-long series of COVID-19 prevention and control measures, such as temporarily canceling group activities and restricting family visits, to provide better protection for this vulnerable population. These factors could have contributed to a lower sleep efficiency at baseline compared with a similar study [52]. We could not control these circumstances, and thus more research in the absence of such confounding factors is necessary.

The quality of life of people with cognitive impairment is a dynamic and multidimensional concept that is vital to their overall well-being [53]. Our results revealed that both interventions significantly improved quality of life from baseline, in line with the existing literature [54-56]. Previous studies have reported that exercise improves physical and mental health-related quality of life, including psychological well-being [55,56]. Therefore, exercise training is thought to have

the potential to improve quality of life. Breathing movements change at a different rate as breathing increases during the intervention, and this is thought to reduce participants' tension and anxiety. Exercise, especially group training, can not only enhance the exercise intensity of older adults with cognitive impairment but also promote communication and encourage individuals to participate in future exercise sessions. Thus, group exercise creates a sense of enjoyment, trust, and belonging, enhancing physical and mental health [57].

According to our findings, an eight-form tai chi intervention could be used to improve physical function, sleep efficiency, and quality of life in people with mild to moderate cognitive impairment. This intervention is simple and safe, and no adverse events were reported during the study. Future research is needed to further explore the mechanism through which exercise improves cognitive impairment outcomes and to facilitate the future application of exercise programs. In addition, this intervention or similar tai chi programs should be recommended in different nursing homes in China and other countries.

8. LIMITATIONS

This study has several limitations. The relevant literature in the field of mathematical statistics indicates a substantial effect size of $f^2 = 0.36$, which may lead to inadequate statistical power; however, we ensured that the inclusion criteria for participants and test data were applied and measured by authoritative international standard scales and experts in cognitive impairment to minimize the issue of statistical power. After a review of related literature, we decided on a moderate effect size of $f^2 = 0.36$. After eliminating group differences among study participants, tai chi was revealed as a viable preventative intervention for a broad range of individuals against cognitive impairment.

All the participants were residents of one nursing home in a single city, so the results may not be generalizable to a broader population; a cluster or multi-center study could provide results that are more representative of people with cognitive impairment in other settings or regions. Unfortunately, our results and especially our baseline data were affected by COVID-19, so future studies that are not limited by COVID-19-associated restrictions are needed, along with follow-up interventions, to draw more convincing conclusions. Another major challenge is that although both exercise interventions utilized moderate-intensity exercise, we have not yet compared the true differences between tai chi and conventional exercise. Conventional exercise is specifically targeted at patients with cognitive impairment and can be conducted in two ways: exercising while standing upright and exercising while sitting in a wheelchair.

To maintain balance between the two groups and ensure their safety, we selected patients with mild cognitive impairment who could stand upright and tried to make the exercise form closer to the movement structure of tai chi as much as possible. This prevented a scenario in which the tai chi intervention was completely conducted in a standing position while the conventional exercise was performed in a seated position. Although we cannot definitively state that tai chi is a more effective intervention, the TC group in our study exhibited superior outcomes regarding their physical performance, sleep, and quality of life. Therefore, tai chi may be a potentially advantageous intervention. Therefore, we hope to conduct more rigorous and scientific research in the future to explore this topic in greater detail.

9. CONCLUSIONS

This double-blinded, three-arm RCT showed that a 12-week tai chi program and a 12-week conventional exercise program improved physical performance, sleep efficiency, and quality of

life in older adults with mild to moderate cognitive impairment. Furthermore, we observed that tai chi was more effective for the management of physical function than conventional exercise. This program is inexpensive, safe, and easy to implement in nursing homes, making it a promising adjunct therapy for older adults with cognitive impairment. Long-term follow-up studies are needed to verify the beneficial effects of tai chi on cognitive impairment outcomes.

Ethics approval and consent to participate

The Institutional Review Board of Kobe University approved this study (approval number: 940), which was registered in the University Hospital Medical Information Network (UMIN) Center (registration number: UMIN000042051). Informed written consent was obtained from all participants. Codes were used to replace names to ensure privacy. The data were locked and will be destroyed 3 years after the end of the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

Funding

Not applicable.

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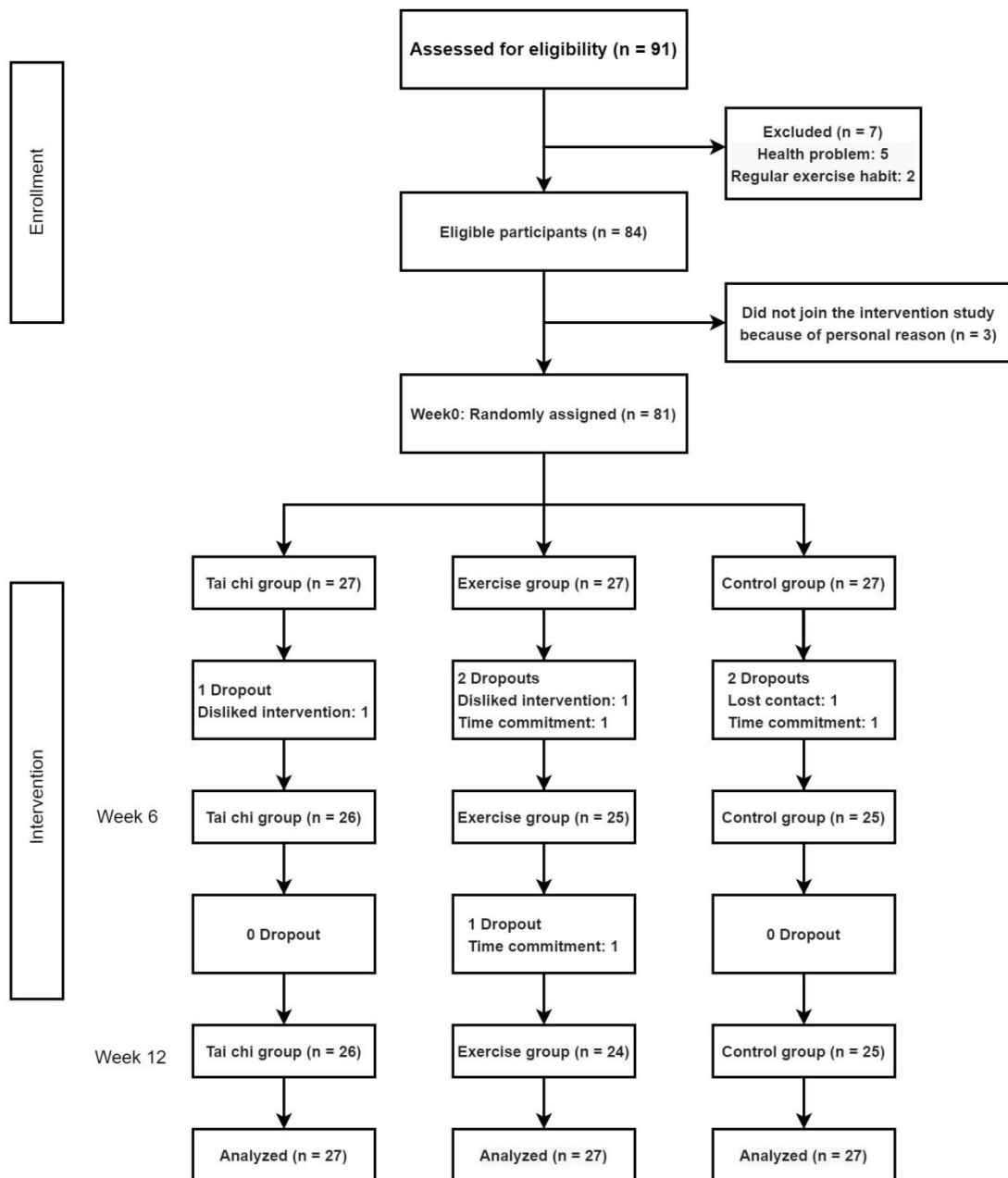


Figure 1. study follow chart

TABLE 1 Outline of Tai chi and conventional exercise intervention

Tai chi group	Warm-up (5-min)	
	1.	Gently relax ankles, wrist, waist, knee flexion and extension
	2.	By expanding the range of motion as you move around the shoulder, hip
	3.	From stretching to the main movement
	Tai chi training (40-min)	
	1.	Starting posture
	2.	Forearm rollings on both sides
	3.	Brush knee and twist step on both sides
	4.	Part the wild horse's mane on both sides
	5.	Cloud hands
	6.	Kick with heel
	7.	Grasp the bird's tail--left and right side,
	8.	Cross hands and closing form
Conventional exercise group	Cool-down (5-min)	
	1.	Gently relax ankles, wrist, waist, knee flexion and extension
	2.	By expanding the range of motion as you move around the shoulder, hip
	3.	From stretching to the main movement
	Warm-up (5-min)	
	Same as Tai chi group	
	Conventional exercise (40-min)	
	1.	Sit in a chair for 10-minute with muscle strength training (https://www.youtube.com/watch?v=h3dCIIGyj3c)
	2.	Standing exercises for 10-minute (https://youtu.be/LgYo5fOhAfw)
	3.	10 minutes radio gymnastics (https://www.youtube.com/watch?v=feSVtC1BSeQ , https://www.youtube.com/watch?v=dzQIMo-Xvyg)
	4.	Walk with music for 10 minutes
	Cool-down (5-min)	
	Same as Tai chi group	

TABLE 2 The demographic characteristics of the recruited sample at baseline

Characteristic	Total		Control Group		TC Group		EX Group		P
	(n = 81)		(n = 27)		(n = 27)		(n = 27)		
Age, mean (SD) ^a	81.0	(7.4)	80.9	(8.4)	78.6	(7.0)	83.3	(6.2)	0.064
Female, n (%) ^b	60	(74.1)	19	(70.4)	18	(66.7)	23	(85.2)	0.238
Education level, n (%) ^b									0.604
Illiteracy	15	(18.5)	2	(7.4)	6	(22.2)	7	(25.9)	
Primary school	24	(29.6)	9	(33.3)	9	(33.3)	6	(22.2)	
Junior high school	13	(16.0)	6	(22.2)	2	(7.4)	5	(18.5)	
High school	17	(21.0)	6	(22.2)	6	(22.2)	5	(18.5)	
Bachelor and above	12	(14.8)	4	(14.8)	4	(14.8)	4	(14.8)	
Marital status, n (%) ^b									0.257
Single	15	(18.5)	7	(25.9)	4	(14.8)	4	(14.8)	
Married	5	(6.2)	2	(7.4)	0	(0)	3	(11.1)	
Divorce	5	(6.2)	1	(3.7)	1	(3.7)	3	(11.1)	
Widowed	56	(69.1)	17	(63.0)	22	(81.5)	17	(63.0)	
Activity, n (%) ^b									0.530
Yes	51	(63.0)	17	(63.0)	15	(55.6)	19	(70.4)	
No	30	(37.0)	10	(37.0)	12	(44.4)	8	(29.6)	
Energy, n (%) ^b									0.627
Excellent	4	(4.9)	2	(7.4)	1	(3.7)	1	(3.7)	
Good	55	(67.9)	16	(59.3)	18	(66.7)	21	(77.8)	
Fair	19	(23.5)	7	(25.9)	7	(25.9)	5	(18.5)	
Poor	3	(3.7)	2	(7.4)	1	(3.7)	0	(0.0)	
MMSE ^a	16.8	(3.3)	17.2	(3.7)	17.2	(3.2)	16.1	(3.0)	0.393
SPPB ^a	7.8	(1.9)	7.4	(2.0)	7.9	(1.6)	7.9	(2.1)	0.593
SE, n (%) ^a	72.2	(11.9)	73.2	(11.0)	72.9	(10.9)	70.6	(13.8)	0.688
QOL-AD ^a	31.9	(4.7)	31.4	(5.0)	33.0	(5.1)	31.3	(3.8)	0.348

Note: SD, standard deviation.

^aOne-way analysis of variance (ANOVA) was used.

^bChi-square or Fisher's Exact tests were used.

MMSE=Mini-Mental State Examination, scores on the MMSE range from 0 (severe impairment) to 30 (no impairment).

SPPB=Short Physical Performance Battery, theoretical range 0-12, higher score indicates higher physical function.

SE=Sleep Efficiency, range from 0% (severe impairment) to 100% (no impairment).

QOL-AD=Quality Of Life in Alzheimer's Disease, theoretical range 13-52, higher score indicates better quality of life.

TABLE 3 Participants' short physical performance, sleep efficiency, and quality of life in Alzheimer's disease before, during and after intervention

Outcome	Control Group (n = 27)	TC Group (n = 27)	EX Group (n = 27)	P_{group}	TC Group vs. Control Group		EX Group vs. Control Group		TC Group vs. EX Group	
					Adjusted Mean	P	Adjusted Mean	P	Adjusted Mean	P
					Difference (95% CI)		Difference (95% CI)		Difference (95% CI)	
Mean SPPB (SD)				<0.001^a						
Week 0	7.4 (0.4)	7.9 (0.3)	7.9 (0.4)		0.5 (-0.8 to 1.8)	1.000 ^b	0.4 (-0.8 to 1.7)	1.000 ^b	0.0 (-1.2 to 1.3)	1.000 ^b
Week 6	7.4 (0.3)	8.4 (0.2)	8.0 (0.3)		0.7 (0.4 to 1.0)	<0.001^a	0.4 (0 to 0.7)	0.077	0.3 (-0.1 to 0.8)	0.109
Week 12	7.1 (0.3)	9.0 (0.2)	8.2 (0.3)		1.5 (1.1 to 1.9)	<0.001^a	0.8 (0.4 to 1.2)	<0.001^a	0.7 (0.3 to 1.1)	0.001^a
t	1.813	-5.525	-1.806							
P	0.083 ^c	<0.001^c	0.083 ^c							
Mean SE (%) (SD)				0.004^a						
Week 0	73.2 (2.1)	72.9 (2.1)	70.6 (2.6)		-0.3 (-8.3 to 7.7)	1.000 ^b	2.3 (-5.7 to 10.3)	1.000 ^b	-2.6 (-10.6 to 5.4)	1.000 ^b
Week 6	88.4 (1.7)	90.2% (1.0)	90.0 (0.9)		1.9 (-2.0 to 5.7)	0.343	1.8 (-2.1 to 5.6)	0.363	0.1 (-2.6 to 2.8)	0.943
Week 12	86.3 (1.7)	93.9 (0.8)	92.0 (1.3)		7.6 (4.0 to 11.3)	<0.001^a	5.8 (1.6 to 10.0)	0.007^a	1.8 (-1.0 to 4.6)	0.205
t	-4.885	-11.807	-8.242							
P	<0.001^c	<0.001^c	<0.001^c							
Mean QOL-AD (SD)				0.001^a						
Week 0	31.4 (0.9)	33.0 (1.0)	31.3 (0.7)		1.6 (-1.5 to 4.7)	0.63b	0.0 (-3.13 to 3.0)	1.000b	1.6 (-1.5 to 4.7)	0.612b
Week 6	32.5 (0.7)	33.8 (0.9)	33.5 (1.0)		0.6 (-1.5 to 2.7)	0.566	1.0 (-1.0 to 3.0)	0.319	-0.4 (-2.8 to 1.9)	0.734
Week 12	31.7 (0.9)	36.4 (0.6)	36.5 (1.0)		4.1 (2.1 to 6.1)	<0.001^a	4.9 (2.7 to 7.2)	<0.001^a	-0.8 (-3.2 to 1.6)	0.498

t	-.610	-2.854	-5.061
P	0.548 ^c	0.009^c	<0.001^c

^aGeneralized estimating equations (GEEs) (three groups).

^bmultiple comparisons was used.

^cmatched samples t-test was used.

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SUPPLEMENTART FILE

To all those who have worked with us

**Research representative: Graduate School of Health Science, Kobe University
Advanced courses in doctoral program Gao Ran**

With the approval of Kobe University Graduate School, we are currently studying exercise in older adults. The aim is to study the effects of exercise on the physical and mental health of older adults and improve these effects.

The specific method is as follows.

1. Do it three times a week (Monday, Wednesday, Friday) for 50 minutes for 12 weeks.
2. In the first, sixth and twelfth weeks (the details will be provided at the time of implementation), install a machine (such as a watch) for three days to measure the participants' activities. This will not interfere with daily life and is very safe.
3. The questionnaire takes 15 minutes and the physical function measurement takes 15 minutes, for a total of 30 minutes.

You can stop participating in this study at any time. Even if you do not participate, there is no benefit. There is no cost burden or adverse effect on the individual participant.

The researchers protected personal information and anonymized and managed the data obtained from the survey. The data was stored for five years before being discarded. The results will be submitted as a doctoral dissertation and presented at academic conferences, and will not be used for any other purposes except for research purposes.

After fully understanding the content of this study, please decide whether to participate or not. If you can participate, please sign the consent form. Thank you for your cooperation.

In addition, if you want to read the research plan or have any questions, please contact.

Professor, Department of Nursing, Graduate School of Health Science, Kobe University
Greiner Chieko
Tel. FAX: 078-796-4520

E-mail: greiner@harbor.kobe-u.ac.jp

Co-researcher (information desk)

Postgraduate course in Nursing, Graduate School of Health Science, Kobe University
Gao Ran
Tel: 090-1572-3283 (direct)

E-mail: 176k056k@stu.kobeu.ac.jp

Professor, School of Nursing, Hainan Medical University
Zhang Hua
Dean of Affiliated Nursing Home of Hainan Medical University
Gao Shuying

Questionnaires (English version):

General information questionnaire

Dear elderly friends: Hello! Please answer the following questions and fill in or tick "√" in the corresponding column. (This survey is only for research, please fill in truthfully, thank you!)

1. Your age () years old

2 Your gender

1. Male	2. Female
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3. Your educational background

1. Illiteracy	2. Elementary school	3. Secondary school
4. High school	5. College	6. Bachelor degree or above

4. Your marital status

1. Married	2. Unmarried	3. Divorced	4. Widowed
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5. Your children's situation

1. Yes _____	2. No
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6. Do you smoke

1. Never smoked	2. Occasional
3. Smoking	4. Quit smoking

7. Do you exercise regularly?

1. No	2. Yes _____ Min / week
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8. How is your sleep?

1. Not good	2. General	3. Good
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9. Do you usually take part in various social activities held by nursing homes? If so, please fill in ()

1. Participated in ()
2. Never participated

10. How do you think your health is?

1. Very good	2. Good	3. Poor	4. Very poor
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Quality of life scale

(Quality of Life in Alzheimers Disease, QoL-AD)

Quality of life: AD (senior access version)				
Name Implementation date Year Month Day				
Ask the investigator to conduct the interview according to the standard instructions: ask the participant “☑” to answer				
1. Physical health	difference	same as	good	beyond compare
2. Energy	difference	same as	good	beyond compare
3. Emotions	difference	same as	good	beyond compare
4. Living conditions	difference	same as	good	beyond compare
5. Memory	difference	same as	good	beyond compare
6. Family relationships	difference	same as	good	beyond compare
7. Marital status	difference	same as	good	beyond compare
8. Relationships with friends	difference	same as	good	beyond compare
9. Overall feelings about yourself	difference	same as	good	beyond compare
10. Ability to do housework	difference	same as	good	beyond compare
11. Ability to engage in recreational activities	difference	same as	good	beyond compare
12. Economic conditions	difference	same as	good	beyond compare
13. Overall state of life	difference	same as	good	beyond compare
count				

Questionnaires (Japanese version):

ご協力頂く皆様へ

研究代表者 神戸大学大学院保健学研究科
博士課程後期課程 高冉

私共は現在、神戸大学大学院の承認を得て、高齢者の運動に関する研究を進めております。運動が高齢者の心や身に及ぼす効果を調査し、それらを改善していくことを目的としています。

具体的な方法は以下の通りです。

1. 週3回(月、水、金曜日)、50分間、連続12週間の運動を行いたいと思います。
2. 第1、6、12週の時に(具体的な内容は実施する時にお伝え致します)、参加者へ活動を測る機械(腕時計のような物)を3日間装着します。これは日常生活に影響はなく安全性も高いです。
3. 質問紙調査に15分、体の機能の測定に15分、合計約30分かかります。

この研究への参加はいつでも自由に取りやめることができます。参加しない場合でも不利益はありません。参加者への個人の費用負担や不利益はありません。

研究者は個人情報を保護し、調査によって得られたデータは匿名化し、管理します。5年間保管した後に廃棄します。結果は博士論文として提出し、学会等で公開します、研究の目的以外には使用しません。

本研究の内容を十分に理解された上で、参加するかどうかご自身の意思でお決めください。参加を頂ける方は同意書にサインをお願い致します。ご協力をお願いします。

また、研究計画書を読みたい場合やご不明の点などがありましたら、以下までご連絡下さい。

神戸大学大学院保健学研究科 看護学領域 教授
グライナー智恵子

電話・FAX：078-796-4520

E-mail：greiner@harbor.kobe-u.ac.jp

共同研究者（相談窓口）

神戸大学大学院保健学研究科看護学領域 大学院博士課程後期課程大学院生
高冉

電話：090-1572-3283（直通）

E-mail：176k056k@stu.kobeu.ac.jp

海南医科大学 看護学院 教授
張華

海南医科大学附属施設 院長
高淑英

一般情報調査票

ご協力ありがとうございます。以下の質問について回答をお願いいたします。
以下の質問について回答をお願いします。

1. あなたの年齢は () 才

2. あなたの性別に○をつけてください。

1. 男性 2. 女性

3. あなたの学歴に○をつけてください。

1. 未就学 2. 小学 3. 中学校
4. 高校 5. 専門学校 6. 大学以上

4. あなたの婚姻状況に○をつけてください。

1. 既婚 2. 未婚 3. 離婚 4. 死別

5. あなたの子供人数に○をつけてください。

1. います _____ 人 2. いません

6. あなたはタバコを吸っていますか？

1. 吸いません 2. 現在、吸っています
3. 過去に吸っていましたが、現在は吸っていません

7. あなたは運動をしていますか、週何分ぐらいかかりますか？

1. いいえ 2. はい _____ 分／週

8. あなたは睡眠の質はどうですか？

1. 良くない 2. 普通 3. よい

9. あなたは施設で行っている様々な活動（ゲームなど）に参加していますか。参加している方は具体的な内容を（ ）にご記入ください。（いくつでも）

1. 参加している（ ） 2. 参加しない

10. あなたの現在の体調はどうですか？

1. とてもよい 2. よい 3. 悪い 4. とても悪い

認知症の QOL 尺度

(Quality of Life in Alzheimers Disease, QOL-AD)

Quality of Life : AD				
ID	実施日 年 月 日			
あなたの過去 1 ヶ月間のことについて伺います。最も当てはまるものに○をつけてください				
1. 身体的健康	よくない	まあまあよい	よい	非常によい
2. 活力・気力・元気	よくない	まあまあよい	よい	非常によい
3. 気分	よくない	まあまあよい	よい	非常によい
4. 生活環境	よくない	まあまあよい	よい	非常によい
5. 記憶	よくない	まあまあよい	よい	非常によい
6. 家族	よくない	まあまあよい	よい	非常によい
7. 結婚	よくない	まあまあよい	よい	非常によい
8. 友人	よくない	まあまあよい	よい	非常によい
9. 自分自身に関して全般	よくない	まあまあよい	よい	非常によい
10. 家事をする能力	よくない	まあまあよい	よい	非常によい
11. 何か楽しいことをする能力	よくない	まあまあよい	よい	非常によい
12. お金	よくない	まあまあよい	よい	非常によい
13. 過去から現在までの生活すべて	よくない	まあまあよい	よい	非常によい
計				

Short Physical Performance Battery

氏名 _____

測定日 _____ 年 _____ 月 _____ 日

1. バランステスト

・閉脚立位
両足を付けた状態で 10 秒保持



秒	10 秒可能	1 点	☐
	10 秒未満	0 点	☐
	実施困難	0 点	☐

・セミタンデム立位
片足の踵ともう片足の親指を付けた状態で 10 秒保持



秒	10 秒可能	1 点	☐
	10 秒未満	0 点	☐
	実施困難	0 点	☐

・タンデム立位
片足の踵ともう片足のつま先を付けた状態で 10 秒保持



秒	10 秒可能	2 点	☐
	3~9.99 秒	1 点	☐
	3 秒未満	0 点	☐
	実施困難	0 点	☐

閉脚、セミタンデムで
0 点だった場合は
「2. 歩行テスト」へ

* 歩行補助道具（杖や歩行器
など）は使用しないこと

* 手でバランスをとったり
膝を曲げてよい

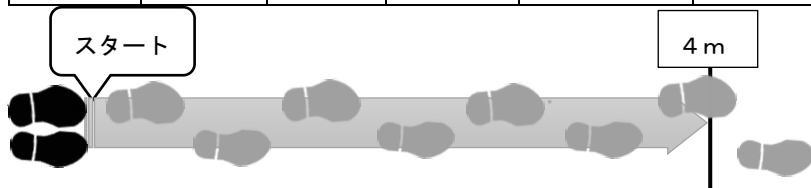
2. 歩行テスト

普通のスピードで 4 m 歩行しその時間を 2 回測定

- ・被験者はスタートラインに足をそろえる
- ・合図とともに被験者が歩き始めたら時間を測定
- ・片方の足がゴールを超えたら測定ストップ
- ・ゴールでは止まらずにラインを越えてもらう

4.82 秒未満	4 点	☐
4.82~6.20 秒	3 点	☐
6.21~8.70 秒	2 点	☐
8.70 秒以上	1 点	☐
実施困難	0 点	☐

1 回目	秒	2 回目	秒	歩行補助具 の使用	あり ・ なし ()
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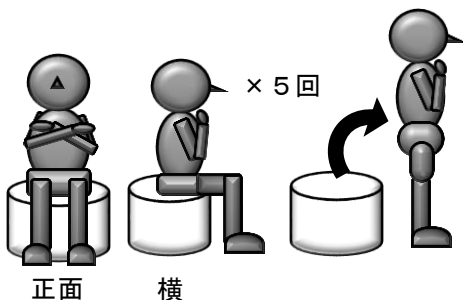
* 歩行補助道具（杖や歩行器など）使用可

3. 椅子立ち上がりテスト

プレテスト：胸の前で腕を組み、椅子から立ち上がる

本番：プレテストと同様に腕を組んだまま、素早く椅子から立ち上がる、座るを 5 回繰り返した時間を測定

11.19 秒未満	4 点	☐
11.20~13.69 秒	3 点	☐
13.7~16.69 秒	2 点	☐
16.7 秒以上	1 点	☐
60 秒以上、実施困難	0 点	☐



秒

《総合点数》	
1. バランステスト	点
2. 歩行テスト	点
3. 立ち上がりテスト	点
合計点数	点