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Original Research

Effect of seated aerobic exercise on physical endurance in long-term care recipients: secondary analysis of a cluster non-randomized controlled trial

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ABSTRACT

Background: Japan's long-term care insurance (LTCI) system provides rehabilitation services. This study examined whether adding seated aerobic exercises to daycare rehabilitation improves endurance and frailty.
Methods: We performed a secondary analysis of a cluster nonrandomized trial conducted at 10 Japanese daycare facilities. Certified older adults requiring care were enrolled in September 2023. Facilities were allocated to the aerobic program or the usual rehabilitation. The aerobic program included seated stepping and arm movements at 120 bpm for two 2-minute sets during rehabilitation for 6 months. Outcomes included the 2-minute step test, Borg scale, grip strength, Timed Up and Go (TUG) test, Barthel Index, and frailty classification using Japanese Cardiovascular Health Study criteria (J-CHS). Analyses used baseline-adjusted analysis of covariance (ANCOVA) with group, frailty category, and interaction as fixed effects. Mixed-effects models with facility as a random intercept were used for sensitivity analyses.
Results: Of 575 screened individuals, 308 were enrolled, and 252 completed the assessment (aerobic, $n = 119$; usual, $n = 133$). The aerobic group showed greater 2-minute step test performance (adjusted mean 103.883 vs. 84.494; mean difference 19.388, 95 % CI 7.350–31.426; $p = 0.002$). Borg scores were lower in the aerobic group (difference −1.093; 95 % CI −2.202 to 0.015; $p = 0.053$). Other measures showed no significant between-group differences. Frailty distribution differed at 6 months ($p = 0.036$), with reduced frailty in the aerobic group.
Conclusions: Brief seated aerobic exercise within LTCI daycare rehabilitation improved endurance and modestly improved frailty classification. These findings support aerobic exercise in LTCI rehabilitation; however, nonrandom allocation and lack of blinding limit interpretation.

1. Introduction

Japan has experienced a progressive increase in its aging population. In 2007, Japan transitioned into a super-aging society, with 21 % of its population classified as older adults. This demographic trend persisted, and by 2017, the population of older adults had increased to 27.7 %. Consequently, the number of older adults requiring nursing care increased. In 2022, approximately 35.9 million individuals in Japan were registered as primary insured beneficiaries under the long-term care insurance (LTCI) system. Japan's LTCI system provides user-oriented social insurance support and facilitates the independence of older adults with disabilities [1]. The Japanese LTCI system offers a range of rehabilitation services for older adults. These services require physician prescriptions and include rehabilitation across the acute, convalescent, and chronic phases [2]. Home-based rehabilitation is delivered by trained rehabilitation staff who visit patients' homes and typically provide 40-minute sessions twice per week. In 2019, approximately 4600 facilities provided services to 115,000 recipients [2]. Outpatient (daycare) rehabilitation integrates hospital-based rehabilitation with nursing care services, including meals and bathing. These services are typically provided 1–2 times per week for 6–7 h per session. In 2019, approximately 8000 facilities served 600,000 recipients [2].

Despite the widespread use of LTCI rehabilitation, a critical gap remains in the evidence regarding specific exercise modalities,

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particularly aerobic exercise, for frail care recipients. Current rehabilitation often emphasizes range-of-motion and gait training [3]; however, the efficacy of incorporating aerobic exercise to address frailty within the LTCI context remains unclear. This study is the secondary analysis of a cluster nonrandomized controlled trial (RCT) to assess the effectiveness of aerobic exercise within rehabilitation under the LTCI system for individuals requiring long-term care. It demonstrates improved endurance over a six-month period and supported the safety and efficacy of aerobic exercise in patients requiring long-term care. Frailty is a major public health concern. Frailty represents a vulnerable condition between successful aging and disability and requires comprehensive preventive intervention [4,5],. Rehabilitation interventions mitigate frailty in older adults by improving physical, cognitive, and social functioning. A previous meta-analysis demonstrated that community-based exercise improves lower limb strength and function [6]. Although evidence supports aerobic and multicomponent exercises for frail older adults [7, 8], few studies have examined the implementation and effectiveness of aerobic exercises within the structured context of LTCI rehabilitation for individuals requiring long-term care. This gap is significant because of the unique population characteristics and service delivery models of the LTCI system. Although an optimal program remains unclear, aerobic exercise offers benefits for cardiovascular health, cognitive function, and quality of life in older adults [9]. Furthermore, seated or chair-based exercise is clinically important because it provides a safe, structured alternative using a chair for stability, thereby minimizing the risk of falls for frail older adults with compromised balance and mobility [10,11]. Beyond safety, chair-based exercises effectively improve upper and lower limb muscle endurance, flexibility, and dynamic balance [12], and can diminish the incidence of physical frailty [13]. Practical examples include seated stepping and rhythmic arm movements, which can be easily and safely implemented within routine care settings. This provides a clear context for day-care rehabilitation, demonstrating that seated modalities offer frail individuals a feasible method to maintain cardiovascular and physical functions. This study aimed to clarify the impact of seated aerobic exercise within LTCI rehabilitation for frail individuals. We hypothesized that both groups would show improved general physical function, and that the aerobic exercise group would demonstrate greater improvements in endurance and a greater reduction in frailty levels compared with that of the usual exercise group.

2. Methods

This study employed a cluster nonrandomized controlled trial (non-RCT) design and adhered to the TREND Statement Checklist guidelines. Participants were individuals who utilized 10 functionally specialized day-service facilities for persons requiring nursing care between September 1 and September 30, 2023, and who were certified as requiring assistance or nursing care. The exclusion criteria included the inability to provide informed consent due to cognitive decline and the inability to complete the baseline evaluation. Ethical approval for this study was obtained from the Epidemiological Research Ethics Committee of the affiliated institution. The study protocol was registered in the Japan Registry of Clinical Trials (jRCT; ID: CRB5180004).

2.1. Allocation

This study used a cluster allocation design at the facility level rather than individual-level randomization. Facilities were assigned to either the aerobic exercise group or the control group before participant recruitment. Practical constraints related to implementing a standardized intervention across multiple existing facilities necessitated manual cluster allocation by an independent administrator. This allocation aimed to achieve an equitable distribution of facilities by considering factors such as facility size and participant demographics to mitigate potential imbalances; however, true randomization at this level was not logistically feasible. Although this allocation method mitigated the potential investigator bias, it did not constitute true randomization. The principal investigator, physical function assessor, and data analyst were not involved in the allocation process. Facility assignment information was withheld until the completion of the baseline assessment to minimize bias.

2.2. Blinding

Given the nature of the intervention, it was not feasible to blind the participants and rehabilitation providers. Additionally, the physical function assessor and data analyst were not blinded to group allocation, which may have introduced a detection or analysis bias. Standardized protocols were employed during assessments, and analyses were conducted using prespecified models to mitigate this risk.

2.3. Intervention

The aerobic exercises consisted of stepping and hand-waving movements. This exercise was conducted in a seated position, with the feet and hands alternately elevated and lowered at a tempo of 120 bpm for two 2-minute sets. This form of aerobic exercise can achieve 70 % of peak oxygen uptake (VO_2peak) during cardiopulmonary exercise testing (CPX) using a bicycle ergometer [14] and can be safely performed by individuals requiring care or frail patients, making it a feasible intervention for day-care rehabilitation. Furthermore, this specific high-intensity, short-duration protocol was selected because low-volume protocols incorporating short sprint-type intervals—such as 2-minute work bouts—can result in significant cardiorespiratory improvements and physiological adaptations in older adults [15]. Participants were divided into two groups: one group participated in a 6-month day-care rehabilitation program that incorporated aerobic exercise (aerobic exercise group), whereas the other group engaged in regular day-care rehabilitation without aerobic exercise (usual exercise group). The standard day-care rehabilitation program for both groups included a 30 minute vital check, a 45-minute warm-up, and 30 min of range of motion (ROM) exercises. Subsequently, the aerobic exercise group participated in a 15-minute seated aerobic exercise followed by a 15-minute rest, whereas the usual exercise group directly took a 15-minute rest. Afterward, both groups completed 15 min of balance exercises (e.g., square steps), 15 min of muscle strength exercises, exercises using a whole-body vibration machine, and stretching.

2.4. Outcome measurement

While the registered primary outcome of the original trial was the Barthel Index, which showed no significant change and is unpublished, this study was explicitly designed as a secondary analysis focusing on the 2-minute step test to evaluate the physiological impact of aerobic exercise on endurance. Results of the Barthel Index and other comprehensive functional measures were reported as secondary outcomes.

During the 2-minute step test, participants alternately elevated their legs to a height midway between the iliac crest and the patella for 2-minutes, and the number of times the right knee reached the specified height was recorded. The test was terminated if the participant experienced pain or difficulty that precluded continuation. The 2-minute step test correlated with the 6-minute walking distance and maximal oxygen uptake [16], and high inter-examiner and test-retest reliability have been established [17]. Other outcome measures included the Borg Scale (breathlessness), grip strength, the Timed Up and Go (TUG) test, the Barthel Index, the Mini-Cog, and frailty classification based on the Japanese version of the Cardiovascular Health Study criteria [18], which encompasses five components: weight loss, weakness, exhaustion, slowness, and low physical activity. Participants who met three or more of these criteria were categorized as "frail," those who met one or two criteria were classified as "pre-frail," and those who met were considered "robust."

2.5. Statistical analysis

All statistical analyses were performed using SPSS software version 29.0 (IBM Corp., Armonk, NY, USA), and statistical significance was set at $p < 0.05$. A per-protocol analysis using analysis of covariance (ANCOVA) was performed to compare the 6-month outcomes between the intervention groups, adjusting for the corresponding baseline values. The intervention group and frailty classification, along with their interaction term, were included as fixed factors. When appropriate, pairwise comparisons were conducted using estimated marginal means with Bonferroni adjustments. For the sensitivity analysis, we fitted linear mixed-effects models with a random intercept to account for clustering. An intention-to-treat (ITT) analysis was conducted for physical function at the final follow-up. Missing data, including dropouts, were handled using multiple imputations with the SPSS Missing Values procedure (IBM Corp., Armonk, NY, USA). A paired *t*-test was used to compare the frailty status, measured by the Japanese version of the Cardiovascular Health Study (J-CHS) score, before and after the intervention.

3. Results

Fig. 1 shows the study flow diagram. A total of 575 individuals were initially recruited, and 308 were enrolled after application of the exclusion criteria. The participants were allocated to either the Aerobic Exercise group or the Usual Exercise group at the facility level (Supplemental Table 1). Of the 252 participants who completed the 6-month assessment, 119 were in the Aerobic Exercise group and 133 in the Usual Exercise group. Table 1 presents participants' baseline characteristics and outcome measures. At baseline, the majority of the cohort was classified as frail. In the Aerobic Exercise group, 93 participants (78.2 %) were frail, 23 (19.3 %) were pre-frail, and 3 (2.5 %) were robust. In the Usual Exercise group, 109 participants (82.0 %) were frail, 24 (18.0 %) were pre-frail, and none were robust. While session-by-session attendance logs were not available, overall adherence to the 6-month program was evaluated based on the completion rate. In the Aerobic exercise group, 119 out of 146 participants (81.5 %) completed the 6-month intervention and final evaluations. The specific reasons for dropout, including discontinued participation, are detailed in Fig. 1.

Outcomes at six months were compared between the groups using ANCOVA, with baseline values as covariates and intervention type (aerobic vs. usual), frailty category, and their interactions as fixed factors. After adjustment, the aerobic group exhibited superior performance on the 2-minute step test compared with the usual group (adjusted mean, 103.883 vs. 84.494; adjusted mean difference 19.388 steps, 95 % CI 7.350–31.426; $p = 0.002$; intervention main effect: $F = 33.641$, $p < 0.001$, partial η^2=0.122; Table 2). For perceived exertion (Borg scale), the aerobic group tended to report lower scores than the usual group (13.295 vs. 14.388; difference −1.093, 95 % CI −2.202 to

Table 1
Characteristics and physical functions of participants included in the per-protocol analysis.

	Aerobic Ex (*n* = 119)	Usual Ex (*n* = 133)	p value
Sex, n (%)			
Men	27 (22.7 %)	33 (24.8 %)	0.403
Women	92 (77.3 %)	100 (75.2 %)	
Age (year)s	82.4 ± 7.3	83.5 ± 5.9	0.213
Height (cm)	152.0 ± 9.0	152.6 ± 8.2	0.590
Weight (kg)	55.7 ± 13.0	54.1 ± 12.0	0.331
Certification of needed long-term care, n (%)			
Support level	64 (53.8 %)	58 (43.6 %)	0.137
Care level	55 (46.2 %)	75 (56.4 %)	
Multimorbidity (≧2 conditions), n (%)	53 (44.5 %)	38 (28.6 %)	0.012
Frailty status (J-CHS), n (%)			
Frail	93 (78.2 %)	109 (82.0 %)	0.172
Pre-frail	23 (19.3 %)	24 (18.0 %)	
Robust	3 (2.5 %)	3 (2.5 %)	
J-CHS (point)	2.06 ± 0.78	1.88 ± 0.48	0.028
2-minute step test (Times)	75.5 ± 30.3	87.4 ± 25.3	< 0.001
2-minute step test (Borg scale)	14.2 ± 2.4	13.7 ± 2.3	0.068
Grip strength (kgf)	16.6 ± 5.4	16.7 ± 5.6	0.902
TUG (s)	16.8 ± 8.0	14.0 ± 4.7	< 0.001
Barthel Index (point)	93.2 ± 8.8	97.4 ± 5.7	< 0.001
Mini-cog (point)	3.3 ± 1.6	3.4 ± 1.6	0.656

J-CHS; Japanese version of the Cardiovascular Health Study criteria, TUG, Timed Up and Go test.

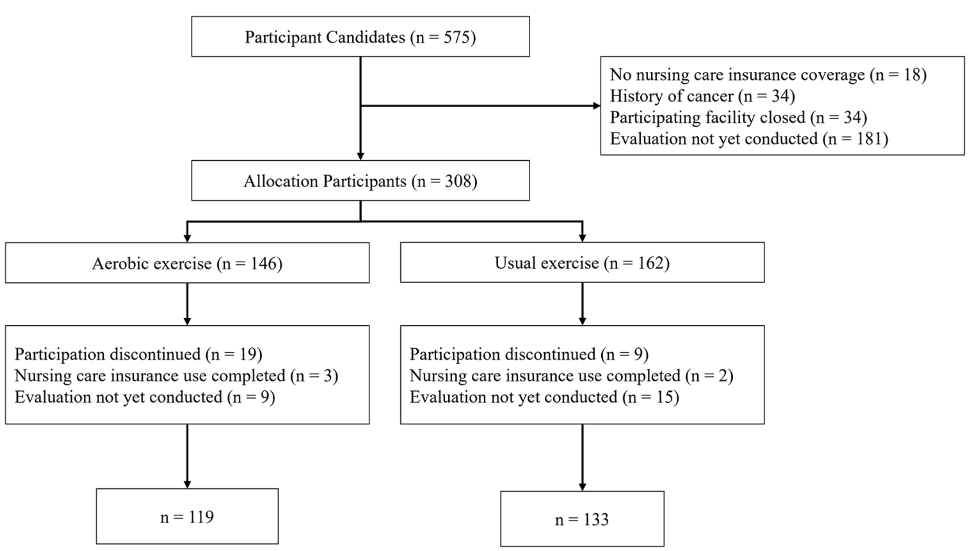

Fig. 1. Flowchart of study participants.
The diagram illustrates the recruitment, allocation, and follow-up processes in the study. Initially, 575 participant candidates were screened. After excluding 267 individuals based on specific criteria (no nursing care insurance coverage, $n = 18$; history of cancer, $n = 34$; participating facility closed, $n = 34$; and evaluation not yet conducted, $n = 181$), 308 participants were allocated to either the Aerobic exercise group ($n = 146$) or the Usual exercise group ($n = 162$). Following the 6-month intervention and excluding those who discontinued or had incomplete evaluations, 119 participants in the Aerobic exercise group and 133 in the Usual exercise group were included in the final analysis.

Table 2
Baseline-adjusted ANCOVA at 6 months of the participants included in the per-protocol analysis.

Outcome	Adjusted mean (Aerobic)	Adjusted mean (Usual)	Difference (A–U)	95 % CI	p value (group)	Partial η^2 (group)	Adj. R^2
2-minute step test (steps)	103.883	84.494	19.388	7.350 to 31.426	0.002	0.122	0.472
2-minute step test (Borg scale)	13.295	14.388	−1.093	−2.202 to 0.015	0.053	0.028	0.087
Grip strength (kg)	16.777	16.439	0.338	−1.083 to 1.758	0.640	0.003	0.786
TUG (s)	13.142	15.029	−1.887	−4.274 to 0.500	0.121	<0.001	0.556
Barthel Index (Point)	96.439	95.864	0.575	−2.030 to 3.180	0.664	<0.001	0.614

Adjusted means were the estimated marginal means at the mean baseline value for each outcome. Models were adjusted for baseline values of the corresponding outcomes.
Adj. R^2, adjusted R-squared; ANCOVA, analysis of covariance; Borg, Borg Rating of Perceived Exertion (RPE); CI, confidence interval; TUG, Timed Up and Go test.

0.015; $p = 0.053$ for the adjusted mean difference), whereas the overall intervention main effect was significant (F = 7.006, $p = 0.009$, partial η^2=0.028, Table 2). No significant group differences were observed in grip strength, TUG test results, or Barthel index ($p = 0.640$, $p = 0.121$, and $p = 0.664$, respectively; Table 2). Intervention-by-frailty interactions were not significant for any outcome (Table 2). Mixed-effects models with facilities as a random intercept yielded estimates in the same direction as the ANCOVA results (Supplemental Table 2). In the ITT analysis, the 2-minute step test remained significant; however, no differences were observed in secondary outcomes, including the Barthel Index (Table 3).

At baseline, significant differences in frailty classification were observed between the aerobic and usual exercise groups (Table 1 and Fig. 2; $p < 0.001$). After six months, the Aerobic Exercise group demonstrated a significant reduction in J-CHS scores compared with baseline (2.06 ± 0.78 to 1.81 ± 0.73, Fig. 2; $p = 0.001$), whereas the Usual Exercise group showed no significant change (1.88 ± 0.48 to 1.81 ± 0.43, Fig. 2; $p = 0.140$).

4. Discussion

This study was a sub-analysis of a nonrandomized controlled trial that evaluated the impact of aerobic exercise in day rehabilitation programs utilizing nursing care insurance, specifically examining its effects on frailty status irrespective of endurance and exhaustion. This study provides additional evidence regarding the effects of aerobic exercise as a specific intervention in rehabilitation programs for pre-frail and frail older adults within the LTCI system. The efficacy of exercise in addressing frailty is well documented, with multicomponent exercise regimens encompassing resistance, aerobic, balance, and flexibility training have been shown to enhance physical function among frail older adults [19]. Additionally, aerobic exercise training alone has been shown to improve cardiovascular fitness and certain physiological parameters in older adults [20]. The physiological benefits of short-duration, high-intensity intervals are well documented. Recent systematic reviews indicate that low-volume high-intensity interval training significantly stimulates the secretion of exerkines, such as brain-derived neurotrophic factor and vascular endothelial growth factor, which induce profound physiological and cardiovascular adaptations even among aging and diseased populations [21]. Conversely, aerobic exercise performed in isolation does not significantly enhance muscle function or mitigate frailty. However, exercise programs targeting muscle function can increase functional capacity and reduce fall risk [22]. This study shows that low-volume, high-intensity seated aerobic exercise added to a multicomponent exercise regimen increased functional aerobic endurance and cardiovascular fitness in older adults with frailty. Multicomponent exercise is generally advocated as it leads to greater improvements in physical function than walking-only interventions among long-term nursing home residents [23]. Similar studies have demonstrated that combining aerobic exercise with resistance or strength training, or with multicomponent training, yields greater improvements in physical performance among older adults than aerobic exercise alone [24]. However, these comparator studies primarily examined general, weight-bearing aerobic interventions, such as walking. In contrast, our study specifically highlights the benefits of seated aerobic exercise. Clarifying this distinction reinforces our key finding: seated aerobic programs provide a safe and effective cardiovascular stimulus, improving endurance even for frail older adults whose fall risks restrict upright activities [25]. This study provides scientific evidence for the efficacy of aerobic exercise in frail individuals requiring nursing care, a population characterized by pronounced physical and environmental frailty. There is a paucity of scientific evidence regarding the effectiveness of specific training within the LTCI framework [3]. In Japan, where population aging is significant, efforts are underway to codify a specific training approach similar to the ICD model [26]. Within this societal context, our findings provide scientific evidence to inform the development of codified evidence-based training protocols, similar to the ICD model, for individuals with pronounced physical and environmental frailty.

The findings indicate that aerobic exercise was particularly effective in improving the endurance and subjective exhaustion components of frailty. Moreover, some participants transitioned from frailty to pre-frail or robust status following aerobic exercise. Numerous studies have demonstrated the efficacy of exercise therapy in addressing frailty, with aerobic exercise combined with resistance training shown to reduce frailty by increasing muscle strength and endurance [27]. Additionally, frailty was correlated with diminished aerobic fitness and physical activity levels, suggesting that aerobic exercise may mitigate frailty [28]. Furthermore, evidence indicates that multicomponent exercises can improve frailty among long-term nursing home residents [29]. Although various exercise therapies have been shown to improve frailty, few studies have directly compared the independent effects of aerobic exercise. This study provided scientific evidence that aerobic exercise reduces frailty in individuals requiring care, resulting in frailty levels comparable to those of healthy individuals.

The primary limitation of this study is the disparity in baseline physical function between the groups before the intervention, which raises the possibility that the observed improvements may partially reflect baseline imbalances and regression to the mean rather than solely the intervention effect. Baseline-adjusted analyses were conducted using ANCOVA to reduce the impact of baseline imbalances. Notably, the between-group difference in the 2-minute step test remained statistically significant after adjustment, indicating an intervention effect beyond the observed baseline differences. Furthermore, even for outcomes that

Table 3
Intention to treat analysis.

Outcome Measures	Difference (B)	95 % CI	p value
2-minute step test (steps)	19.94	[3.00 to 36.89]	0.021
2-minute step test (Borg scale)	−1.41	[−2.96 to 0.15]	0.076
Grip strength (kg)	−0.48	[−2.90 to 1.95]	0.701
TUG (s)	1.57	[−2.31 to 5.45]	0.421
Barthel Index (Point)	0.40	[−4.54 to 5.33]	0.874

CI, confidence interval; TUG, Timed Up and Go test.

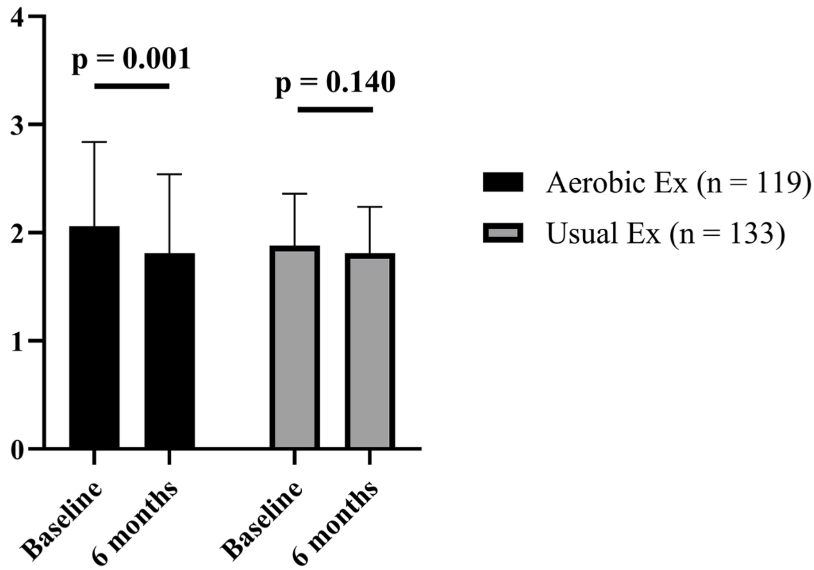

Fig. 2. Comparison of J-CHS scores between baseline and the 6-month follow-up.
Changes in the Japanese version of the Cardiovascular Health Study (J-CHS) scores are shown for the Aerobic exercise group ($n = 119$) and the Usual exercise group ($n = 133$). Data are presented as mean ± standard deviation. The Aerobic exercise group demonstrated a significant reduction in J-CHS points from baseline to 6 months ($p = 0.001$), indicating improved frailty status. In contrast, no significant change was observed in the Usual exercise group ($p = 0.140$).

demonstrated significant differences, the effect sizes for some secondary outcomes, such as grip strength (partial $\eta^2 = 0.001$) and TUG (partial $\eta^2 = 0.010$), were small and not statistically significant, raising questions regarding the clinical significance of the measures. However, in a comparable study involving older adults who engaged in aerobic exercise, the mean number of steps completed in the 2-minute step test was 62.47 [30], suggesting that intervention characteristics (e.g., intensity, supervision, and adherence) may significantly influence achievable gains. The mode of aerobic exercise, whether performed individually or in combination, may be critical. In rehabilitation treatment, greater effectiveness is often observed when treatment is administered by an experienced therapist [31–33]. This factor may explain the modest effect observed in this study, which relied on a group-based program with potentially variable delivery across sessions and locations. Additionally, selection bias resulted in a comparatively smaller number of frail participants in the Usual Exercise group, which could potentially impact the generalizability of findings regarding frailty improvement across groups despite the use of ITT. This imbalance is likely attributable to the cluster RCT design; different results might have been observed if participants had been individually randomized. Although this limitation is inherent to cluster randomized controlled trials, the results of the ITT analysis demonstrated the effectiveness of aerobic exercise in frail individuals. Therefore, this limitation does not negate the overall findings of this study. Furthermore, this study involved a six-month mid-term intervention, and no long-term effects were observed. Further research is needed to determine whether the effects of aerobic exercise on frailty improvement persist for an extended period.

5. Conclusion

In summary, this study demonstrates that aerobic exercise is an effective intervention in an outpatient rehabilitation setting under nursing care insurance. Regardless of the type of insurance provided, substantial uncertainty remains on the actual content of rehabilitation interventions; evidence-based rehabilitation has not yet been consistently implemented [3,34]. This study is clinically significant because it partially addresses this gap in knowledge.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Makoto Asaeda reports financial support was provided by Government of Japan Ministry of Health Labour and Welfare. Ken Kouda reports financial support was provided by Government of Japan Ministry of Health Labour and Welfare. Yukio Mikami reports **financial support** was provided by Government of Japan Ministry of Health Labour and Welfare. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

Declaration of the use of generative AI and AI-assisted technologies in scientific writing and in figures, images and artwork

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript, nor in the creation of any figures, images, or artwork.

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Ethics

The study was approved by the Ethics Committee of Wakayama Medical University (Approval No. 3446) and the institutional review boards of all participating institutions. The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their enrollment in the study.

CRediT authorship contribution statement

Makoto Asaeda: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Kiyo Ueda:** Conceptualization, Methodology, Supervision. **Takeya Araki:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Supervision, Project administration. **Noriaki Maeda:** Writing – review & editing, Visualization. **Yuki Nakashima:** Methodology, Data curation, Supervision. **Kouki Fukuhara:** Methodology, Data curation, Supervision. **Ken Kouda:** Conceptualization, Methodology, Supervision, Project administration, Funding acquisition. **Yukio Mikami:** Conceptualization, Methodology, Supervision, Project administration, Funding acquisition.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjfa.2026.100184.

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