


Mobile application for home exercise adherence in patients with knee osteoarthritis

A pilot study

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Abstract

Background: The adherence to home exercise is generally low despite its well-known effect on knee osteoarthritis. Therefore, we developed a home exercise application, LongLifeSupport, to provide patients with daily basic exercise videos and an automatic recording calendar. We hypothesized that this application would encourage patients to exercise and help maintain their motivation; this pilot study aimed to determine their exercise adherence rates. Using outcome measures, we also aimed to determine the effect of home exercise using this application and the factors for its continuation.

Methods: Twenty patients with knee osteoarthritis were included. The participants exercised for 12 weeks. Using pre- and post-tests, we examined their satisfaction with continuation (only in the post-test), Japanese knee osteoarthritis measure score, short physical performance battery score, bilateral knee extension muscle strength, and short test battery for locomotive syndrome. Furthermore, we investigated correlations between adherence rates and pretest scores of Japanese knee osteoarthritis measure and short test battery and between pretest scores and variations in Japanese knee osteoarthritis measure and short test battery.

Results: The mean adherence rate was 82.4%. The participants showed ease of continuation (100%) and significant improvements in the degree of knee pain, pain, and stiffness, and daily life conditions using the Japanese knee osteoarthritis measure score, total score, walk seconds, and chair stand seconds of the short physical performance battery, as well as the extension muscle strength of the right- and pain-side knee. No significant correlations were identified between the adherence rate and the pretest or variation.

Conclusion: The adherence rate to the application was over 80%. Participants with knee osteoarthritis showed almost full satisfaction, reduced pain, and improved physical ability. Therefore, the use of this application provided a safe exercise program and maintained the exercise motivation of participants. Thus, it may be useful for unsupervised home exercise.

Abbreviations: JKOM = Japanese knee osteoarthritis measure, KOA = knee osteoarthritis, SPPB = short physical performance battery.

Keywords: application; home exercise; knee osteoarthritis

1. Introduction

Knee osteoarthritis (KOA) is a common condition in older adults. Its prevalence has doubled since the mid-20th century.^[1] In the United States, KOA accounts for more than \$27 billion of the annual healthcare costs.^[2] Therefore, KOA is a major socioeconomic parameter. Knee pain is highly prevalent among elderly adults and is related to locomotive syndrome (LS).^[3]

Exercise therapy is a major recommendation for patients with KOA.^[4,5] All types of exercise, such as aerobic, mind-body,

strength, flex/skills, and mixed, significantly improved pain, function, performance, and quality of life, as indicated by meta-analysis.^[6] In another meta-analysis, supervised and unsupervised home exercise programs for KOA significantly improved pain and functionality.^[7] However, during the recent COVID-19 pandemic, people have refrained from medical consultation and physical activity.^[8] In this case, home exercise has been important. In contrast, 38% of patients with KOA demonstrated non-adherence in a home exercise study.^[9] The same study showed that low income affected adherence to exercise.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

This study was approved by the Teikyo University Ethical Review Board for Medical and Health Research Involving Human Subjects (No. 19-282). We obtained informed consent from each participant. All methods were carried out in accordance with relevant guidelines and regulations.

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Reve et al showed that a tablet training program improved gait and physical performance in older people with high adherence rates.^[10] Therefore, we believe that watching an exercise video on a phone or a tablet can help improve physical performance and adherence rate.

Hence, we developed an unsupervised home exercise application with exercise videos and an automatic recording calendar post-exercise (LongLifeSupport). The main objective of this pilot study was to assess exercise adherence rates in patients with KOA. The secondary objective was to determine the effect of home exercise using this application and the factors for its continuation using outcome measures.

2. Materials and Methods

2.1. Study design

This was a small-scale, open-label, single-arm pilot study. The study was conducted in 2021. This study was approved by Teikyo University Institutional Review Board (Case No. 19-282) and registered in the WHO Registry Network jRCT (Case No. 1030210102).

2.2. Participants

Participants aged ≥ 50 years were recruited from the outpatient clinic of the orthopedic department of Teikyo University Chiba Medical Center. An orthopedic surgeon explained the study objectives to each participant and obtained informed consent from each participant. The patients had KOA and did not exercise regularly. Those on analgesic medications were instructed to continue taking them during the test period and not to change them throughout the study period. The exclusion criteria were the following: inability to walk on both legs unaided, the presence of mental disorders, including severe dementia but excluding depression, HbA1c level of $>10\%$ in patients with diabetes mellitus, and the presence of proliferative retinopathy, heart failure, or coronary artery disease. Before study initiation, a standing position Kellgren–Lawrence radiographic grade (KL) of the pain side of each participant, which was evaluated by 2 orthopedic surgeons, was obtained.^[11] If a participant had pain on both sides, the pain side was considered as the most painful. For beginner participants who were not experienced with using smartphones or tablets, we lent tablets with the application installed for a trial period of 1 or 2 weeks. Participants performed the exercises using the application for 12 weeks (84 days). Beginners performed for the same period after the trial weeks. Before and after the test period (pre- and post-test), self-reported questionnaires were administered except for the satisfaction survey, and physical tests were performed in the outpatient clinic and rehabilitation room. The physical tests were performed by the same physical therapists before and after the exercise test. Each participant visited the outpatient clinic once a month and was assessed for body condition and exercise adherence.

2.3. Mobile application and exercise

LongLifeSupport is a tablet and smartphone software that facilitates unsupervised home exercises. The application has 2 displays: the upper display shows the exercise video, and the lower displays the participant's own body using the built-in camera of the mobile device. The home screen consisted of a monthly calendar. After the exercise, a special ideogrammatic icon appeared automatically on the exercise day of the calendar (Fig. 1). The application contained seven exercise videos, each lasting 10 to 12 minute, and involved stretching, self-weight training with no exercise equipment (i.e., no balance ball, no rubber band), and multicomponent exercises.^[12] The

estimated exercise intensity corresponded to four metabolic equivalents (METs). Each video was named after the day of the week. The participants were instructed to perform the exercises daily while watching one video. Up to 3 exercises could be performed daily, depending on the participant's engagement.

2.4. Outcome measures

The main outcome measures were the adherence rates (the total number of exercise days/ $84 \times 100\%$) and the number of special ideogrammatic icons on the home screen calendar. The secondary outcomes were the satisfaction survey for continuation, Japanese knee osteoarthritis measure (JKOM) score,^[13] short physical performance battery (SPPB) score,^[14] knee extension muscle strength (Nm/kg) using a hand-held dynamometer,^[15] and short test battery (STB) for LS.^[16] The satisfaction survey for continuation in the post-test was an original questionnaire consisting of the following two questions: "How easy was continuing to exercise daily with the application?" with five possible answers: very easy, easy, neutral, moderately difficult, and difficult and "How do you feel about the duration of the exercise?" with, again, 5 possible answers: best, moderately long, long, moderately short, and short. The participants were allowed to choose only 1 answer per question. The JKOM score is a patient-reported quality of life outcome measure used to evaluate several aspects of the KOA-specific Japanese lifestyle. It includes the degree of knee pain (visual analog scale [VAS]) and 25 items in four categories: pain and stiffness in the knee, condition in daily life, general activities, and health conditions. Each question bore a score from 0 to 4, and the maximum total JKOM score was 100. The best total score was 0.^[17] The SPPB is a physical performance test to assess lower extremity function and mobility. It consists of a balance test, the time (in seconds) required to walk 4 m, and the time (in seconds) required to stand up from a chair five times (termed "the chair stand-up"). Each component bore a score of 0 to 4. The total score corresponds to the sum of all scores. The STB for LS consists of physical tests (stand-up test and 2-step test) and the 25-questions Geriatric Locomotive Function Scale (GLFS-25). Each test has 4 stages depending on each value, namely from stage 0 to stage 3.^[18] The stand-up test score ranged from 0 to 8. The 2-step test value is defined as the length of 2 steps divided by the participant's height.^[19] The GLFS-25 is a self-reported measure that includes pain, disabilities in daily life activities, social functions, and mental health status during the last month (25 items). The GLFS-25 score ranged from 0 to 100. The participants' demographics and mean computer proficiency questionnaire (CPQ) scores are shown in Table 1.^[20] The CPQ score measures the computer proficiency in basic computer usage, printing, communication, use of the internet, calendaring software, and multimedia use. A low CPQ score (approximately 10) indicates low computer proficiency.

2.5. Statistical analysis

Sample size was determined as 20, as referred by Reve's study.^[10] The values of outcome measures between pre- and post-exercise test periods and the adherence rates between men and women were analyzed using the Wilcoxon signed-rank test. The adherence rate was also compared between different KL grades using the Kruskal–Wallis test. To clarify factors associated with adherence rate and values such as pretest and variation, correlations between adherence rate and the scores of each JKOM and STB category, as well as between pretest and variation of each JKOM and STB category, were assessed using the Spearman rank correlation coefficient. Statistical significance was set to $P < .05$ for all statistical tests.

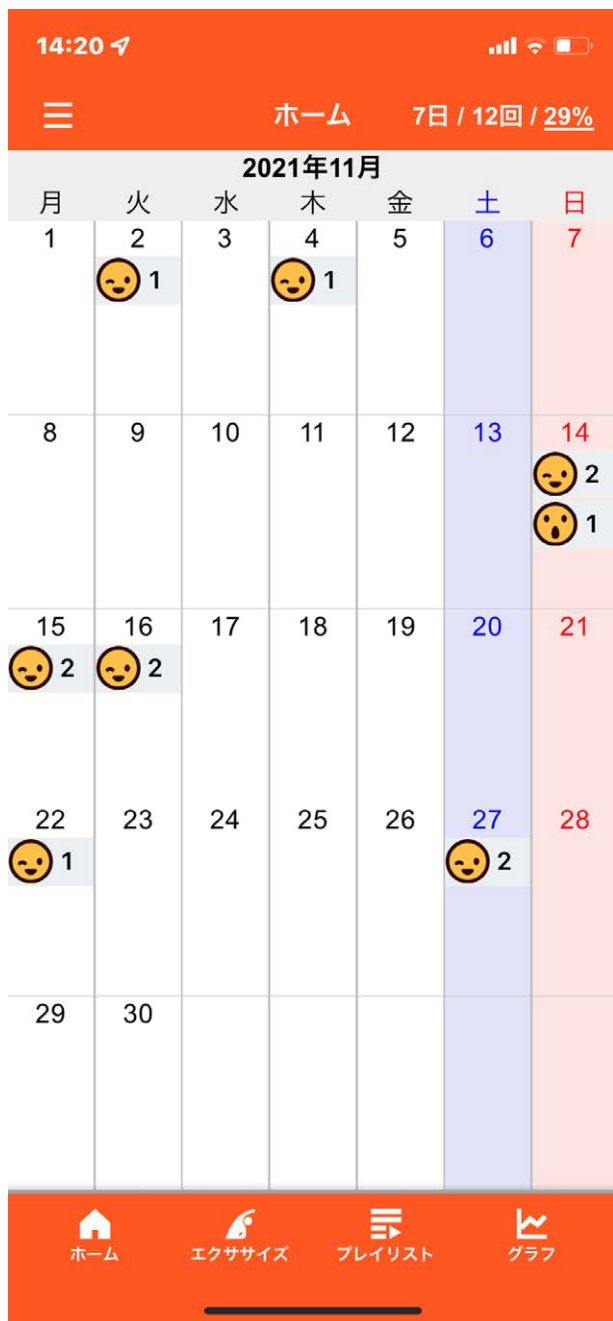


Figure 1. Special ideogrammatic icon placed on the home screen calendar.

3. Results

No participant was injured during the exercise. All 20 participants completed the outcome measurements except for STB. Only 16 participants completed the STB. Exercise adherence rates are shown in Table 1. The remaining outcomes are presented in Tables 2 and 3. The satisfaction survey for continuation yielded for the following scores, for question 1: 30% (n = 6) in very easy, 70% (n = 14) in easy, as well as 0% (n = 0) in neutral, moderately difficult, and difficult. For question 2, the identified scores were: 80% (n = 16) in best, 10% (n = 2) in moderately long and moderately short, and 0% (n = 0) in long and short. There were no significant differences in adherence rates between men and women ($P = .080$) and KL grades ($P = .478$). Significant differences between pretest and post-test were observed in VAS, total score, pain, and stiffness in the knee, and condition in daily life categories of the JKOM; total score, walk seconds, and chair

Table 1

Participants' demographics, adherence rate, computer proficiency questionnaire score and Kellgren–Lawrence grade.

Participants' characteristics	Number of participants	Adherence rate (SD)
Participant demographics		
Number of participants	20	82.4 (15.3)
Male	6	71.6 (10.4)
Female	14	87.0 (14.8)
Mean age (SD, range)	66.5 (11.0, 51–84)	
Mean computer proficiency questionnaire score (SD, range)		14.6 (5.8, 6–20.4)
Kellgren–Lawrence grade		
0–I	0	0
II	7	82.1 (12.5)
III	9	84.7 (19.8)
IV	4	77.6 (7.9)

SD = standard deviation.

stand seconds of the SPPB; and extension muscle strength of the right- and pain-side knee. No significant correlations were observed between adherence rate and values such as pretest and variation.

4. Discussion

LongLifeSupport is a new application designed by orthopedic surgeons. We showed a high adherence rate to and satisfaction from home exercises in patients with KOA. The JKOM scores, SPPB scores, and knee extension muscle strength improved in the post-test. Furthermore, significant correlations were unraveled between the adherence rate and pretest values of the JKOM and STB for LS.

This study showed high adherence rates (82.4%) to unsupervised exercises performed using the application and no correlation between adherence rate and pretest values. According to these results, this application and exercise are suitable for severe knee pain or low physical function. In a previous study, the adherence rate of home-based exercise, for which the therapist visited twice a week, in patients with KOA was 84%.^[21] In contrast, another study reported that the participants' adherence rate, defined as the percentage of high self-rating of knee or hip osteoarthritis, to unsupervised home exercise of usual care was 44% at 13 weeks.^[22] Accordingly, visits by therapists influenced the adherence rates to unsupervised home exercise. However, not every patient with KOA is entitled to therapist visits for home exercise. In this study, participants without visits for supervised home exercises were offered the support of a tablet to maintain a high adherence rate. Reve et al showed that the adherence rate of older adults using a tablet for home exercise was higher (80%) than when using brochures as exercise guides (59%). Moreover, older individuals exhibited low efficiency of exercise and neutral adherence. One way to strengthen self-efficacy is to set an easy and simple goal.^[23] In our study, almost all participants reported our application and exercise guide to be easy and of the best duration. Although further studies are needed to verify our findings, we believe that our tablet exercise support will strongly contribute to increasing patients' motivation to exercise.

In this study, 50% of the participants had not used smartphones or tablets, and 40% of them were aged >70 years. Moreover, the CPQ scores were lower than young average scores.^[20] However, the satisfaction survey showed that all the participants had the impression that operating our application was easy. According to the Consumer Confidence Survey in Japan in March 2022, the penetrance ratio of smartphones in

Table 2**Results of JKOM score, SPPB score, knee extension muscle strength, and STB stage and score for LS.**

Outcome measure [mean (SD)]	Pretest	Post-test	P value
JKOM			
Degree of knee pain (VAS)	58.0 (27.3)	41.7 (30.3)	.01*
Total score	48.1 (21.1)	36.2 (20.6)	.01*
Pain and stiffness in knees	15.4 (8.2)	10.7 (6.7)	<.001*
Daily life condition	17.4 (8.9)	13.4 (7.3)	.02*
General activities	10.6 (5.9)	8.0 (5.7)	.09
Health conditions	4.6 (1.7)	4.0 (2.0)	.09
SPPB			
Total score	9.8 (2.1)	10.4 (1.9)	.03*
Balance score	3.6 (0.5)	3.6 (0.5)	>.99
Walk score	3.4 (0.9)	3.6 (0.6)	.17
Chair stand score	2.8 (1.2)	3.1 (1.2)	.19
Walk (s)	5.1 (2.1)	4.3 (1.4)	.01*
Chair stand (s)	13.2 (6.0)	11.7 (4.8)	.01*
Knee extension muscle strength (Nm/kg)			
Right	0.82 (0.41)	0.93 (0.39)	.01*
Left	0.85 (0.42)	0.91 (0.31)	.33
Pain side	0.74 (0.35)	0.88 (0.34)	.01*
STB for LS			
Stand-up test stage	2.1 (0.8)	1.8 (0.8)	.17
Two-step test stage	2.1 (1.0)	2.0 (1.0)	.76
GLFS-25 stage	2.5 (0.8)	2.3 (0.9)	.21
Stand-up test score	2.0 (1.0)	2.3 (1.4)	.17
Two-step test (value)	0.89 (0.25)	0.95 (0.25)	.21
GLFS-25 (value)	35.5 (16.3)	31.1 (18.0)	.06

JKOM = Japanese Knee Osteoarthritis Measure, GLFS-25 = 25-question geriatric locomotive function scale, LS = locomotive syndrome, SD = standard deviation, SPPB = short physical performance battery, STB = short test battery, VAS = visual analog scale.

* $P < .05$.

Table 3**Results of correlations in JKOM score and STB score for LS using the Spearman rank correlation coefficient.**

Outcome measure correlation coefficient	Adherence rate in pretest	Adherence rate variation	Pretest value variation
JKOM			
Degree of knee pain (VAS)	0.03	0.35	0.11
Total score	0.03	0.06	0.30
Pain and stiffness in knees	0.18	0.04	0.54*
Condition in daily life	0.13	0.01	0.34
General activities	0.27	0.04	0.62**
Health conditions	0.26	0.34	0.62**
STB for LS			
Stand-up test score	0.01	0.13	0.40
Two-step test (value)	0.10	0.01	0.07
GLFS-25 (value)	0.20	0.01	0.07

JKOM = Japanese Knee Osteoarthritis Measure, GLFS-25 = 25-question geriatric locomotive function scale, LS = locomotive syndrome, STB, short test battery, VAS = visual analog scale.

* $P < .05$.

** $P < .01$.

households over 70 years of age was 82%.^[24] This ratio increases every year. Hence, we speculate that an increasing number of elderly smartphone users will result in an increased number of users of this application.

In this study, the OA grade and sex did not significantly influence exercise adherence rates. However, male participants tended to have lower adherence (71.6%) than female participants (87.0%). Tuakli et al also showed that age, OA grade, knee pain, self-reported function, quality of life, and functional performance were not factors associated with adherence to home exercise. However, they found that low income and male sex were predictive of poor adherence.^[9] On the other hand, in a meta-analysis, cardiac rehabilitation adherence was significantly lower in women than in men.^[25] Sex differences in exercise adherence remain unclear. We aim to investigate this problem in the future.

This study showed that exercise significantly improved the JKOM score, knee extension strength, and total SPPB score in

patients with KOA. However, each category in the STB for LS did not improve significantly. We estimated that the reason for this was the low METs exercise. Our estimated exercise intensity was only 4 METs. Progression of LS limits the independent performance of daily activities.^[26] Our application concept was to initially increase the exercise habits of a user with low METs and then guide them to perform exercise with high METs. We included exercises of approximately six METs in the videos of this application. We plan to conduct a study using high METs exercise videos in the future and continue investigating the use of STB for LS.

This study has some limitations. First, as this was a single-arm pilot study, the number of participants was small, and the trial period was short. The main objective of this study was to determine the adherence rate for this application. However, we observed significant differences in the JKOM score, SPPB score, and knee extension strength. Based on these results, we

plan to conduct a large scale comparative study of patients with KOA, with and without the use of this application, for a long period. Second, this study was conducted in only one place, our hospital. Therefore, sample selection bias was included. Another research is needed to conduct a multicenter study. Third, we used the JKOM score instead of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score.^[27] Many rehabilitation or exercise studies on KOA have used the WOMAC score.^[28] The JKOM score does not directly compare to the WOMAC score. However, the Japanese lifestyle differs from that of Western countries. The JKOM score was calculated for Japanese patients with osteoarthritis. Therefore, the JKOM score is more suitable than the WOMAC score for Japanese patients with KOA.

5. Conclusions

The adherence rate and satisfaction of participants with KOA who used the unsupervised home exercise application, LongLifeSupport, were high. Significant differences were observed in VAS, total score, pain and stiffness in the knee, and condition in daily life categories of the JKOM; total score, walk seconds, and chair stand seconds of the SPPB; and right- and pain-side knee extension muscle strength. This application could provide a safe exercise program and maintain the exercise motivation of the participants. Therefore, this approach may be useful for unsupervised home exercises.

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