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Original Article

A 30-day kendama program for community-dwelling elderly: Effects on participants' physical and cognitive functions and the practicality of the program

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ABSTRACT

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Purpose: This study examined the effects of a 30-day kendama program on physical and cognitive functions and the practicality of the program for community-dwelling elderly individuals to reduce the risk of dementia and musculoskeletal disorders.

Method: Seventeen community-dwelling elderly persons aged ≥65 years participated in a 30-day kendama program wherein they practiced kendama in groups once a week for a total of four times and individually for at least 20 minutes a day for 30 days. The frequency and duration of the group and individual practices were surveyed to assess the practicality of the program.

Results: The physical function assessment revealed that knee extension muscle strength increased significantly by 18.8% after the intervention ($p < 0.01$). Further, the cognitive function assessment showed that the time required to perform the Stroop test decreased by 10.1%, the number of Symbol Digit Modalities Tests (SDMTs) performed increased by 5.6%, and the number of correct answers in the word memory test increased by 17.8% after the intervention, with each showing a significant change ($p < 0.05$). The results of the questionnaire on the participants' 30-day kendama program showed that approximately 30% answered that the frequency of individual practice was "a little too much," indicating that the program needed to be modified.

Conclusion: The results of this study suggested that kendama can be enjoyed easily and is expected to be practiced continuously with friends. Therefore, kendama can serve as an exercise program for reducing the risk of dementia and musculoskeletal disorders. In the future, it will be necessary to reconsider the frequency of individual kendama practice.

Keywords: physical function, cognitive function, community-dwelling elderly, kendama

Introduction

In 2019, the difference between the average life expectancy and healthy life expectancy in Japan was 8.8 years and 12.2 years for men and women, respectively. Extending healthy life expectancy has been reported to be an important issue [1] as the population requiring long-term care continues to increase [2]. The leading reasons for requiring care are reported to be dementia (18.1%), cerebrovascular disease (15.0%), weakness due to aging (13.3%), fractures/falls (13.0%), and joint diseases (11.0%) [3]. Therefore, the prevention of dementia and musculoskeletal disorders in the community-dwelling elderly is an urgent issue.

Due to the aging of society, the increase in the number of elderly people with dementia globally has become a serious problem; it is predicted that 5–8% of the population aged 60 years and older will develop

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dementia [4]. In response, the World Health Organization (WHO) published guidelines for "reducing the risk of cognitive decline and dementia" in 2019 [4], in which physical activity interventions were highly recommended. Specifically, they recommended that older adults without cognitive impairment perform moderate aerobic exercises and resistance training as often as possible in their lives [5]. There is also evidence that people without cognitive impairment benefit more from exercise than those with mild cognitive impairment [6].

In a report on musculoskeletal disorders, the WHO published guidelines on physical activity and sedentary behavior in 2020, which recommended that older adults aged 65 years and older should engage in at least 150−300 minutes of moderate-intensity aerobic physical activity and at least 75−150 minutes of high-intensity aerobic physical activity throughout the week to obtain health benefits from exercise or an equivalent amount of aerobic exercise with a combination of moderate- and high-intensity physical activity [7]. For the prevention of musculoskeletal diseases, at least two days per week of muscle strengthening activities and at least three days per week of multi-component physical activity emphasizing strength training and balance exercises are recommended [7].

Therefore, effective and efficient exercise programs aimed at reducing the risk of dementia and musculoskeletal disorders in healthy elderly individuals living in communities are needed. With the spread of the novel coronavirus infection (COVID-19) and restrictions on going out, the first author (hereafter "the author") focused on "kendama" as an exercise program that can be easily introduced at home, as previously recommended programs are difficult to implement with restricted access. Kendama has begun to attract attention as a health promotion tool with the potential to improve physical and cognitive functions [8, 9], and has been reported to be effective in creating opportunities for communication and self-affirmation [9]. Kendama is a traditional Japanese toy that can be played anytime, anywhere, by anyone, and has recently begun to spread in Europe and the United States [10−12]. Kendama can be performed indoors in an area as small as one tatami mat, regardless of weather conditions such as rain, and it is inexpensive and easy to introduce. It has been introduced as an exercise that combines aerobic exercise by continuing to perform kendama and resistance exercise by actively using knee flexion and extension to facilitate movement execution [9, 13, 14]. It is also known to require good balance ability [15] for fast body movements back and forth, left and right, up and down, concentration, sustained attention, and attention selection and distribution for successful execution of the technique.

Although exercise intervention using Kendama as one of the programs to reduce the risk of dementia and musculoskeletal disorders in healthy elderly people living in the community is expected to be effective, effectiveness studies have been limited to subjects in adulthood [15−17] and have not investigated the effects of exercise on dementia and musculoskeletal disorders in the elderly living in the community. Therefore, the purpose of this study was to examine the effects of kendama on physical and cognitive functions and its practicality by implementing a 30-day kendama program (hereafter "the program") aimed at preventing dementia and musculoskeletal disorders in the elderly living in the community.

Subjects and Methods

1. Subjects

In August 2021, information about the "Healthy Kendama Trial Session" was sent to 84 graduates of "Kiyosu Citizen Genki College," a public-academic collaboration between Aichi Medical College and

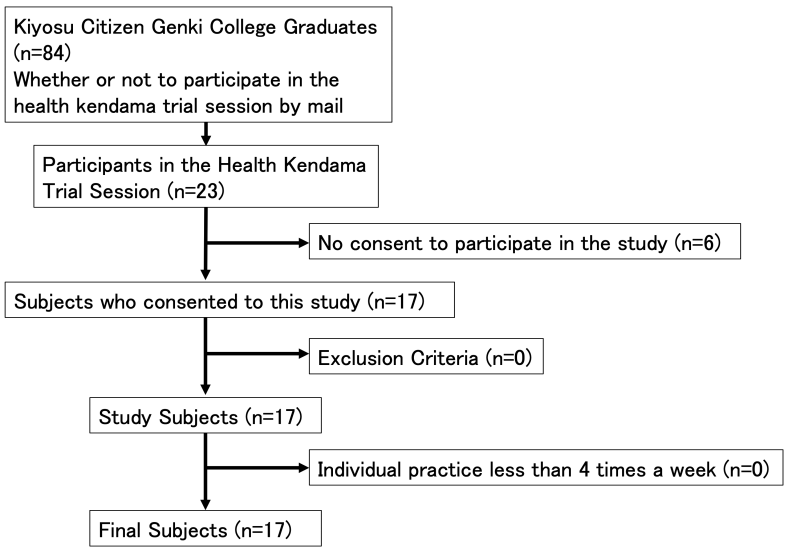

Figure 1. Selection of subjects.

Kiyosu City in Aichi Prefecture. Twenty-three elderly people aged 65 years or older who participated in the kendama trial were informed of the content of this study in writing by the author, and those who agreed to participate were included in the study (Figure 1).

The eligibility criteria were healthy elderly people living in a community with no preexisting diseases or cognitive decline. Exclusion criteria were those who were not independent in daily living; those who were certified as requiring nursing care or support; and those who had cardiovascular, respiratory, neurological, orthopedic, or psychiatric diseases that limited their ability to perform exercise.

2. Procedure

Subjects who met the eligibility criteria, did not meet the exclusion criteria, and provided written consent were asked for basic information, exercise habits during the past year (exercise twice a week for at least 30 minutes per session), and total exercise time per week, and underwent physical and cognitive function assessments before the start of the study. The participants were then asked to play kendama for 20 minutes or more every day for 30 days, and their physical and cognitive functions were assessed before the intervention. Questionnaires regarding the frequency and content of group and individual practice in the intervention program (Figure 2) were administered to the subjects and the kendama instructors, and A5-size notebooks (hereafter "record notebooks") distributed during the program period were collected. Kendama instructions were provided by the author, who is certified as a kendama sensei (Global Kendama Network certification), and one assistant who is also certified as a kendama sensei.

3. Contents of the intervention program

The program consisted of group and individual practices. The group practice was divided into two groups based on the days of the week in which the subjects could participate, and the group practice was conducted on separate days. Group practice sessions of 60 minutes each were held once a week, four times in total, in a classroom at the college to which the author belongs.

The first half of each group practice session (30 minutes) consisted of stretching exercises as a warm-up exercise, followed by practicing the basic three-level kendama skills (large cup, small cup, base cup, five times of moshikame, spike) and two-level kendama skills (baseball, easy big cup, spike, small cup to large cup, 10 times of moshikame, airplane) of the Kendama Test (Global Kendama Network, Inc.). The students were reminded of how to hold the kendama, the basic posture with feet shoulder-width apart, lowered center of gravity, and the key points of each technique. The second half (30 minutes) was free practice, during which the subjects taught each other techniques, and the instructor gave individual instructions for approximately five minutes to each subject. The instructor identified the subject's poor or unsuccessful techniques, demonstrated two or three points related to each technique, and provided feedback to the subject on repeated error patterns both verbally and through demonstrations. Considering concentration and fatigue, the subjects were asked to take a break every 15 minutes during free practice.

For individual practice, the subjects were instructed to practice kendama techniques at home for at least 20 minutes every day for 30 days at any given time, referring to the techniques used in the Kendama Test [12]. To check the daily practice status, we distributed a record notebook and asked the participants to write down the details, time, and impressions of the exercises. We also told them that, if they were not feeling well or were busy with work or other events, they need not practice more than twice a week.

The kendama used in this program was the KROM POP Mr. (made in Denmark), which has a large cup. The balls are coated with gripping paint to make it easy to perform the moves (Figure 3).

Kendama 30-Day Program Questionnaire (Subjects)

1. How many times a week is the appropriate frequency for weekly group practice?
2. How often was the frequency of individual practice (every day)?
   No problem, a little, a lot
3. How about more than 20 minutes per day?
   Not much, just right, a lot
4. Would you like to continue playing Kendama after the program?
   Yes, No, Can't say either
5. Please describe freely what you liked about the program and what you would like to improve.

Kendama 30-Day Program Questionnaire (Instructors)

1. Please describe freely what you liked about the implementation of this program and what you would like to improve.

Figure 2. Questionnaire content of the Kendama 30-day program.

Figure 3. Kendama used: KROM POP (made in Denmark).

4. Evaluation items

The following evaluations were conducted at the beginning and end of the program.

4.1 Basic information and exercise status

At the beginning of the program, the participants' age, sex, exercise habits during the past year (exercising twice a week for at least 30 minutes per exercise session), and total exercise time during the week before the start of the program were assessed using a self-administered survey form to determine the latest activity status. The total weekly exercise time [18] is a subjective evaluation used in the National Survey of Physical Fitness and Exercise Capability, Exercise Habits, etc. by the Sports Agency, and is based on the physical activity guidelines [19] of the Ministry of Health, Labour and Welfare, and is defined as "In a typical week, how much time do you spend on sports and physical activities (including walking, active hobbies, work, and housework) per day? Please fill in the box each day of the week."

At the end of the program, the total exercise time for one week after the completion of the program, excluding the time spent playing kendama, was surveyed to confirm the changes in their life conditions before and after the start of the program.

4.2 Evaluation of physical function evaluation

1) Grip strength

Grip strength was measured twice with the dominant hand, which was the hand in which the kendama was played, and the higher value was used. A digital grip strength meter (Takei Kiki Kogyo TKK-5401) was used to measure grip strength.

2) Knee extensor strength

Knee extensor muscle strength was measured using a Mobie pull sensor (Sakai Medical MT-150) [20]. The measurements were performed using the traction method with a belt. The measurement posture was sitting with knee extension at the hip joint, knee flexion of 90°, ankle dorsiflexion, and plantar flexion of 0°. A belt was wrapped around the ankle joint and a leg of the bed and the subject was asked to extend the knee as strongly as possible. If there was a difference of more than 10% between the two measurements, the measurement was repeated and the larger value was used.

3) Functional reach test (FRT) [21].

The FRT was used to evaluate balance. The subject assumed a closed-leg standing posture parallel to a wall. From a starting posture with the dominant shoulder joint flexed at 90° and the elbow in extension, the subject bent both feet forward to keep them off the floor and reached as far forward as possible. The maximum distance that the participant could move forward from the tip of the fist in the starting position was measured using a tape measure. The number of times the test was performed was based on the method of Dai [22] and others, and the higher value of two measurements was used to reduce the burden on the subject.

4.3 Cognitive function evaluation

1) Stroop test [23]

The Stroop test, which measures prefrontal cortex function, is a test in which a sequence of words whose colors do not match the meanings of the words (red, blue, yellow, and green) is presented on an A4 sheet of paper and the subject is asked to read out the colors of the words. First, the participants were asked to read five colors as a practice exercise, and then to read 50 colors (5 words × 10 lines) as quickly as possible. The test was performed once. The results of this test reflect the executive function of the prefrontal cortex of the left and right cerebral hemispheres, which inhibits the reading of unnecessary words [24].

2) Symbol Digit Modalities Test (SDMT; a test item of the Standardized Attention Test: CAT [25])

The SDMT is an item of the CAT, which is a standardized attention test that evaluates distributive attention. Within a time limit (90 seconds), participants were asked to fill in numbers corresponding to symbols based on a symbol-number correspondence chart. The more numbers that are correctly filled in, the higher is the distributive attention.

3) Word memory test [23]

The word memory test evaluates memory ability. The test consisted of a form with 30 three-letter hiragana words (irrelevant words), and the participants were asked to memorize as many words as possible in two minutes. The order of memorization and recall was not considered; only the number of words recalled was evaluated. After two minutes, the paper was turned over, and the words remembered were written on a new sheet. This test was designed to evaluate the function of the prefrontal cortex, which handles short-term memory in the left cerebral hemisphere. To eliminate the effects of the second test, the content of the questions was changed before and after the intervention.

4.4 Practicality of the program

A questionnaire regarding the utility of the program

(Figure 2) was administered after completion. The questions included the frequency of group and individual practices, duration of individual practice, and continuation of kendama. Opinions and impressions of the program and teaching methods of the instructors (authors and assistants) were surveyed by open-ended questions.

The subjects' kendama practice at home was recorded in a notebook after completion of the program, and the date of practice, total practice time, and average practice time per day (minutes) were recorded.

5. Data analysis

The normality of the physical and cognitive function assessments was confirmed using the Shapiro-Wilk test for the data at the beginning and end of the program. Next, to examine the changes in each evaluation item before and after the start of the program, the corresponding t-test was used for normality, and the Wilcoxon signed-rank test was used to evaluate the differences in each evaluation item before and after the intervention.

The statistical analysis software JMP14 (SAS) was used, and the statistical significance level was set at 5%.

6. Ethical considerations

After obtaining approval from the Ethics Committee of Aichi Medical College (approval number: 21030), the purpose of the study, method of implementation, and management and use of the obtained data were explained to the participants, and their written consent to participate in the study was obtained.

RESULTS

1. Basic information and exercise status

The author explained the content of this study in writing to 23 elderly persons aged 65 years or older who participated in the kendama trial session, and 17 persons (4 males and 13 females) agreed to participate (Figure 1). The mean age was 73.2±4.0 years (Table 1). Thirteen participants had a habit of exercise during the past year. At the beginning of the program, the total exercise time during the week before the program started was 4.6±2.3 hours. At the end of the program, the total exercise time for the week after the end of the program, excluding kendama, was the same, and no change in lifestyle habits other than kendama practice was observed. None of the subjects missed group practice or did not practice individually for an average of at least three days, and all subjects completed the program.

2. Changes in physical and cognitive functions

Corresponding *t*-tests were conducted for FRT, SDMT, and word memory test scores, for which normality was confirmed. Wilcoxon's signed-rank test was used for other items to evaluate changes before and after the intervention (Table 2).

In the physical function assessment, knee extension muscle strength showed a significant change from 22.4±6.7 kgf at the beginning to 27.6±7.2 kgf (18.8% increase) at the end ($p < 0.01$). In the cognitive function assessment, the Stroop test result significantly changed from 51.1±11.9 seconds at the beginning to 45.9±8.7 seconds at the end ($p < 0.01$); the number of correct answers on the SDMT changed from 50.1±7.5 at the beginning to 52.9±7.4 at the end ($p = 0.024$), and the number of responses to the word memory test changed from 7.3±2.2 at the beginning to 8.6±1.8 at the end of the program ($p = 0.048$), showing a significant change.

3. Questionnaire results after the completion of the program and the state of kendama implementation

Figure 4 presents the results of the questionnaire regarding the program. The frequency of group practice was once a week for 76.5% (13 subjects), but 17.6% (3 subjects) wanted the group practice to be

Table 1. Subject characteristics.

Sex (male: female)	4: 13
Age (years)	73.2±4.0
Exercise habits (persons)	Yes: 13 No: 4
Total exercise time (h)	
Baseline	4.6±2.3
Post-test	4.6±2.3※

※Excluding kendama practice time $n = 17$

Table 2. Results of Physical and Cognitive function ($n = 17$).

	Baseline	Post-test	Change (%)	*p*
Physical function				
Grip strength (kg)	24.9±6.1	26.0±6.0	8.3	0.055
Knee Extensor Strengt (kgf)	22.4±6.7	27.6±7.2	23.2	<0.01
FRT (cm)	35.5±4.6	41.4±4.1	16.6	<0.01
Cognitive function				
Stroop test (sec.)	51.1±11.9	45.9±8.7	10.1	<0.01
SDMT (Number)	50.1±7.5	52.9±7.4	5.6	0.024
Word Memory Test (Number)	7.3±2.2	8.6±1.8	17.8	0.048

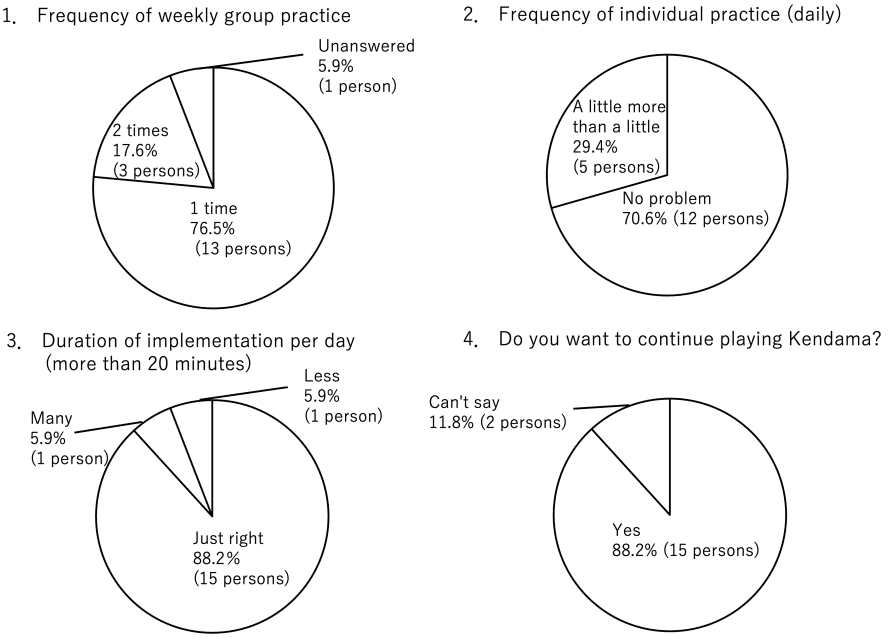

Figure 4. Results of the Kendama 30-Day Program Questionnaire.

increased to twice a week to provide more opportunities for instruction. The frequency of individual practice was 70.6% (12 subjects) every day and 29.4% (5 subjects) slightly more often, and most of these respondents were non-exercisers. As for the duration of each individual practice session, 88.2% (15 subjects) answered that at least 20 minutes was just right, a high percentage.

About 90% of the participants answered that they would like to continue playing kendama after completing the program. Regarding free opinions about the program, three respondents wanted an instruction manual because they had forgotten how to hold the kendama and perform the techniques, and two respondents said that airplane skills were difficult.

The average time spent at home was approximately 27 minutes, and the average number of days during the 30 days that the program was not practiced was approximately four.

Discussion

The results of this study showed that the program had a positive effect on the physical and cognitive functions of elderly people living in the community.

1. Changes in physical functions

The program improved knee extension muscle strength and balance. Kendama requires squatting movements accompanied by up-and-down movements of the trunk to increase the success rate of the skills [14], which may have led to an improvement in the strength of the quadriceps, gluteus maximus, adductor muscles, and other muscles [26]. Ryuushi et al. [27] stated that squat training for elderly subjects contributes to the improvement of balance in addition to lower limb muscle strength. Takahashi et al. [28] also reported that balance exercises for trunk muscles showed effects on static and dynamic balance, upper and lower limb muscle strength, and flexibility.

Although this study did not measure weight transfer, it is known that kendama involves vertical movement by knee flexion and extension and that the body moves quickly back and forth, left and right, and up and down according to the trajectory of the ball, indicating that lower-limb muscle strength and balance ability may be improved by kendama intervention. Further investigation into the effects of kendama on fall prevention is required.

2. Changes in cognitive function

Participants' participation in the program may have improved executive function and memory, according to the results of the Stroop and word memory tests, and improved distributive attention according to the shorter time of the SDMT.

Regarding the effects of exercise on cognitive function, Guadagni et al. [29] reported that middle-aged and older adults who had no exercise habits improved cognitive functions, such as memory, attention, and executive function, by performing aerobic exercise for 20–40 minutes, three to four times a week. Northey et al. [5] recommended performing at least moderate aerobic exercises and resistance training as many days as possible. The program implemented in this study included aerobic exercises performed for at least 20 minutes, resistance training requiring knee flexion and extension, and an exercise component to improve balance by moving the body faster in accordance with the trajectory of the ball.

Sobinov et al. explained that the visual induction of dexterity involves a broader brain network than simple hand movements and helps to activate not only the primary motor cortex but also pathways in the primary visual cortex, such as those in the parietal reach area [30]. Kendama requires coordinated eye and hand movements, and a quick response. Therefore, it can be inferred that a large number of motor commands and sensory inputs are generated in a wide range of brain regions, which may affect the executive function of the prefrontal cortex and memory. In addition, the need for sustained concentration and attention during the 20 minutes of individual kendama practice may have influenced the improvement in distributive attention.

These results suggest that kendama may contribute to the maintenance and improvement of cognitive function.

3. Practicality of this program

According to the results of the questionnaire survey, the frequency and duration of group practice and the 20 minutes of individual practice required per day were favorable. Although the time for individual practice was favorable, about 30% of the subjects answered that the frequency was "a little too much," suggesting that the weekly frequency should be reviewed to eliminate the missing subjects.

In the comments, several subjects requested the distribution of instruction manuals on how to hold the kendama and perform the skills. Therefore, it is necessary to create instruction manuals with pictures of each skill that are easy for the elderly to understand, and to take pictures of the instructor's movements with the subjects' smartphones. In addition, the time required for individual kendama instruction is short (approximately five minutes per person), and personnel are needed to handle people with hearing difficulties; therefore, it is desirable to increase the number of instructors and assistants who can teach kendama.

Yoshimoto [9] stated that kendama is inexpensive, portable, can be played anywhere, provides moderate exercise intensity without strain, and is an effective communication tool that can be enjoyed alone, in groups, and across generations, making it effective for elderly people who tend to be isolated. Similarly, Ogawa [31] stated that the characteristics of kendama are (1) easy enjoyment anytime and anywhere, (2) joy and excitement from successful moves, and (3) expansion of the circle of friendship through kendama. As expected, approximately 90% of the participants indicated that they would like to continue playing kendama after completing this program. Therefore, by addressing these issues, kendama may become an exercise program to reduce the risk of dementia and musculoskeletal disorders.

Limitations and Future Prospects of the Study

This study was designed as a before-and-after comparative study. The following limitations were noted: (1) there was no control group; (2) the intervention period was short (30 days); (3) the number of subjects was small; and (4) the proportion of male and female participants was skewed. Limitations (3) and (4) occurred because the participants were limited to graduates of Citizen's Genki College B. In addition, it is likely that many subjects already exercised. Therefore, it is necessary to reexamine the methods of group practice and individual guidance, including for those who do not have an exercise habit, in consideration of the physical burden, to examine the effectiveness of this program for elderly people living in the community. In the future, we would like to reexamine the selection of subjects, the amount and frequency of practice, and the effects on physical and cognitive functions by implementing a kendama intervention program with a control group.

Although this study has some limitations as described above, it is the first to examine the effects of a kendama intervention program on healthy elderly people living in the community, and we were able to demonstrate the possibility of a positive impact on physical and cognitive functions. In the future, it will be important to establish a control group, address the issues revealed by this study, and examine the effectiveness of a kendama intervention program.

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