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Original Article

Effects of a progressive walking program on the risk of developing locomotive syndrome in elderly Japanese people: a single-arm trial

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Abstract. [Purpose] This study aimed to identify the efficacy of a progressive walking program on the risk of developing locomotive syndrome among untrained elderly Japanese people. [Participants and Methods] Twenty-four untrained elderly individuals (68 ± 4 years) completed a 17-week progressive walking program. The stand-up, two-step tests and the 25-question geriatric locomotive function scale were used to assess the risk of locomotive syndrome at baseline, the 8-week midpoint (2 months), and the 17-week endpoint (4 months). Maximal isometric muscle strength of the knee extensors and flexors were measured using a dynamometer with the hip joint angle at 90° of flexion and physical function (the 30-s sit-to-stand, sit-up, 10-meter walk, and grip strength) were evaluated. [Results] The 4-month walking program significantly improved the two-step test and geriatric locomotive function scale scores. This may be attributable to the improvement in knee flexor strength and physical function. [Conclusion] A 4-month program of progressive walking effectively lowered the risk of developing locomotive syndrome in elderly Japanese people by improving knee flexor muscle strength and physical function.
Key words: Walking training, Locomotive syndrome, Muscle weakness

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INTRODUCTION

Locomotive syndrome (LS) is the term proposed by the Japanese Orthopedic Association (JOA) to identify individuals with musculoskeletal conditions who are at a higher risk of requiring nursing care[1)] due to weakness and fragility that limit the physical function needed for activities of daily living and mobility[2)]. Recently, the JOA developed two functional tests (the stand-up and the maximal step length tests) and a 25-question geriatric locomotive function scale (GLFS) to assess the risk for LS[3)]. Using these three outcome measures, recent studies have shown an age-dependent increase in the risk of LS among healthy adults aged 23- to 95-years-old[2, 4)].

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As skeletal muscle is the most common and widely distributed muscle tissue in the body (comprising around 40% of the body's total mass), the loss of skeletal muscle mass and strength associated with aging can result in a drastic reduction in an individual's quality of life and lead to an increased risk for the development of insulin resistance and various chronic health conditions[5, 6]. Thus, maintaining skeletal muscle mass and strength are necessary to prevent LS in elderly individuals. Although numerous reports have demonstrated the effectiveness of exercise training in increasing (or maintaining) skeletal muscle mass and physical function in elderly individuals[7], the effectiveness of training in lowering the risk of LS, however, remains unclear.

Aoki et al.[8] demonstrated that a 3-month program of locomotion training (single leg stance with eyes open and squatting) was effective in improving scores on physical function tests (single-leg stance and five repetitions of sit-to-stand) among 97 community-dwelling adults (76.8 ± 5.8 years). However, the effect of training on the JOA LS risk test scores was not evaluated. Hashizume et al.[9] reported on the effectiveness of a 3-month video-based program of exercise (comprised of 10 physical and mobility training exercises) in improving single-leg stance and 6-m walking time among elderly individuals, aged 65- to 88-years-old, who had concomitant chronic diseases (musculoskeletal and internal diseases). However, LS risk, assessed using the scores on a self-reported questionnaire (25-question GLFS), was not significantly changed after the training period. Thus, whether an exercise intervention can improve LS risk test scores is still unknown.

The effectiveness of a walking-based training program to improve skeletal muscle mass and strength in elderly individuals has previously been reported[7]. Walking is the most popular aerobic exercise for middle-aged and older individuals, as it is low impact and requires minimal equipment. Walking can also be performed at any time of the day and at one's own pace, without worrying about risks associated with some forms of vigorous exercise. Despite the advantages of a walking program, previous studies have shown higher intensity of endurance training to be more effective for maintaining muscle mass among middle-aged or older obese women[10, 11]. Nemoto et al. demonstrated that a 5-month program of high-intensity interval walking (5 or more sets of low-intensity walking for 3 min at 40% of peak aerobic capacity, followed by a 3-min high-intensity walking above 70% of peak aerobic capacity for 4 or more days/week) was effective in reducing the rate of an age-associated decrease in thigh muscle strength among healthy middle-aged and older people. In fact, a loss of muscle strength is a more consistent risk for disability and death[12], therefore, high-intensity training might be more effective for increasing muscle strength than a moderate-intensity continuous walking training[13]. Thus, high-intensity training could be effective in lowering LS risk among elderly individuals as it improves and maintains muscle strength. However, whether high-intensity walking can improve LS risk test scores (stand-up and two-step tests, and the 25-question GLFS) remains unclear. However, it is important to consider that for untrained elderly individuals, high-intensity interval walking may not always be easy to perform. Therefore, it is important to evaluate the effectiveness of a progressive walking program where the walking duration and intensity are gradually increased every other week to reduce the burden of interval training on elderly individuals who are at risk for LS. Accordingly, the objective of this study was to identify the efficacy of a progressive walking program on the risk of LS in elderly Japanese people.

PARTICIPANTS AND METHODS

Twenty-four untrained elderly individuals (12 men and 12 women; mean age, 68 ± 4 years; mean height, 159.3 ± 8.9 cm; mean weight, 60.7 ± 10.0 kg) completed the 17-week (4-month) progressive walking program. Participants had not performed any resistance training for at least 1 year prior to the start of the study. We excluded individuals who were unable to follow our instructions and those with chronic orthopedic conditions or any health or medical condition that limited the ability to undertake light-to-moderate walking. This study was approved by the Ethics Committee of the Juntendo University (Approval Number: 27-10), and all participants provided a signed informed consent.

The intervention program consisted of progressive walking at a self-selected pace for weeks 1–2 (20–25 min/day, 3 days/week), walking at 55–60% heart rate reserve (HRR) for weeks 3–8 (30–45 min/day, 3–5 days/week), and 5–8 sets of high-intensity walking for 3 min at 65–80% HRR, followed by a 2-min interval of light walking for weeks 9–17 (65–75% HRR for weeks 9–14, 4–5 days/week, and 65–80% HRR for weeks 15–17, 4–5 days/week). Walking speed, at baseline and at every 2 weeks during the period of intervention, up to the endpoint of the program at 4 months, was measured using treadmill walking in the laboratory.

The following outcome measures were obtained: body composition, LS risk, maximal isometric muscle strength, and physical function. Measurements were obtained in the laboratory at baseline (approximately 1 week prior to the start of the program), at week 8 (midpoint of the program, 2 months, 2M), and the end-point of the program at week 17 (4M). Measurements were performed at approximately the same time of day at each time point to control for diurnal effects on the outcome variables.

After the walking program, height and body weight (BW) were obtained, and the muscle mass, fat mass and percent of body fat (%Fat) measured by bioelectrical impedance analysis, using a body composition analyzer (InBody730; InBody Co., Ltd., CA, USA).

The LS risk test (stand-up, two-step test and GLFS) was used to assess the risk of LS. The stand-up test was used to evaluate leg strength. Participants were asked to stand from a sitting position on two legs or one leg, and from four different seat heights (40, 30, 20, and 10 cm). Participants were instructed to stand up without leaning back to gain momentum and to maintain the standing posture for at least 3 s. If a participant was unable to perform the stand-up on one leg (right or left)

Table 1. Test-retest reliability and internal consistency of measurements

Measurement (n)	Test-retest reliability ($ICC_{1,1}$)	Internal consistency (Cronbach's α)
Stand-up test (10)	0.87	0.93
Two-step test (10)	0.90	0.95
GLFS (10)	0.76	0.88
Knee extension strength (9)	0.95	0.97
Knee flexion strength (9)	0.95	0.95
CS-30 (9)	0.78	0.93
Sit-up test (8)	0.99	1.0
10-m walking test (10)	0.83	0.91
Grip strength (9)	0.99	0.99

GLFS: a 25-question geriatric locomotive function scale; CS-30: 30-sec repeat sit-to-stand test.

from a seat height of 40 cm, the stand-up test was recorded as a fail. A score from '0' to '8' was allocated to the performance, as described by Ogata et al[4].

For the two-step test, participants with the toes of both feet behind a starting line and to then perform two maximal stride lengths, one with each foot, and the distance from the starting line was measured. The score for the two-step test was calculated as follows: length of the two steps (cm)/height (cm)[4]. Two maximal step lengths were obtained twice for both legs, with the higher score used for analysis.

The 25-question GLFS was developed by Seichi et al[14]. The GLFS is a self-reported questionnaire, which is a comprehensive measure consisting of 25 items that include items regarding pain, activities of daily living and mental health during the last month. These 25 items are graded on a five-point scale, from 0 (no impairment) to 4 (severe impairment) points, with the scores summed to provide the total GLFS score, with a higher GLFS score associated with a higher risk of developing LS.

According to the JOA, two stages of LS are defined, based on the sum of the score on the stand-up, two-step and GLFS tests[15]. LS stage 1 is defined as difficulty with stand-up from a seat height of 40 cm on one leg (either the right or left), a two-step score of <1.3 and GLFS score ≥7. LS stage 2 is defined difficult with stand-up from a seat height of 20 cm using both legs, a two-step test score of <1.1 and a GLFS score ≥16. Both LS 1 and 2 were considered to be indicative of a progressive decline in mobility. It should be noted that participants classified as LS-2 were excluded from the LS-1 group to avoid repetition of participants.

The maximum isometric strength of knee extension and flexion were measured using a hand-held dynamometer (Takei, Tokyo, Japan). During the measurement, participants were seated in a chair with the hip joint angle at 90° of flexion (0°, full hip extension), and exerted a maximal (isometric) force in either knee flexion or extension, for 5 s against the dynamometer. Two or three trials were performed in each direction, with the greatest strength measure in flexion and extension normalized to body weight to provide the weight-bearing index (WBI).

Physical function was assessed using the following: the 30-s repeat sit-to-stand test (CS-30 test), the sit-up test, and the 10-m walk test and grip strength. For the CS-30 test, participants were asked to complete the maximum number of sit-to-stand trials (from a 40-cm seat height), without using their arms. For the sit-up test, participants were asked to lie in a supine position on a mat, with both hands slightly clenched and arms held crossed across the chest and knees flexed to 90°, and to perform as many sit-ups as possible in 30 s, with an assistant stabilizing both knees. For the 10-m walk test, participants completed the 10-m straight walking path, with a 1-m width, on a hard-surfaced floor, as fast as possible, without running. Participants completed two timed trials and were encouraged to maintain a straight course. Performance time was measured using a digital stopwatch (LC058; CITIZEN, Tokyo, Japan), with the fastest time used in the analysis. Hand grip strength was measured using an analog dynamometer (Takei Kiki Kogyo, Niigata, Japan), with two trials completed for each hand, alternating between the two hands, with the highest value for each hand used in the analysis.

Internal consistency and test-retest reliability of measurements were evaluated in a group of 10 community-living adults, ≥60 years-old, using the intra-class correlation coefficient (ICC) and Cronbach's α, respectively. All measurements (LS risk test, maximum isometric strength tests, and physical function tests) were performed in the laboratory, 4 days apart. Instructions, procedures, and laboratory setting were consistent across both testing sessions. Among the 10 participants included, one participant had high blood pressure on the first day, and therefore, only LS risk test and the 10-m walking test were performed. In addition, another participant was unable to perform the sit up test due to lower back pain. Test-retest ICC coefficients for all measurements were >0.75, with Cronbach's α coefficients >0.70 (Table 1), with ICC coefficients >0.75 and Cronbach's α values between 0.7 and 0.9 being acceptable[16].

The change in measured outcomes at 2 M and 4M, from baseline were evaluated using a one-way analysis of variance (ANOVA), followed by Tukey's multiple comparisons test to evaluate multiple pairwise comparisons. A two-way repeated measures ANOVA (LS × time) was used to evaluate training effects. All analyses, except Cronbach's α and ICC analysis, were performed using Prism software (ver. 6.0; GraphPad Software Inc., San Diego, CA, USA). Cronbach's α and ICC

Table 2. Comparison of outcome variables at each time-point of measurement

	Baseline	2M	4M	% change
Weight (kg)	60.7 ± 10.0	60.6 ± 10.2	60.2 ± 10.1	−0.7 ± 1.5
Body fat percentage (%)	30.0 ± 6.6	29.1 ± 6.2	29.6 ± 6.1	−0.9 ± 5.4
BMI (kg/m^2)	23.8 ± 2.5	23.7 ± 2.5	23.6 ± 2.5	−0.7 ± 1.6
Total skeletal muscle mass (kg)	23.1 ± 5.0	23.3 ± 5.1	23.0 ± 4.9	−0.1 ± 2.0

Values are reported as the mean ± standard division (SD). 2M: 2-month midpoint; 4M: 4-month endpoint; BMI: body mass index. n (male, female)=24 (12, 12). Percent (%) change means the change at 4M from baseline.

Table 3. The duration and frequency of walking during the program

Intensity	Weeks 1–2	Weeks 3–8	Weeks 9–14	Weeks 15–17	Weeks 1–17
	Self-selected pace	55–60% HRR	High-intensity interval walking 65–75% HRR	High-intensity interval walking 65–80% HRR	
Duration (min/day)	27.1 ± 9.7	40.1 ± 5.6	37.2 ± 6.5	41.2 ± 5.4	38.0 ± 5.1
Frequency (days/week)	3.0 ± 0.7	3.7 ± 0.8	3.7 ± 0.9	3.2 ± 1.5	3.5 ± 0.6

HRR: heart rate reserve. Values are shown as the mean ± standard division (SD).

Table 4. Effects of the progressive walking program on the risk of locomotive syndrome and the number of participants with a locomotive syndrome, stage 1 or 2, at each time-point of measurement

	Baseline	2M	4M
Stand-up test	4.5 ± 1.1	4.5 ± 0.9	4.8 ± 0.8
Stage 2	2 (1, 1)	0	0
Stage 1	6 (3, 3)	9 (5, 4)	7 (3, 4)
Two-step test	1.36 ± 0.08	1.39 ± 0.07	1.43 ± 0.08*†
Stage 2	0	0	0
Stage 1	6 (2, 4)	3 (2, 1)	1 (0, 1)
GLFS	5.7 ± 4.5	3.0 ± 2.8*	3.3 ± 2.7*
Stage 2	1 (1, 0)	0	0
Stage 1	6 (2, 4)	1 (1, 0)	4 (2, 2)
LS stage 2	3 (2, 1)	0	0
LS stage 1	12 (4, 8)	7 (3, 4)	6 (2, 4)
Non-LS	9 (6, 3)	17 (9, 8)	18 (10, 8)
LS (%)	62.5	29.1	25.0

2M: 2-month midpoint; 4M: 4-month endpoint; GLFS: a 25-question geriatric locomotive function scale; LS: locomotive syndrome. Values are shown as the mean ± standard division (SD). *$p<0.05$ vs. Baseline, †$p<0.05$ vs. 2M. n (male, female).

analysis were performed with Excel for statistical analysis. The statistical significance for all analyses was set at $p<0.05$.

RESULTS

Relevant characteristics of the study group at baseline and at the 2M and 4M time-points of measurement are summarized in Table 2, with the % change from baseline to 4M reported. No significant differences in weight, body fat percentage, BMI, and total skeletal muscle mass were identified over the intervention period.

Table 3 shows the duration and frequency of walking during each period of the training program. Over the study period, participants walked on average 38.0 ± 5.1 min/day, 3.5 ± 0.6 days/week.

The change in the LS risk test score form baseline and the number of participants with a locomotive syndrome, stage 1 or 2, at the 2M and 4M time-points are shown in Table 4. Although no significant difference was observed in the stand-up test (decrease number of participants with locomotive syndrome stage 2), the score on the two-step test increased from baseline

Table 5. Effects of the progressive walking program on maximal isometric muscle strength

		Baseline	2M	4M	Group × Time	Group	Time
Knee extension (kg)	Non-LS	45.1 ± 13.2	45.9 ± 11.6	47.9 ± 11.0	n.s.	0.072	n.s.
	LS	39.9 ± 9.8	40.9 ± 10.0	43.5 ± 10.1			
Knee flexion (kg)	Non-LS	15.7 ± 4.3	18.2 ± 5.8	22.5 ± 5.9	n.s.	0.015	0.005
	LS	12.6 ± 4.7	15.0 ± 5.5	16.4 ± 3.7			
Knee extension (WBI, kg/kg BW)	Non-LS	0.74 ± 0.16	0.78 ± 0.16	0.81 ± 0.11	n.s.	0.016	n.s.
	LS	0.65 ± 0.14	0.67 ± 0.16	0.72 ±0.17			
Knee flexion (WBI, kg/kg BW)*	Non-LS	0.26 ± 0.04	0.31 ± 0.08	0.39 ± 0.10	n.s.	<0.001	<0.001
	LS	0.20 ± 0.06	0.24 ± 0.07	0.27 ± 0.07			

Values are shown as the mean ± standard division (SD). Non-LS; n=9 (6, 3), LS; n=15 (6, 9). 2M: 2-month midpoint; 4M: 4-month endpoint; WBI: weight bearing index; LS: locomotive syndrome. The results of two-way ANOVA are reported. *Significant difference between baseline and 4M (p<0.05).

Table 6. Effects of the progressive walking program on physical function (30-s repeat sit-to-stand, sit-up, 10-m walking test, and grip strength).

		Baseline	2M	4M	Group × Time	Group	Time
30-s repeat sit-to-stand (n)	Non-LS	22.5 ± 5.5	24.2 ± 4.4	27.4 ± 6.1	n.s.	n.s.	0.044
	LS	21.3 ± 4.7	22.2 ± 5.0	24.3 ± 5.5			
Sit up (n)	Non-LS	12.3 ± 6.1	15.0 ± 6.8	15.1 ± 5.5	n.s.	0.052	n.s.
	LS	9.4 ± 7.2	11.2 ± 6.3	12.1 ± 7.6			
10-m walking test (sec)	Non-LS	4.9 ± 0.6	4.6 ± 0.6	4.6 ± 0.5	n.s.	<0.001	n.s.
	LS	5.4 ± 0.5	5.1 ± 0.5	5.2 ± 0.5			
Grip strength (kg)	Non-LS	34.9 ± 7.8	33.4 ± 7.7	34.8 ± 8.2	n.s.	n.s.	n.s.
	LS	31.1 ± 8.5	31.0 ± 8.3	31.3 ± 8.6			

Values are shown as the mean ± standard division (SD). Non-LS; n=9 (6, 3), LS; n=15 (6, 9). 2M: 2-month midpoint; 4M: 4-month endpoint. The results of a two-way ANOVA are reported.

and 2M to 4M (p<0.05). Additionally, the GLFS score decreased from baseline at 2M and 4M (p<0.05). Among our study group, 15 of 24 participants (62.5%) fulfilled the diagnostic criteria for LS, with 12 of 15 participants classified as LS-1 and 3 of 15 as LS-2 at baseline. However, after the intervention, only 6 participants (2 men and 4 women) met the diagnostic criteria for LS (a 25% decrease in the prevalence of LS score after the intervention).

We observed a significant improvement of knee flexor strength, and the WBI of knee flexion, with no effect on knee extension (Table 5). Furthermore, the WBI of knee flexion was increased significantly at the end-point of the training program (4M) for both LS and non-LS participants.

The change in physical function is shown in Table 6. An overall increase in the CS-30 test was identified at 4M, from baseline. The LS was found to significantly affect the 10-m walking test, with no effect of training. No significant differences were found in the results from the sit up and grip strength test over the training period.

DISCUSSION

In the current study, we demonstrated for the first time that a 4-month progressive walking program can significantly lower the risk of LS, as measured using the LS risk test of the JOA. The measured variables were valid and reliable, with an ICC>0.75 and Cronbach's α>0.87. The lowered risk of LS was associated with an increase in knee flexor strength and physical function over the short 4-month period of intervention. The prevalence of LS, based on scores of the stand-up test, two-step test and the GLFS, was 33.3%, 25.0% and 29.2%, respectively. The prevalence of LS, overall, was 62.5%, which was comparable to the prevalence previously reported[2, 4, 17]. Although our intervention did not improve stand-up performance, our progressive walking program did improve performance on the two-step test and on the GLFS at 4M, relative to baseline, regardless of LS status. Notably, 15 of our 24 participants fulfilled the diagnostic criteria for LS (LS-1 or 2) at baseline, with only 6 participants meeting the diagnostic criteria for LS after the intervention. This equates to a decrease in the prevalence of LS by 25% after the intervention, with the change being observed in the LS-1 group. Our data demonstrates that a 4-month walking intervention decreases the risk of LS among untrained-elderly people, with a specific increase in the WBI of the knee flexion strength and the CS-30 after our 4-month progressive walking program, regardless of LS status. Therefore, our walking program was effective in improving (as well as preventing) the risk of LS among untrained elderly Japanese individuals.

As mentioned above, maintaining the ability to walk is important to avoid LS. Our findings of a significant improvement in knee flexion strength and the WBI of knee flexion after our 4-month intervention were comparable to those of Kubo et al.[18] who reported a 19.6% increase in knee flexion strength and 2.2% in knee extension strength with a 6-month program of progressive walking, performed at a self-selected pace, increasing the duration by 15–40 min/day and frequency to 3–4 days/week. Furthermore, Nemoto et al.[13] demonstrated that a 5-month program of high-intensity interval walking training produced a 13% increase in knee extension strength and 17% in knee flexion in healthy middle-aged and older individuals. These increases were significantly greater than those produced by a program of continuous walking at a moderate-intensity (9,439–9,833 steps/day), despite a similar walking duration (51–66 min/day) and frequency (4.4–4.5 days per week) between the programs[13]. By comparison, our 4-month program of progressive walking yielded a 40% increase in knee flexion, with the 10% increase in knee extension not being significant. Direct comparison of outcomes of training between studies, however, is not possible due to differences in baseline characteristics. However, given the significant increase in the muscle mass and strength by continuous walking after more than 6 months of training as mentioned above[7], our progressive walking program, which included a high-intensity walking, was effective in improving knee flexion strength, over a relatively short period of time in untrained elderly individuals. The knee flexors (hamstrings) are two-joint muscles that act as knee flexors and hip extensors. Their action at the hip is important to support the body mass during the stance phase of walking, while knee flexion strength is important during the swing phase of walking. Furthermore, the hamstring muscle is activated with the rectus femoris component of the quadriceps just before heel contact during normal gait[19], this coactivity being useful to stabilize the knee by increasing the compressive force[20]. Accordingly, it seems reasonable, therefore, that the increase in knee flexor strength among elderly individual with our walking program would improve knee stability during gait and thereby lowering the risk for LS (improving LS risk scores).

Unfortunately, our intervention did not improve stand-up performance. The stand-up test yielded a score of ‘0’ to ‘8’ according to the difficulty in standing up from each seat height (40, 30, 20, and 10 cm for two legs or one leg), thus, the data from the stand-up test is not continuous but instead is a step-by-step evaluation value. Therefore, this measurement is useful for screening purposes but is not sensitive enough to detect training effects. Additionally, our program did not improve knee extensor muscle strength, which drastically decreases with age and is highly associated with mortality, in a 4-month training period. Some studies have reported that the stand-up performance is significantly correlated to the strength of knee extensor muscles[21, 22]. This suggests that a longer training period or a higher-intensity walking program is required to increase the knee extension strength and thereby improve the stand-up test score.

This study has several limitations that should be acknowledged. First, although the internal consistency and test-retest reliability of the measurements was high, our outcomes would have been stronger if compared to a no-intervention control group. Moreover, although we confirmed the walking speed of participants at 2-week intervals on a laboratory treadmill, we cannot confirm if an individual’s walking pace guidance was sufficient for training between the measured intervals. Despite these limitations, our 4-month progressive walking program was effective in improving the risk of LS among untrained elderly Japanese individuals. Our data suggest that the walking program that progressively increases the duration and intensity, even for elderly people who have no experience with exercise, improves the knee flexor muscle strength in a relatively short period and it can be an effective intervention as the first step in improving the risk of LS.

In conclusion, we demonstrated for the first time that a 4-month progressive walking program is effective in lowering the risk of LS among elderly people by improving knee flexor muscle strength and physical functions.

Presentations at conferences

The current study was presented at the 23rd Congress of The Japanese Society of Health, Fitness and Nutrition, Kobe, Japan, Mar. 5, 2016 (Abstract no. P17, abstract book page 53, which is not available online). A part of this study was also presented at The 2nd Asian Conference for Frailty and Sarcopenia, Nov. 4–5, 2016 (Abstract no. P59, abstract book page 109).

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Conflict of interest

There are no conflicts of interest to declare.

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