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Effect of Treadmill Training on Specific Gait Parameters in Older Adults with Frailty: Case Series

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Abstract

Background and Purpose—Treadmill walking training (TWT) as an intervention to improve the gait of frail older adults has not been well studied. In this pilot study, we describe the feasibility, tolerance, and effect of TWT on specific gait parameters during overground walking in four frail older adults as a prelude to developing larger scale exercise intervention trials in this high-risk population.

Case Description—Four community-residing frail older individuals (age>70) with Mini-Mental Status Examination score of 26 or higher and no activity limitations. Frailty was defined as presence of at least three out of the following five attributes: slow gait (<1 m/sec), unintentional weight loss (>10 lbs in prior year), self-report of poor grip strength, exhaustion, and low level of physical activity.

Intervention—TWT consisted of 24 sessions (3 times/week for 8 weeks). Five quantitative gait parameters [velocity, stride length, swing time, percentage of double support phase, coefficient of variation (COV) of stride length] during overground walking were measured at baseline, weekly during training, and immediately post-TWT.

Outcome—All participants tolerated TWT without significant complications. Following TWT, gait velocity increased in all participants by 6.4 to 26.8 cm/sec, which was larger than the reported value for meaningful change in gait velocity (4 cm/sec). Stride length and double support phase also showed improvement in all participants (mean percentage increase of 10.8 % for stride length, and 17.1% reduction for double support phase post training compared to baseline). Swing time

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improved in three participants (mean reduction of 4.5 %). The COV of stride length did not show consistent improvement.

Discussion—This case series shows that TWT is feasible and well tolerated by frail older adults, and may improve most gait parameters in this high-risk population.

Keywords

gait; exercise; frail older adults; rehabilitation

BACKGROUND

Gait performance is an indicator of general health status¹ and a strong predictor of risk for developing dementia,^{2, 3} falls,⁴ and institutionalization⁵ among older adults. Improvement in gait speed has been associated with longer survival in older adults.⁶ Treadmill walking training (TWT) is a widely used rehabilitation method to improve gait in individuals with various neurological conditions.⁷⁻⁹ However, the use of TWT as an intervention to improve gait performance among frail older adults and its feasibility in this high risk population has not been well studied. Gait performance is mostly reported in terms of velocity; on the other hand, other gait parameters such as stride-to-stride gait variability (fluctuation of stride length from one gait cycle to the next) are also recently recognized as a strong predictor of negative outcomes including injurious falls among older adults.^{4, 10} Information of TWT effects on gait parameters other than velocity is limited. In this case series, we described feasibility and tolerance of low to moderate intensity TWT of eight weeks duration and its effect on different gait parameters in four frail older individuals. The knowledge gained from this preliminary study will help to design future TWT interventions to improve gait performance in frail older adults.

METHODS

Recruitment of Participants

We recruited potential participants from a waiting list of research volunteers at our research center¹¹ who were initially identified through the Bronx County Board of Elections voter registration lists. From this list, 12 individuals were contacted by a telephone call by a research assistant. Of the 12, two refused to participate, 10 were invited to undergo in-person screening to determine eligibility to participate in this pilot study. Inclusion criteria on in-person interview was age 70 and older as well as presence of frailty modified from the Fried criteria¹² by meeting at least three out of the following five attributes : slow gait (<1 m/sec), unintentional weight loss (>10 lbs during prior year), muscle weakness (self-report of poor grip strength), self-reported exhaustion, and low levels of physical activity (exercise once a week or less). Exclusion criteria were Mini-Mental Status Examination score ≤25, self-reported activity limitations requiring personal assistance in seven activities of daily living (bathing, dressing, grooming, feeding, walking indoors, toileting, and transfer from a chair) using the disability questionnaire developed by Gill and Kurland,¹³ or contraindications¹⁴ for participation in exercise program such as uncontrolled hypertension or unstable angina. Among the 10 individuals who completed the in-person evaluation, one refused to participate in this study, four did not meet frailty criteria (i.e.; not frail), one was excluded due to uncontrolled hypertension, and the remaining four individuals (2 men, 2 women) participated in the study. Written informed consent was obtained from all participants and all study protocols were approved by Committee on Clinical Investigations at Albert Einstein College of Medicine.

Clinical Evaluation

Information on medical illness and medications was collected using structured questionnaires designed for the Einstein Aging Study.^{2, 15-17} Height and weight at baseline was measured by a research assistant trained to collect anthropometric data. Knee extensor strength was also assessed since knee extensor strength is a known correlate of gait velocity in frail older adults.¹⁸ A board certified physiatrist with research experience of studying frail older adults measured isometric knee extensor strength in kilograms of force using a hand held dynamometer (Lafayette Manual Muscle Test System, Lafayette Instrument Company, Lafayette, IL) with 90 degrees of knee flexion. Maximum value of three trials was obtained for each side and the mean of the values from both sides was recorded for each participant at baseline and post training. The results were then converted into Newtons (N) by multiplying kilograms by 9.81 m·sec⁻².

Quantitative Assessment of Gait

Research assistants conducted quantitative gait assessments using a computerized walkway (457 × 90.2 × 0.64cm) with embedded pressure sensors (GAITRite system CIR systems, Inc, Havertown, PA). The GAITRite system is widely used in clinical and research settings and has excellent validity and reliability for measuring temporal and spatial gait parameters.¹⁹ The inter-rater reliability for gait velocity was reported to be excellent in our cohort²⁰ (ICC 0.96). All research assistants completed training for administration of instructions to participants, operation of software program, data processing, and were certified on test procedures. Participants were asked to walk on the walkway at their “usual pace” in a quiet well-lit hallway without windows or other distractions wearing comfortable footwear. All participants had previous exposure to the walkway and were allowed practice trials prior to the baseline assessment to minimize practice effects. Based on footfalls recorded on the walkway, the software automatically computes gait parameters as the mean of two trials. We a priori selected five gait parameters for analysis; velocity (cm/sec), stride length (cm), swing time (msec), double support phase (%), and stride-to-stride gait variability based on associations with adverse outcomes including falls and disability reported in our and other studies.^{4, 21, 22} Stride-to-stride gait variability was operationally defined as change in stride length from one gait cycle to the next and calculated as [coefficient of variation (COV)^{23, 24} of stride length]. The COV of stride length was included for analysis since it was shown to be a better predictor for falls including injurious falls compared to other gait parameters in our previous study.⁴ Gait parameters were measured at baseline, weekly during TWT, and immediately post training. The baseline and post training values were reported descriptively.

Intervention (Treadmill Walking Training)

The treadmill (T630m, SportsArt Fitness, Woodinville, WA) walking training protocol was based on the recommendations of the American College of Sports Medicine (ACSM)¹⁴ and American Heart Association (AHA)²⁵ for older adults. The training sessions were three times per week over an eight week period (total 24 sessions). Each training session started with five minutes of warm-up walking at comfortable speed. Then, the speed was gradually increased to the level of workload at which participants felt ‘somewhat hard’ (12-14 on Borg scale²⁶) for two 15 minutes sessions with one to two minute break in between (total 30 minutes) followed by a five minute cool down period. However, training interval was gradually increased from six 5-minute intervals per session to two 15-minute training periods per session over the first two weeks. As recommended,²⁵ a gradual approach was applied to increase the exercise intensity in participants with low baseline level of physical activity and who were unfamiliar with treadmill walking. No suspension harness was used; however, the treadmills included extended side handles for safety and participants were allowed to hold onto the side railing during the training. Pulse and blood pressure were

assessed before and after each session to assure that the values were not deviated by 10 or more (/min, mmHg) from the values of initial assessment for pulse and systolic blood pressure. During TWT, participants were monitored for both with a subjective rating scale (Borg scale score²⁷) as well as the heart rate tracked by a physiatrist (study clinician) with extensive clinical experience in the rehabilitation of frail elderly. Subjective rating scale (Borg scale score) was assessed every 5 minutes during the entire session. Study clinician encouraged the participants to increase the training velocity if the subjective rating of exercise intensity was low (fairly light, Borg scale score < 12). The treadmill speed was reduced or the exercise was aborted if there were any untoward symptoms such as cardiovascular symptoms, fatigue, or excess workload (hard, Borg scale score >14). Heart rate was measured during the break between the two 15-minute training periods and the second period was only initiated after the value was below the 70% of estimated maximum heart rate (220 minus age¹⁴).

RESULTS

Two men (ages 72, 74) and two women (ages 74, 81) participated in the study (Table 1). One participant was morbidly obese (body mass index of 44.0). Three participants reported hypertension which was well controlled. One participant had history of coronary artery disease and was being managed medically. Two participants had history of gout; however, there was no evidence of active arthritis in their joints. Two participants missed one session each and one participant missed two sessions out of 24 sessions due to the reasons not related to health resulting in an overall high participation rate (95.8%). None of the four participants engaged in any exercise activities other than the TWT protocol during the eight week training period.

Clinical Observations

None of the four participants had used a treadmill before this study. All participants held onto the side rails during most training sessions, but particularly at training velocities that were higher than their usual overground gait velocity. No participants experienced falls or near-falls during the intervention. There was no medical complaints including chest pain, shortness of breath, excessive fatigue, or pain in the joints reported during TWT or after the session. Mild soreness of calf muscles were reported by one participant with morbid obesity in the 3rd week, which resolved spontaneously before the next session. Three participants reported that the overall TWT experience was enjoyable and expressed desire to continue the training after the study was over. One participant (woman, age 81) reported that she felt less tired in doing daily activities with TWT, however, could not continue TWT without supervision. All participants felt that the supervised TWT was safe. They also expressed the opinion that TWT helped them walk better compared to the baseline.

Gait Performance of Overground Walking

All participants started TWT at a velocity lower than their baseline gait velocity during overground walking. All four participants were able to walk on the treadmill continuously for two 15-minute periods at or higher than the baseline gait velocity by the 3rd week (sessions 7 to 9). The values of pre and post training for gait parameters and knee extensor strength are summarized in Table 1. Following TWT, gait velocity showed improvement in all participants by 6.4 to 26.8 cm/sec (mean percentage increase from baseline; 18.8%), which is larger than the meaningful change in gait velocity (4 cm/sec) among older adults reported in our cohort²⁸ and in another cohort.²⁹ Interestingly, the largest improvement in gait velocity (27.2% increase from baseline) was noted in the oldest participant (age, 81) who had the highest gait velocity at baseline. Even one morbidly obese participant showed modest improvement in gait velocity by 8.4 cm/sec (8.8% from baseline).

Similar to gait velocity, stride length increased in all participants by 4 to 22.2% and double support phase was reduced by 7.4 to 29.8% from baseline values. Swing time was reduced (improvement) in three participants and no change in one participant (mean percentage reduction from baseline; 4.5%). The COV of stride length was reduced (improvement) in only one participant and increased (worse) in the other three participants. Knee extensor strength showed increase in only one participant and slight reduction in the other three following TWT. Figure 1 shows the change in gait velocity during overground walking over the training period for each participant and the mean value of the peak treadmill training velocity. Mean peak training velocity ($\pm$ standard error; SE) on the treadmill reached 4.4 ($\pm$ 0.8) km/hour (123.0 ± 22.2 cm/sec) during the last session of the training. The largest increment in the mean peak treadmill training velocity ($\pm$ SE) after a week of familiarization was seen between the 2nd and the 3rd week, from 2.9 ($\pm$ 0.4) to 3.9 ($\pm$ 0.2) km/hour (from 80.6 ± 11.1 to 108.3 ± 5.6 cm/sec). Increasing trend in gait velocity during overground walking was shown for all participants, although there was some fluctuation in the values over the training period.

DISCUSSION

This case series shows that frail older adults were able to participate in eight weeks of TWT without major complications. For frail older adults with sedentary lifestyle, TWT can be perceived as an overwhelming physical activity, however, our clinical observations in this small sample support the feasibility of this approach in frail seniors. Introduction of TWT to our participants was gradual, starting at a treadmill velocity lower than the usual overground walking velocity and was done over multiple blocks of brief walking periods. Within a 2 to 3 week period (6-9 sessions), all participants were able to walk 15 minutes at the baseline gait velocity or higher. This training regimen seems to be well tolerated among frail older adults. All participants in our study following the intervention felt that supervised TWT was safe and enjoyable.

Treadmill walking training induced improvements in most overground gait parameters except stride-to-stride gait variability in all participants in our pilot study. The magnitude of improvement in gait velocity was higher than meaningful change in gait velocity reported in previous studies.^{28, 29} The mean percentage change from baseline was 10.8% increase for stride length, 17.1% reduction for double support phase, and 4.5% reduction for swing time. Meaningful change units have not been reported for these other gait parameters. Future studies examining whether the initial gain in overground walking is maintained with or without additional treadmill training sessions will help to define optimal duration for treadmill exercises in frail elderly.

The effect of TWT on gait parameters in frail elderly has not been well described. Patterson and colleagues reported improvement in gait velocity and stride length in 39 stroke patients after six months of TWT (22% for gait velocity, 13% for stride length),⁷ which were comparable to our results in frail older adults. Stride-to-stride gait variability was not measured in that study. Six weeks of TWT improved gait velocity in nine patients with Parkinson's disease, but not stride-to-stride variability as in our study.⁸ Alternate approaches such as extending TWT beyond eight weeks may be explored to improve stride-to-stride gait variability.

The knee extensor strength increased in one participant and was reduced in the other three after TWT. However, these changes are smaller than the minimal detectable change (ranging from 21 to 55 N or 28% change from initial value) for knee extensor strength reported in the literature.³⁰⁻³² The lack of detectable change in knee extensor strength in this study concurs with the results of a previous study that reported no significant improvement in knee

extensor strength after 8 weeks of low-intensity aerobic exercise among sedentary older adults.³³

The mechanisms underlying TWT effects on overground walking is not well understood. Treadmill walking training may stimulate reorganization in the central nervous system^{34,35} or activate cortical areas involved in walking such as the prefrontal cortex.³⁶ The gait changes occurring within a short period (eight weeks) with relatively low exercise intensity in our study, and no significant improvement in muscle strength favors neural mechanisms rather than solely a musculoskeletal or cardiovascular training effect.

Strengths of this case series include the weekly quantitative gait assessment with standardized protocol and minimal missing sessions. The main limitation of this study is small sample size, and our findings should be considered exploratory and used as guide to design studies of larger scale. Inclusion of morbidly obese individual could have affected the result. Although morbidly obese individual was able to complete all 24 training sessions, the size of improvement was relatively less than another participant with similar baseline gait velocity. It is possible that the overall effect of TWT on gait performance of frail older adults in this study might be underestimated by including the result of this morbidly obese participant. Other limitations include subjective assessment of grip strength and level of physical activity, however, similar subjective assessments were used to define frailty criteria in a previous study.³⁷

CONCLUSION

Treadmill walking training is well tolerated and may improve gait performance among frail older adults. These findings can help design future studies to determine the optimal training period to improve gait as well as to design focused interventions for specific gait parameters in frail seniors.

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FIGURE 1.
Change in gait velocity of overground walking for each participant and mean peak training velocity over the training period.

Table 1
Demographics, Clinical Characteristics, and Gait Parameters of Pre and Post Treadmill Training

Participants	Age	Sex	BMI	Medical History	Knee extensor strength (N)		Velocity (cm/sec)		Stride length (cm)		Swing time (msec)		Double support (%)		COV of stride length (%)	
					Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	81	F	27.9	None	163.7	152.1	98.4	125.2	107.6	120.9	0.40	0.37	29.8	21.4	4.8	4.2
2	74	F	44.0	HTN, obesity	167.6	180	95.5	103.9	113.6	119.1	0.39	0.37	40.4	37.4	3.1	4.1
3	72	M	29.0	HTN, CAD, gout	190.0	171	64.6	84.2	86.5	105.7	0.45	0.45	42.0	35.5	3.3	3.5
4	74	M	23.6	HTN, gout	264.6	247.5	62.8	69.2	94.6	98.4	0.53	0.50	44.3	36.8	3.8	4.0

Abbreviation: BMI, body mass index. COV, coefficient of variation. Pre, pre training. Post, post training. HTN, hypertension, CAD, coronary artery disease. All gait parameters were for overground walking at usual pace.