Immediate effect of rhythmic auditory stimulation on the spatio-temporal parameters of gait in old people: a pilot study

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Abstract

Objectives: Evaluate the immediate effect of rhythmic auditory stimulation (RAS) with music on the spatio-temporal parameters of gait in sedentary old people and analyze possible interactions with episodes of falls. *Methods:* Pilot intervention study with sedentary old people (n= 15), age ≥60 years, both sexes, independent in gait. Additionally, participants were divided into two groups, *fallers* (n= 5) and *non-fallers* (n= 10), based on the history of falls in the last year. The evaluation of the spatio-temporal parameters of the gait was performed using the 10-meter walk test performed with free walking (T0), repeated with RAS with music (T1), and without RAS again (T2). For data analysis, repeated measures ANOVA and two-way ANOVA were used for comparison between groups, with Tukey's *post hoc*. The effect size of the intervention was also calculated. *Results:* There was a significant reduction in time and number of steps and an increase in walking speed ($p<0.0001$; with great effect) between moments T0-T1 and T0-T2. Both the *faller* and *non-fallers* groups showed a significant reduction in time and number of steps ($p<0.0001$) and an increase in speed ($p<0.0001$), but only in the cadence variable was there an effect of the group and of time and group interaction. *Conclusion:* There was an immediate positive effect of the use of RAS on the space-time parameters of gait in sedentary old people, with a greater effect on the cadence of *non-falling* old people.

Keywords: Health of the Elderly. Gait. Acoustic stimulation. Music.

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INTRODUCTION

Due to the demographic transition, Brazil has an increasingly aging population with the prospect of reaching the mark of 41 million old people in the year 2030[1]. Accompanying this growth, concerns about the difficulties that affect this age group also increase[2]. The limitation of physical independence is one of the greatest fears during the aging process, being one of the factors that can make old people more and more dependent[1-3]. Decreased agility, altered muscle strength, decreased functional capacity, changes in gait and loss of balance are factors that can contribute to mobility problems[4].

Changes in mobility are manifested in the form of instability when walking, difficulty in sitting and getting up from a chair, among others, closely related to changes in gait that are easily identified in the old people population[5]. The reduction in gait speed, the decrease in stride length and the reduction of cadence, can occur in pathological conditions or in physiological changes related to aging[6,7], increasing the risk of adverse mobility results, including falls[8,9].

It is estimated that about a third of the old people fall at least once a year. The annual fall rate is between 28-35% in the population over 65 years old and this prevalence increases among old people 70 years old or more to 32-42%[10]. Studies on fall profiles show that the decline in gait speed is proportional to the increase in age, in which individuals aged 70 years or more have significant reductions in gait speed when compared to individuals aged 40 to 59 years old[7,11]. Deficit and gait disorders are important factors to be studied for the prevention of falls and their consequences[12]. With this, it is perceived the need for effective strategies in prevention, in the control of health problems, rehabilitation measures and incentive to active participation in improving health so that it is possible to add quality to additional years of life[13].

A form of gait therapy for old people that has been recently implemented is training with rhythmic auditory stimulation (RAS), presenting itself as an area of emerging interest that is still underestimated in this population. RAS uses rhythmic techniques, such as hand clapping, musical beat and metronome as auditory cues that synchronize auditory-motor responses and have been used mostly as a strategy in the rehabilitation of gait disorders[14-17]. However, the effects of external rhythmic cues on specific gait parameters in sedentary old people, as well as their relationship with episodes of falls, are not yet clear and deserve further investigation. Therefore, this study aimed to evaluate the immediate effect of RAS with music on the spatio-temporal parameters of gait in sedentary old people and to analyze possible interactions with episodes of falls.

METHODS

This is a pilot intervention study (immediate effect), carried out between August and December 2019, with participants from the Health of the Old People Project at the Hospital Regional Belarmino Correia (PSI/HRBC), Goiana, Pernambuco (PE), Brazil. The Health of the Old People Project was implemented in 2017 as an initiative that aims to monitor the aging process through health actions aimed at improving the quality of life, given the need for specialized care aimed at this population. The project's activities aim to prevent injuries and promote the health of old people through multidisciplinary care.

The base population registered with the PSI/HRBC in 2018, was composed of 300 participants according to the medical file sector. The selection of subjects and the verification of eligibility for the study was carried out in the geriatric consultations that take place once a week at the clinic. The sample was selected for convenience. Twenty old people were interviewed, among whom, five were excluded for not meeting the eligibility criteria. Thus, 15 old people were included in the data analysis (5% of the base population) and later divided into two groups, fallers (n=5) and non-fallers (n=10).

Old men and women, aged ≥60 years, physically inactive, with the ability to move independently, without medical contraindications for walking, with the ability to understand instructions and active participation in tasks, were included, considering the scores of Mini Mental State Examination (MMSE) corresponding to their level of education[18,19].

Exclusion criteria were: old people who had neurological diseases, orthopedic, rheumatic and/or vascular pathologies that led to moderate or severe functional restriction in one or both lower limbs, with a history of fracture in the last year, labyrinthitis and/or uncontrolled or severe vestibulopathy, hypertension and/or uncontrolled heart disease. Also excluded were old people with visual impairment that led to moderate or severe functional restriction, such as deafness or with moderate or severe difficulty in listening to music. Other disorders of the external ear that were seen in the routine of the consultation with the service's geriatrician were also considered.

Participants were instructed on their collaboration in the research and study objectives, as well as the risks and benefits, issuing their formal consent by signing the Informed Consent Form. All stages of the study followed the guidelines of the resolutions of the National Health Council No. 466 of 2012 that govern research involving human beings. The project was approved by the Human Research Ethics Committee of the Federal University of Pernambuco (CAAE: 17868719.5.0000.5208).

Initially, information on age, sex, education, fear of falling (with the possibility of answering yes or no) and the history of falls in the last year were collected, which was used to divide the old people into two groups, fallers and non-fallers.

To assess the level of physical activity, it was asked if the old person had practiced any type of physical exercise and/or sport in the last three months and how often. Old people who answered 'no' were considered physically inactive. After this stage, the participants were sent to the outpatient corridors to carry out the analysis of the spatio-temporal parameters of the gait, using the 10-meter walk test (10mwt).

The 10mwt is an instrument used for kinetic and kinematic analysis of gait that consists of walking during a 10-meter (m) course, which initial 2m is for acceleration, 6m for walking at normal speed and 2 m for deceleration. The patient was instructed to walk on a flat surface, in a straight line and at a comfortable pace. The test has good reproducibility and reliability (Intraclass Correlation Coefficient =0.86, with an average difference of −0.03±0.16 m/s and the 95% Bland and Altman agreement limits for the mean difference were −0,33 to 0.27) 20, in addition to being a simple measure, of quick execution and with a prognostic factor of the risk of falls in old patients.

For the analysis of the variables of time and number of steps, the central 6 meters were considered, in which the components of acceleration and deceleration of the gait were discounted. The evaluator used a 1/100s digital stopwatch (Poker Ergo Digital, REF 08089-2018®, Montenegro, RS, Brazil), to get the walk time for the volunteers. The number of steps was counted during the test and a camera was positioned to assist in confirming the capture of the number of steps. The cadence, expressed in steps / second, was calculated by dividing the total number of steps (P) by the time (T) in seconds, spent on the route. Multiplying by 60 [C=P/Tx60] was performed to select the song whose frequency is expressed in beats per minute (bpm). The speed was calculated by dividing the total distance (D) by the time (T) spent in seconds to complete the route and multiplied by 60 [V= D/T x 60][21].

Participants performed an initial take of the 10mwt to familiarize themselves with the test and knowledge of the route. After this phase, the steps of the experiment were carried out. Sequentially, the old people performed the 10mwt without stimulation to measure the variables (T0 - without RAS). Then they performed the same test with rhythmic auditory stimulation with music, in which the same variables were measured (T1 - with RAS). Finally, they performed the 10mwt without stimulation (T2 - without RAS). In each 10mwt outlet, three measurements were made sequentially, namely: T0 (T01, T02 and T03), T1 (T11, T12 and T13) and T2 (T21, T22 and T23), the final result of each outlet being obtained through the arithmetic mean of the three measurements at each moment.

The tests were carried out in a single meeting, successively, with a resting time of 1 minute between the measurements of the space-time parameters of the gait, so that there was a return to the initial condition of the test. If necessary, the rest time could be increased. However, no old person presented this need and all were able to carry out the nine measurements, taking an average of 20 minutes between the explanation and the tests.

The RAS used was composed of musical tracks with a marked and constant rhythm provided by the ParkinSONS® app using a smartphone, Android operating system. The app was developed by the research group Pró-Parkinson (Registration with the National Institute of Intellectual Property - INPI, nº BR512020001451-8) and is in the process of commercialization. The comfortable cadence obtained in the 10mwt was used as a parameter for selecting the RAS for stage T1. The comfortable cadence was increased by 10% to obtain the training cadence, enabling the selection of music for the RAS. The regional musical rhythms provided by the app present the frequencies 70 bpm, 80 bpm, 90 bpm, 100 bpm, 110 bpm and 120 bpm, which can be selected individually for each participant. The sound intensity offered was approximately 75 dB HL (decibel hearing level), a level above that perceived by old people with mild to moderate peripheral hearing loss, verified by audiometry, which is around 30 to 70dB HL[22]. Connected supra-aural headsets were used simultaneously by the old person and therapist to guarantee the performance of the test in the selected training cadence. In addition, a check was made to listen to the music and understand the test before it was performed.

The RAS provides patients with a temporal orientation that facilitates the regulation of their movements during walking. This is because the auditory and motor systems have rich connectivity at various cortical, subcortical and spinal levels. The auditory system - a fast, accurate and temporal information processor - projects itself into motor structures in the brain, creating a connection between the rhythmic signal and the motor response[23]. Therefore, it is recommended the early incorporation of rhythmic auditory cues with time variations of ± 10% in relation to the preferred cadence to improve gait performance. With the RAS customized for the individual's cadence, the speed that can be achieved is respected and, at the same time, it encourages and encourages the improvement of their gait pattern[15,17,23].

The data were tabulated in a Microsoft Excel spreadsheet and compiled using descriptive statistics and processed using the Statistical Package for the Social Science software version 20.0 (SPSS Inc, Chicago, IL, USA). The normality of the data was confirmed through the Shapiro-Wilk test. To evaluate the differences between the measures for the total sample, an ANOVA of repeated measures was used. The two-way ANOVA with repeated measures was used to compare the outcome variables considering the group (fallers vs. non-fallers) and time (T0, T1 and T2) as comparison factors followed by the Mauchly sphericity test and if necessary Greenhouse-Geisser correction was applied. In both analyzes, Tukey's post hoc was used to spot differences and considered $p < 0.05$. The size of the immediate effect of RAS with music on the spatio-temporal parameters of gait was also calculated using the Hedges test (g), with its values classified as: insignificant (<0.19); small (0.20-0.49); medium (0.50-0.79); large (0.80-1.29) and very large (>1.30)[24].

RESULTS

Sociodemographic data, study time and the survey on falls are shown in Table 1. The average age was 71.3 ± 6.45 years, with a minimum age of 65 and a maximum of 83 years. In the sample, 33% of the old people reported having suffered a fall episode in the last year and 73% expressed the fear of falling, whether they were fallers or not.

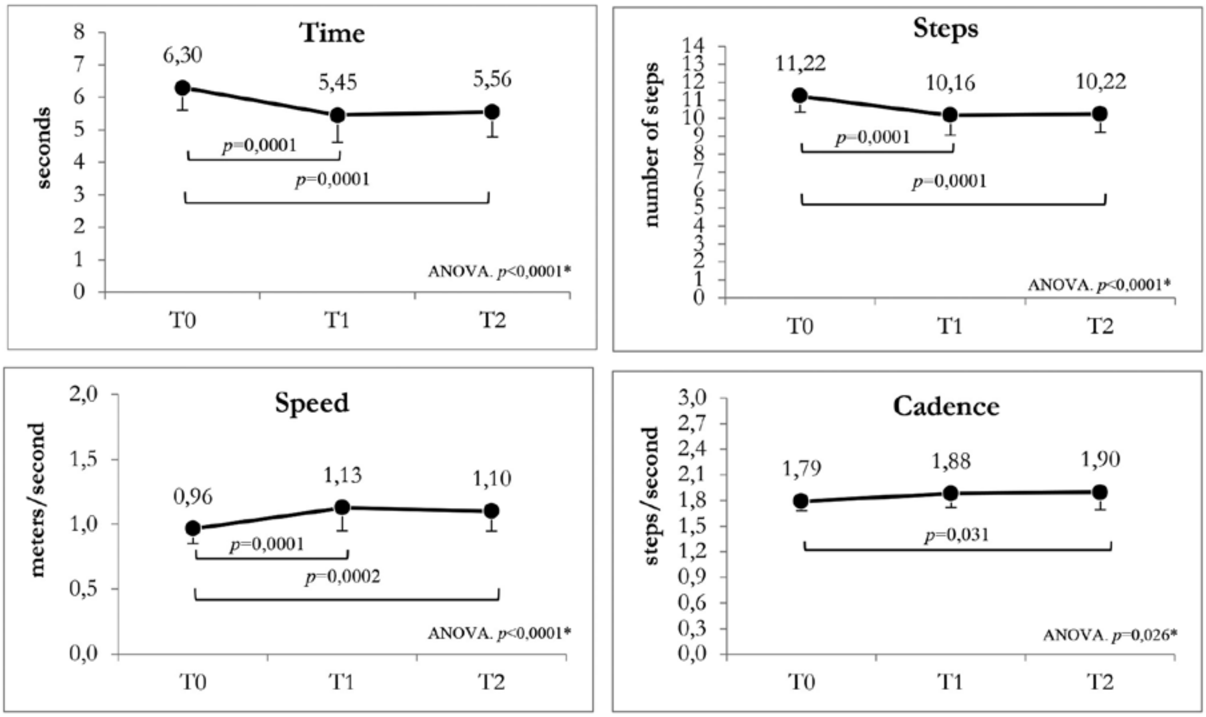
The results regarding the effect of the RAS effect with music on the spatio-temporal parameters of the gait of the old people were presented in Figure 1 and the analysis of the effect size in Table 2. There was a significant reduction in the walking time in the 10mwt (ANOVA. $P<0.0001$). The post hoc indicated that the time to perform the gait on the 10mwt reduced significantly between moments T0 and T1 (-0.85sec), with a large effect size (g=1.07), and this effect was maintained in T2. Regarding the number of steps, there was a significant reduction (ANOVA. $P<0.0001$). In the post hoc test, significant reductions were observed between T0-T1 and between T0-T2, with a large effect (g=1.03

and g=1.02, respectively). In the speed parameter, ANOVA indicated a significant increase (p<0.0001). The post hoc indicated a significant increase in speed between T0-T1 with the maintenance of this large effect (g=1.05) in T2. As for cadence, it was possible to verify a significant increase (ANOVA. P=0.026*). The post hoc indicated a significant increase between T0 and T2 with large effect size (g=0.97).

Table 1. Characterization of the sample of users of the Health for the Old Person Project(n=15). Goiana, PE, 2019.

Characteristics	Median (sd)	
Age	71.3 ± 6.45	
Years of education	3.67 ± 3.92	
Sex	n (%)	
Female	7 (46.7)	
Male	8 (53.3)	
Survey on falls	Yes n (%)	No n (%)
Falling episode (faller)	5 (33)	10 (67)
Fear of Falling	11 (73)	4 (27)

sd = standard deviation



Repeated measures ANOVA with Tukey's post hoc; T0: initial walk test as an evaluation parameter without Rhythmic Auditory Stimulation; T1: walk test using Rhythmic Auditory Stimulation and T2: final walk test as a reevaluation parameter without Rhythmic Auditory Stimulation.

Figure 1. Repercussion of the immediate effect of rhythmic auditory stimulation with music on the spatio-temporal parameters of gait in old people (n=15). Goiana, PE, 2019.

Table 2. Size analysis of the immediate effect of rhythmic auditory stimulation with music on the spatio-temporal parameters of gait in old people (n=15). Goiana, PE, 2019.

Space-time gait parameter	g of Hedges		95% CI	Effect Size Classification
Time	T0 vs T1	g= 1.07	[0.31 - 1.81]	Large
	T0 vs T2	g= 1.07	[0.31 - 1.81]	Large
	T1 vs T2	g= 0	[-0.70 - 0.70]	Insignificant
Steps	T0 vs T1	g= 1.03	[0.28 - 1.77]	Large
	T0 vs T2	g= 1.02	[0.27 - 1.76]	Large
	T1 vs T2	g= -0.06	[-0.76 - 0.64]	Insignificant
Cadence	T0 vs T1	g= -0.63	[-1.34 - 0.09]	Medium
	T0 vs T2	g= -0.64	[-1.35 - 0.08]	Medium
	T1 vs T2	g= -1.07	[-0.80 - 0.60]	Large
Speed	T0 vs T1	g= -1.05	[-1.79 - -0.30]	Large
	T0 vs T2	g= -0.97	[-1.71 - -0.23]	Large
	T1 vs T2	g= 0.10	[-0.54 - 0.85]	Insignificant

CI: confidence interval; T0: initial walk test as an evaluation parameter without Rhythmic Auditory Stimulation; T1: walk test using Rhythmic Auditory Stimulation and T2: final walk test as a reevaluation parameter without Rhythmic Auditory Stimulation.

Table 3 presents the results of the repercussion of the RAS on the spatio-temporal parameters of gait in the falling and non-falling groups. In both groups, there was a significant reduction in time [$F_{(2,26)}$=21.00; p<0.0001] and number of steps [$F_{(2,26)}$=24.23; p<0.0001] and increase in speed [$F_{(2,26)}$=17.68; p<0.0001], no effect of group or interaction (ps> 0.05).

On the cadence variable, there was an effect of the group [$F_{(1-13)}$= 5.36; p=0.037], indicating a significantly higher cadence in the non-falling group. In addition, there was an effect of the time x group interaction [$F_{(2,26)}$=4.66; p=0.018], where the post hoc pointed out that the cadence increased only in the non-falling group between T0 and T1 (p=0.024) and between T0 and T2 (p=0.004) (Table 3). The Mauchly test indicated that the sphericity of the cadence data was not violated (X^2=4.83; p=0.089), and it was not necessary to apply Greenhouse-Geisser correction.

Table 3. Repercussion of the immediate effect of rhythmic auditory stimulation with music on the spatio-temporal parameters of gait in the falling (n=5) and non-falling (n=10) groups. Goiana, PE, 2019.

Variables	Condition	T0	T1	T2	*p*-value T	*p*-value G	*p*-value TxG
Time	Fallers	6.57 ± 0.25	6.02 ± 0.25	5.95 ± 0.62	<0.0001[a]	0.119	0.260
	Non-fallers	6.16 ± 0.81	5.17 ± 0.89	5.36 ± 0.81			
Steps	Fallers	11.67 ± 0.53	10.53 ± 0.77	10.47 ± 0.84	<0.0001[a]	0.316	0.692
	Non-fallers	11.00 ± 0.97	9.97 ± 1.23	10.10 ± 1.11			
Cadence	Fallers	1.78 ± 0.09	1.75 ± 0.13	1.74 ± 0.12	0.146	0.037	0.018
	Non-fallers	1.80 ± 0.12	1.94 ± 0.14*	1.98 ± 0.20**			
Speed	Fallers	0.91 ± 0.04	1.00 ±0.04	1.02 ± 0.12	<0.0001[a]	0.084	0.100
	Non-fallers	0.99 ± 0.13	1.19 ± 0.18	1.14 ± 0.16*			

Two-way ANOVA with Tukey's post hoc, followed by the Mauchly test; [a]effect of time, indicating a reduction in the time and steps parameters and an increase in the gait speed parameter in both groups. *effect of the group, indicating an increase in cadence between moments T0 and T1* and T0 and T2** only in the non-falling group; T0: initial walk test as an evaluation parameter without Rhythmic Auditory Stimulation; T1: walk test using Rhythmic Auditory Stimulation and T2: final walk test as a reevaluation parameter without Rhythmic Auditory Stimulation; T = effect of time; G = group effect; TxG = interaction between group and time effects.

DISCUSSION

The present study investigated the immediate effect of RAS with music on the spatio-temporal parameters of gait in sedentary old people. The results show a significant reduction in the time and number of steps and an increase in the speed and cadence of the gait when the old people perform the route using the RAS resource with music (T0 vs T1). The effect tended to remain when the route was taken again without the use of the resource (T0 vs T2), which may indicate that the RAS with music had an immediate positive effect on the spatio-temporal parameters of the gait of these old people.

It is known that gait speed is an important indicator for its ability to predict adverse events such as loss of independence, increased disability, functional limitations, falls, hospitalizations and death. Physiological aging is responsible for a 1.2% reduction in gait speed annually[25]. One of the most affected systems is the neuromuscular with the loss of alpha motor neurons in the spinal cord, with the deterioration of their axons and consequent attenuation in the recruitment of motor units, resulting in limitations in the functioning of these systems, impacting the performance and speed of gait in old people[26].

A key concept of RAS is auditory-motor synchronization through the spinal reticulum. As a neurophysiological explanation, the activation of the motor areas of the brain using stimuli with rhythm can increase the excitability of spinal motor neurons, reducing the substantial time for the muscles to respond to a motor command, improving muscle activation and control of movements influencing the speed improvement[21,27].

The study by Wilson et al.[28] suggests a clinically significant difference> 0.05m/s, which was obtained during the comparison of gait speed between different tests. The average speed increase of 0.17m/s (T0 vs T1) and 0.14m/s (T1 vs T2) was higher than the one considered clinically significant, also verified by other authors in studies with RAS[21,29].

The reduction in time, the increase in cadence and speed in walking, observed in this study reflect a qualitatively better gait[29]. These parameters showed a significant improvement indicating that the natural rhythmic movements of the gait can be corrected through synchronization processes and external attention promoted by RAS[30]. During the aging process, the gait ceases to be carried out automatically, with greater compensatory executive control. With the use of auditory stimulus, the neuromuscular system can perform the action with less conscious control and allowing for smoother movements, which can result in improved gait[31,32].

The results also showed that the spatio-temporal parameters of gait in old people were positively influenced with the use of the auditory stimulus, with an improvement that remains even without the auditory stimulus (T2). It is possible to observe a possible motor learning provided by RAS, promoting an indicative of immediate effect that remained after the test was carried out without the presence of the stimulus that may be related to the somatosensory system. The somatosensory system of the motorways is also responsible for the coordination and perception of the body and environmental status that are essential for movement control. The use of rhythmic-sound beat excites the auditory-motor pathways to create a quick connection leading to a temporal synchronization between the sensory input and motor output mechanisms, reconfiguring this system through neuroplasticity[16,33]. Thus, it promotes an increase in rhythmic awareness, allowing to increase concentration, attention and the ability to perceive both the direction of movement and the speed of the movements performed, reflecting in the improvement of gait parameters[34].

Another hypothesis to be considered to explain the findings is the old person's learning curve in the face of repetitions at each moment of the test that would be independent of the RAS offer. However, two arguments can refute this hypothesis. First, it would be expected, in this case, to observe significant differences between all moments (T0 vs T1; T1 vs T2 and T0 vs T2) demonstrating the learning related to progressive improvement in performance with the increase of repetitions, which did not occur. The second point concerns the modulation of the gait rhythm provided by the RAS at T1, where the old people were offered a stimulus with an increase of 10% in their comfortable walking cadence, which favored the performance during the offer (T1 moment) and its maintenance (moment T2). However, the absence of a control group and other studies in the literature does not allow us to completely exclude the effect of time (repetition/learning), making this finding to be interpreted with caution.

A review study showed that changes in space-time parameters improve gait variability, which is important in preventing falls. The gait variability found in the old people population has been associated with an increased risk of falling and thus, the greater rhythmicity that is promoted by the RAS has been shown to reduce the variability in the musculoskeletal activation patterns, thus allowing acceleration of joint movements, reducing the time of gait and increasing speed[15].

Both in the fallers group and in the non-fallers group, a significant reduction in time and number of steps was observed, as well as an increase in walking speed when the old people perform the route using the RAS with music (T0 vs T1). The effect was maintained when the route was taken again without the use of the resource (T0 vs T2) which indicates that the RAS with music promoted an immediate positive effect on these parameters regardless of the history of falls. However, when comparing the groups, we observed that the non-fallers group performed significantly better than the fallers group in all the gait parameters analyzed, pointing to the possibility that the history of falls also influences the benefits obtained with interventions like this. The absence of comparison with other variables that could explain or interfere in this relationship leads us to be cautious in the interpretation of these results, which should be analyzed in future studies.

All old people who are fallers in the sample reported the fear of falling. Some authors report that the fear of falling has a negative effect on the gait of old people, with estimates of the frequency of falls varying between 29% and 77%[35]. Hadjistavropoulos et al.[35] presented a model representing strong associations between fear of falling and reduced balance, impairing gait performance in old people. Only one study investigated the effect of using RAS to prevent falls, this being in the population with Parkinson's disease[17]. The results indicated that gait training with RAS reduced the number of falls and modified gait kinematics in falling individuals with Parkinson's disease (with an increase in gait speed and stride length).

The use of the RAS strategy showed good viability, low cost, easy application and encouraging results regarding the immediate effect in this sample. However, it is worth mentioning that an uncontrolled pilot study limits the generalization of results that must be interpreted with caution. We recommend conducting clinical trials that can investigate the effect of using this strategy on gait and the possible repercussions on the daily activities of sedentary old people.

We emphasize that the theme is new and relevant, and similar studies with the use of RAS in the sedentary old population are not found in the national literature. We also consider that the strategy has potential for use in other areas besides physical therapy in the context of intervention in rhythmic functional activities.

CONCLUSION

This pilot study points to an immediate positive effect of the use of rhythmic auditory stimulation on the space-time gait parameters of sedentary old people, especially gait speed, which is an important indicator for predicting adverse events such as falls and changes in functionality. There was a better performance in the parameters of time, speed and gait cadence of non-faller old people submitted to RAS. However, clinical trials are needed to investigate the effects of this strategy on healthy aging.

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