

A Pilot Design for a Modified Tap Dance Program for Ankle Function Improvement and Fall Prevention

Qianwen Wang¹, Yanan Zhao^{2,*}

Physical Education, Nanjing Normal University, Nanjing, China

*Corresponding author: zhaoy125@qq.com

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Abstract This study was to record a preliminary design for a 12-week modified tap dance program (MTD) for ankle function improvement among older adults. Four steps were included in the formation of this program, including 1) Training principles, 2) Selecting and modifying elements, 3) Identifying ankle function and ankle function-related fitness, 4) Adjusting based on experts and end-users' evaluations. This design will be implemented as a targeted exercise into a randomized controlled trial (RCT) clinical study to evaluate its efficiency and feasibility among older community-dwellers.

Keywords: ankle function, falls, modified tap dance, balance, aging

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1. Introduction

According to the World Health Organization, about 666,000 fatal falls occur each year, of which more than 80% occur in low- and middle-income countries, which is the second largest cause of personal accident deaths after traffic accidents. 20-30% of the elderly suffer from moderate to severe injuries such as bruises, hip fractures or head trauma due to falls in the United States. Moreover, the economic impact of falls is critical to family, community, and society. Healthcare impacts and costs of falls in older age are significantly increasing all over the world. The average health system cost per one fall injury episode for people 65 year and older in Finland and Australia was US\$ 3611 (originally AUS\$ 6500 in 2001-2002) and US\$ 1049 (originally in €44 in 1999) respectively [1]. With the rapid aging of the world's populations, falls in older adults are a significant public health issue.

Falls occur as a result of a complex interaction of risk factors. The main risk factors reflect the multitude of health determinants that directly or indirectly affect well-being. Those are categorized into three dimensions: physical, psychological, environmental and socioeconomic factors. Physical factors embrace characteristics of individuals that are pertaining to the human body, including lack of physical activities [2], visual deficits [3], balance deficits [4], muscle weakness [5], gait impairment [6], cognitive impairment [7].

Fortunately, Speachley and Tinetti [8] have shown that even adjustments to a risk factor have important therapeutic and practical implications. This study focus on

improving ankle function. Gatev [9] has provided evidence that body sway in quiet standing is like the motion of an inverted pendulum pivoted at the ankle joint. The use of the ankle strategy in balancing a large inverted pendulum equivalent in mass and inertia to a human body. Choi [10] demonstrated that postural sway increased linearly with age. Thus, ankle function acts an essential role in maintaining static balance.

Ankle function includes the muscle strength and range of motion. Moreover, the combination of foot, tendon and muscle determines the intrinsic stiffness of the ankle joints [11]. Advancing age accompanied with reduced ankle muscle strength and joint movement [12], which weaken the intrinsic stiffness of ankle function and eventually trigger a fall in the older adults. Toosizadeh [13] suggested that ankle muscles can improve balance via reducing body sway during standing in elderly persons prone to balance malfunctions.

Ankle range of motion is also an important predictor of physical function in older adults and age-related decline in ROM is greater in women than men at the same age [14]. Nodehimoghadam and his colleges [15] also agreed that reduced ankle ROM, as a natural consequence of the muscle-tendon unit and surrounding connective tissue stiffness with aging has been considered as a major cause of falls, which will limit the elderly perform jog [16], upstairs [17] and other functional activities.

Above all, ankle function is related to maintain balance and reduce risk of fall in older adults. A great number of functional trainings have focused more on strength than flexibility. This study applied modified tap dance program to comprehensively improve ankle function in older adults and enhance their functional fitness.

At present, the main interventions to improve ankle function include: 1) balance training; 2) joint mobilization training; 3) strength training; 4) stretch. Many studies have proved that balance training can improve ankle function and reduce fall risk at the same time [18,19]. Joint mobilization training focuses on improving the mobility of the ankle joint and has less effect on increasing strength [20,21]. Strength training was proved to be effective in improving strength and perceived ankle instability. However, even with strength gains and the patients' reports of greater stability in the ankle, improvements in functional performance and dynamic balance were limited [22], Mckeon and Wikstrom [23] indicated that stretch training can enhance ankle range of motion. Many studies have shown that effective interventions should include targeted strength and activity training content, plus multi-task functional training content to improve ankle function comprehensively [24].

Dancing is regarded as a low to moderate intensity physical activity that has been recommended as a therapy to improve physical ability, including positive changes in bone mineral content, aerobic capacity, strength, balance, and gait speed [25]. In addition, dancing programs have been known for encouraging interaction among older adults with quotidian lives due to the incentive of enjoyment and pleasure.

Tap dance requires the dancers to use different parts of the ankle to strike the floor to express different emotions and rhythms. Compared with other common sports activities (such as square dance and Tai Chi), the tap dancers pay more attention to the comprehensive development of ankle function.

Resnick and Spellbring [26] pointed out that the main reason for most elderly people to give up participating in sports is the lack of interest and fear. MTD is one of the dance therapy that is different from other traditional dance program. One of its advantage is that the elderly can experience the joy and sense of accomplishment in the process of step-by-step training [27]. On the other hand, dance program may reasonably be expected to produce measurable improvements in balance and subsequently reduce the risk of falling by virtue of strengthening muscles and improving flexibility. In Granacher's study [28], age-related deficits in measures of static and particularly dynamic postural control can be mitigated by salsa dancing for eight weeks in older adults.

In addition, tap dance generates relatively low ground reaction forces and joint forces that contributes to less injuries [29]. Mayers and her colleges found an apparent lower injury occurrence rate in tap dancers compared to other dance and athletic activity [30]. Nilsson reported a mean of 3.8 injuries/dancer during a five-year observational period with a calculated occurrence rate of 0.62 injuries/1000 hours of ballet dance. Foot and ankle injuries comprised 54% of the total. [31], however only 0.31 injuries/1000hours occurred in the most experienced tap dancer [30].

Therefore, MTD may not only directly improve ankle function, but also improve the balance ability of the elderly. [27,32,33,34].

Purpose of this study was to describe the development of a 12-week modified tap dance program (MTD) for ankle function improvement and falls prevention among

older non-fallers. Results from this study can enrich the current literatures related to the development of exercise program for ankle function improvement and falls prevention.

2. Design Procedure

Four steps were included in the formation of this program, including: 1) Training principles, 2) Selecting and modifying elements, 3) Identifying ankle function and ankle function-related fitness, 4) Adjusting based on experts and end-users' evaluations.

2.1. Training Principles

2.1.1. Ankle Function Targeted

Most movements were selected to improve ankle muscle strength by standing still on toes, implying weight-loaded training with different duration in tandem stance, lifting up and down on toes and other movements. Improving ankle joint mobility by stretching full range of motion of ankle.

2.1.2. Training Strategy

The delivery process of the 12-week MTD is suggested to include three stages based on the classic learning stage model [35], they are the cognitive stage (week 1 to 4), the associated stage(week 5 to 10), and the autonomous stage (week 11 to 12). Thus, different training strategies are required to corresponding training stages. In the cognitive stage, the main strategy would be emphasized with careful guidance and active encouragement to inspire participants understand and learn the MTD. Moreover, stimulating participants' interest to attend the training sessions is important as well. In the associated stage, correcting their unqualified movements would prevent participants from hurting their knees or ankle joints and enhance the effectiveness of MTD. For example, to help participants to reach certain angle of plantar flexion, a tutor may hold participants' ankle at the required ankle to give him/her a sense of ankle position. In addition, adopting evaluations from each other besides from tutor will enhance their comprehension in movements and routines. In the autonomous stage, a number of repeated practice need strengthening memory and increasing movement quality during this time.

2.2. Selecting and Modifying Elements

MTD mainly focus on ankle movements. Movements in ankle and the lower extremities including striking the floor with tiptoes or heels, walking on toes, digging, cramping, hopping, straightening or bending knees, pointing the toes, which is revised from the basic steps in tap dance. The basic movements in the upper limbs included, waving arms, bending arms, clapping hands. The upper limb's movements were secondary to the lower extremity movements with the main purpose to increase the complexity and organization of movements. Basic elements have been selected based on their function which were evidenced in previous studies [29].

Considering the physical condition (poor learning ability and memory) of older adults, all the elements from tap dance have been adjusted to less complex by slowing speeds, disassembling the intricate movements, substituting the dangerous movements. However, all these movements were choreographed using different directions, speeds, and ranges, in accordance with the various requirements for physical training.

2.2.1. Routines

All the elements originating from basic steps were combined into eight routines, including Step (Routine 1), Multi-angle of ankle movement (Routine 2), Switching of toes and heels (Routine 3), Digging and cramp roll (Routine 4), Touch (Routine 5), Multi-directional revised paddle (Routine 6), Hopping in single leg stance (Routine 7), and Jumping forward and shuffle step (Routine 8).

2.3. Identifying Ankle Function and Ankle Function Related Fitness

2.3.1. Evaluations on Ankle Function Abilities

Ankle strength was evaluated using the sit-to-stand test. Time is taken to rise from a 43-cm-high chair 5 times without using the arms as fast as possible [36].

A standard goniometer was used for measuring passive range of motion of ankle joints. Each measurement was repeated twice to allow evaluation of reliability. The right and left ankle joints were assessed for each participant. The mean of the two measurements was considered as the joint motion value. Participants were seated on a treatment table with the knees fully extended (0°) and the feet hanging off the end of the table. For each ROM measurement, the participant was completely relaxed; the investigator passively moved the ankle into dorsiflexion from a neutral starting position (ie, 90 °angle between shank and foot segments) until a firm end feel was elicited. The axis of the goniometer was centered over the lateral malleolus and the arms were aligned with the fibular shaft and the head of the fifth metatarsal.

2.3.2. Evaluation on Ankle Function-related Fitness

Given the close relationship mentioned above, balance ability and functional fitness in older adults were tested in this study [37]. Balance test in this study was measured by using an available balance device, the RS Footscan system (RS; Medical Systems, Belgium) and functional fitness was assessed by using the Senior Fitness Test (SFT) battery [38].

Balance Test

The RS consists of a force plate that is interfaced with a computer software (Footscan Balance, Version 7), which enables it to serve as an objective assessment of balance. The BBS can measure static balance.

Participants are required to stand barefoot on the platform, with hands at their sides, eyes open or closed and looking straight ahead. Tests are ended if their legs moved. Four tests were adopted in this study.

Test 1: Participant stands on the center of the plate, and his legs are closed in a way that both of his heels and toes are touching. Posture is upright, head straight, hands on hips and eyes opened.

Test 2: Participant stands on the center of the plate, and his legs are closed in a way that both of his heels and toes are touching. Posture is upright, head straight, hands on hips and eyes closed.

Test 3: Participant is placed lengthwise on the board, so that his feet are completely on the board, right feet in front of left feet, toes of left leg touching the right heel. Posture is upright, head straight, hands on hips and eyes opened.

All test lasts 33 seconds [39].

Functional Fitness

SFT battery is used to assess the five dimensions of physical fitness, which including six test items:

- 1) 30-s chair stand for lower limbs' muscle strength,
- 2) 30-s arm curl for upper limb muscle strength,
- 3) 2-min step test for aerobic endurance,
- 4) chair sit-and-reach test for lower body flexibility,
- 5) back scratch test for upper body flexibility,
- 6) 8 foot up-and-go test for mobility and dynamic balance

[38].

2.4. Adjusting Based on Experts and End-users' Evaluations

2.4.1. Expert Consultation

The main purpose of the expert consultation was to complete the MTD considering their professional knowledge and experience in related areas. The qualified experts meet following requirements: 1) having more than 5 years of working experience in a related area of tap dance teaching, and 2) having professional knowledge on ankle function improvement. Finally, two experts were accepted the invitation to provide their evaluations in terms of consistency, safety, suitability and gracefulness about MTD. One round of consultations were conducted with a month apart. The first round was conducted to gather detailed opinions and advice from the two experts before the study. Then, during the round two, assessments were made using the Likert 5-point scale (i.e., very bad =1, bad = 2, neutral = 3, good = 4, and very good = 5). They were required to give suggestions for each item with a score less than four (Pass: mean score \geq 4, and Fail: mean score $<$ 4). Modifications were then conducted following their feedback.

All the numbers listed in Table 1 were the average values given by the experts. The comparatively low values were presented in the safety and gracefulness of Routine 1, the suitability of Routine 5 & 6. Other values in corresponding items were all over 4, indicating that the routines were suitable to be performed in the target population.

Table 1. Expert Evaluation on the Consistency, Safety, Suitability and Gracefulness of MTD

	Consistency	Safety	Suitability	Gracefulness
Routine 1	3	5	4	3
Routine 2	4	5	4	4
Routine 3	4	5	4	4
Routine 4	5	5	4	4
Routine 5	4	5	3	4
Routine 6	4	4	3	4
Routine 7	5	5	4	4
Routine 8	5	4	4	5

2.4.2. Changes Made after Expert Consultation

Routine 1: Switching the COM and adding the plantar flexion so as to increase the load and intensity of stimulation on ankle muscle. No change was made in Routine 2,3,4. Routine 5: stressing the switch of the COM and adding appropriate arm movement to improve muscle force, stability, coordination.

2.4.3. End-user Evaluation

An end-user evaluation on the initial MTD was conducted to assess the suitability and feasibility of this program, and to gather participants' feedback and opinions about this program. Ten older adults were randomly selected from the local community (males: n=6; females: n=5) to participate in the initial MTD for two weeks, with 60 min per session and 3 sessions per week. Their biographic information was presented in means (95% CI).

Table 2. Demographic Characteristics of End-user Evaluation Participants

Age (yrs)	Height (cm)	Weight (kg)
66.8 ± 6.29	164.1 ± 6.92	68.76 ± 10.52

Participants were required to give their comments and feelings about the difficulty, safety, and novelty of MTD. The numbers "1, 2, 3, 4, 5" were used to score on the above aspects. Higher values in different aspects represents more satisfaction among the older adults would consider about the MTD. Finally, average scores are summarized in [Table 3](#).

Table 3. Participants' Evaluation on the difficulty, safety, and novelty of the MTD

	Difficulty	Safety	Novelty
Routine 1	1	3	5
Routine 2	1	4	5
Routine 3	1	3	4
Routine 4	2	4	5
Routine 5	2	3	4
Routine 6	1	4	5
Routine 7	3	4	4
Routine 8	3	4	5
Overall	2	4	5

2.4.4. Summary of Participants' Feedback

Routines 7, 8 were considered to be more difficult due to the requirements of changing direction and a great many of new elements involved. Together with experts' suggestions, it was decided to lower the requirements for these two routines. For Routine 7, hops were reduced to only 2 in the whole Routine. In Routine 8, the number of jumps were decreased with adding other elements, like dig, brush which are easier to performance. The overall scores demonstrated that participants considered that this exercise program was not very difficult (overall score = 2), very interesting (overall score = 5) and participants were satisfied they were interested in it (overall score = 4). Finally, the basic tap dance steps and routines were summarized and illustrated in [Table 4](#) and [Table 5](#) below.

Table 4. The Selected Basic Tap Dance Steps

Name	Function
Step	Increase the ROM of plantar flexion and enhance the strength of the plantar flexor. It is the basic step of tap dancing, which is convenient for switching the dance steps.
Touch	Increase the angle of plantar flexion and strengthen the strength of the plantar flexor.
Stamp	Enhance the stability of the ankle joint.
Toe	Stimulate the flexor muscles to improve the flexibility of the ankle joint.
Heel	Stimulate the dorsiflexion muscles such as the calf triceps, and combine with Toe to improve the flexibility of the ankle joint.
Stomp	Enhancing the stability of the ankle joint and increase strength of the quadriceps.
Punch	Improve the control of ankle muscles to and enhance their stability.
Roll	Fully active ankles for flexibility.
Cramp Roll	Fully active ankles for flexibility and enhance the stability of the ankle joint through jumps.
Dig	Stimulate the dorsiflex muscles of the tibialis anterior muscle.
Shuffle	Enhance the strength of dorsiflexion and plantar flexion, increase the joint mobility of ankle dorsiflexion and plantar flexion.
Basic Crawl	Fully active ankles for flexibility during the ascent and landing process.
Paddle	Fully active ankles for flexibility during the ascent and landing process.
Hop	Improve the control of ankle muscles to and enhance their stability.

Table 5. The Modified Tap Dance Program (MTD) for Ankle Function Improvement

Name	Details		Focus
	Content	Trajectory	
Warm up (10 min)	The warm up process focus on the lower extremities, which adapts to the main purpose of each of the various training sessions		Flexibility; warming up body
R 1 Step	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 step → touch 1.3 Knee extension 1.4 clap hand → Hands on hips	Control of COM; Muscle strength of plantar flexion, Knee extension & hip flexion; coordination
R 2 Multi-angle of ankle movement	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Plantar flexion → Ankle dorsiflexion → Toe → Heel 1.3 Knee flexion → Knee extension 1.4 Hands on hips	Muscle strength of ankle dorsiflexion and plantar flexion; ROM of the Ankle Agility.

Name	Details		Focus
	Content	Trajectory	
R 3 switching toes and heels	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Stand on toes → Basic crawl 1.3 Knee flexion → Knee extension 1.4 Swing arms right to left	Muscle strength & power of ankle dorsiflexion, plantar flexion and knee flexion; ROM of the ankle; coordination; Agility.
R 4 Digging and cramp roll	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Dig → Cramp roll → Toe → Heel 1.3 Knee flexion 1.4 Hands on hips	Muscle strength & power of ankle dorsiflexion and plantar flexion; ROM of the ankle; coordination; Agility.
R5 Touch	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Touch 1.3 Stay Extension 1.4 Clap hands forward & backward	Control of COM; Muscle strength & power of ankle dorsiflexion and plantar flexion; Stability;
R6 Multi-directional revised paddle	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Dig → Brush → Touch → Heel 1.3 Knee flexion 1.4 Hands on hips	Control of COM; Muscle strength & power of ankle dorsiflexion and plantar flexion and knee flexion; Stability;
R 7 hopping in single leg stance	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Shuffle → Hop in single leg stance → Shuffle → Step → Stamp → Stomp → Step → Heel → Shuffle → Heel → Dig → Toe → Dig → Toe 1.3 Knee flexion 1.4 Hands on hips → Clap hands	Control of COM; Muscle strength & power of ankle dorsiflexion and plantar flexion and knee flexion; Stability;
R 8 jumping forward and shuffle step	1.1 Trunk 1.2 Ankle 1.3 Knee 1.4 Arm	1.1 Straighten body 1.2 Dig → brush → Touch → Heel → Jump Forward → Jump Backward → Shuffle Stomp → Touch 1.3 Knee flexion 1.4 Hands on hips	Control of COM; Muscle strength & power of ankle dorsiflexion and plantar flexion and knee flexion; Stability; Coordination; Agility.

3. Conclusion

This study described the development of a community-based exercise program for ankle function improvement. Feedbacks from the expert and end-user evaluations indicated that the MTD is effective and safety for older adults to improve ankle function. A study with a randomized controlled trial (RCT) design has conducted among a group of older community-dwellers. The MTD would be slightly adjusted based on the results from the validation study.

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