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Impact of Otago versus Tai Chi Exercises on Lower Limb Strength in Older Adults

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Abstract

Background: Balance training plays a crucial role in improving strength and mobility, as well as reducing the risk of falls, for elderly individuals who experience balance issues. This is achieved by strengthening the muscles in the lower limbs and enhancing functional ability. ***Aim***: We aim to compare the effect of the Otago exercise program (OEP) and Tai Chi exercise (TCE) on lower limb strength (LLS) in elderly individuals. ***Design:*** A randomized controlled trial (RCT) with single-blinding. ***Setting:*** Alsafa Nursing Home, Cario, Egypt. ***Subjects***: Seventy-five older individuals were randomly assigned into three equal groups (n = 25). Group A received OEPs plus conventional balance training (CBT), Group B received TCEs along with CBTs, and Group C served as the control group, receiving only CBT. ***Tools:*** Pre- and post-testing involved the assessment of LLS using a Handheld dynamometer. ***Results***: The scores on the dynamometer for the calf muscle showed a significant improvement in all three groups, with no statistical variation between them (p <0.05). ***Conclusion***: Our findings highlight the importance of utilizing different types of exercises, such as OEPs, TCEs, and CBTs, to enhance LLS and reduce fall risk and injuries in the elderly population. ***Recommendations:*** Based on comparing the effects of Otago and TC exercises on LLS in elderly individuals, it is recommended to incorporate a combination of OEPs, TCEs, and CBTs into the routine of elderly individuals experiencing balance issues. This combination can help improve LLS, mobility, and functional ability, ultimately reducing the risk of falls and injuries in this population.

Keywords: Traditional balance exercises; Dynamometer; Otago; Tai Chi exercises

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Introduction

Falls represent a significant health concern among older individuals, accounting for both fatal and nonfatal injuries and contributing to morbidity and mortality, primarily due to impaired balance control. Maintaining balance involves a complex interplay of multiple systems, including the musculoskeletal, central nervous, and sensory systems, enabling swift adjustments to prevent falls [1].

The most common fall-related injuries include soreness, bruises, fractures, and, in severe cases, cerebral hemorrhage. Various factors increase the risk of falls, such as the use of assistive devices, a history of falls, environmental hazards, and medical conditions like muscle weakness, vertigo, and diabetes mellitus [2].

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Age-related changes in skeletal muscle, including decreased mass, strength, and rate of force generation, contribute to impaired postural balance and mobility. Regular exercise, particularly targeting lower limb muscles, can delay muscular degeneration and enhance quality of life [3].

Older adults are advised to engage in diverse exercises, including walking, stretching, aerobic activities, and muscle-strengthening exercises, to maintain muscle strength and improve balance and mobility [4]. Tai Chi exercise (TCE) represents a traditional Chinese exercise emphasizing flexibility and coordination of the entire body while promoting balanced movement in space by focusing on proprioceptive and extroceptive cues. The TCE has been shown to be a useful exercise for enhancing flexibility and balance in older people, which may help prevent falls [5]. Moreover, TCE lowers the risk of falls in older persons, enhances proprioception, balance control, and postural adaptation, and strengthens lower extremity muscles [6].

Strength and balance training, an Otago Exercise Program (OEP), aims at preventing falls among senior citizens. Five warm-ups and seventeen strength and balance exercises make up the OEP, which is advanced throughout the course of the treatment plan [7]. Strength training and endurance exercises that maximize flexibility and postural control are part of conventional balance training (CBT), which has been shown to improve functional capability and lower the fall risk in older population [8]. Additionally, CBT is done to help older people avoid falls and injuries, maintain better posture and strength, and enhance their standing balance and locomotor function [9].

Given these interventions' efficacy, our aim was to compare OEP and TCE effects on lower limb strength (LLS) in elderly individuals. We hypothesized no significant difference between the implications of these two exercise regimens on LLS, prompting our comparative study.

Materials and methods

Participants

This randomized controlled trial (RCT) with single-blinding was conducted from June 20th, 2023, to September 19th, 2023. Every participant was provided with an overview of the study's aims and possible risks and provided informed consent by signing a permission form. The Cairo University Physical Therapy Faculty Ethical Committee approved the study (Approval No: P.T.REC/012/003906).

Seventy-five individuals of both genders were recruited from Alsafa Nursing Home, Cario, Egypt. Eligible participants were aged 65-75 years, with a body mass index (BMI) of 25–29.9 kg/m^2, a Berg Balance Scale score of 0 to 40, and an independent level according to the Katz index of independence in activities of daily living (score = 6). Individuals with foot ulcers, orthopedic or surgical issues affecting gait, lower extremity amputations, unstable medical conditions,

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impaired vision or hearing, or recent plantar skin sores or joint replacements within the past year were excluded from the study.

Procedures

Before the commencement of the trial, all participants underwent a thorough physical assessment conducted by a qualified physiotherapist to ascertain their suitability for participation. Demographic data were collected using a survey, calculating each participant's BMI based on recorded height (cm) and weight (Kg).

Randomization into one of three groups—OEP plus CBT, TCE plus CBTs, or only CBTs—was achieved using a closed-envelope method. The likelihood of placement into any group was equal for each participant. An assigned researcher, unaware of the experiment's specifics, allocated participants to their respective groups based on the envelope seen.

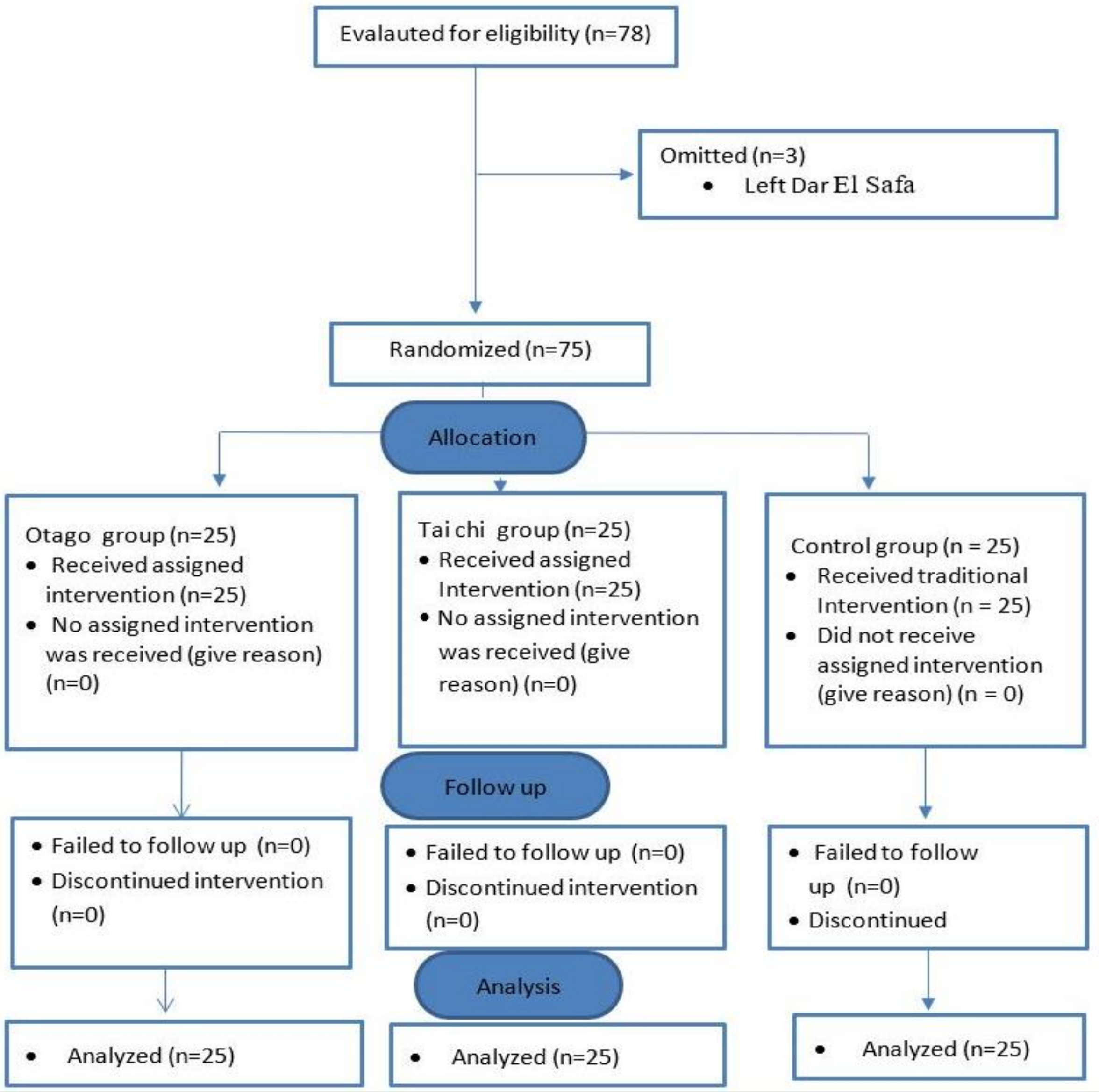

Fig 1. Study flow chart.

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Outcome measures

Lower-extremity muscle strength

Lower-extremity muscle strength was assessed through a handheld isometric dynamometer (Lafayette Manual Muscle Tester Model 01163). This portable computerized instrument enables accurate and unbiased muscle testing, allowing assessors to steady persons while keeping one hand free. An assessment was performed to measure the ankle plantar flexor muscles on both sides. Subjects were directed to execute maximum isometric contractions that lasted a minimum of 3 seconds [10].

Interventions

The OEP for group (A)

The OEP encompasses a walking regimen, 12 various balancing exercises, and five distinct strengthening exercises. Following the protocol, specific exercise modalities were implemented, with adjustments made to repetitions, ankle load weights, and balance training intensity based on individual capabilities.

During the strengthening exercises, ankle cuff weights of 0.5, 1, and 2 kg were utilized. The session typically commenced with participants using a 0.5 kg weight, progressively increasing the load as tolerated. Ultimately, individuals could manage ankle cuffs weighing up to 2 kg.

The walking program was scheduled twice weekly, each session lasting 30 minutes. Participants were encouraged to select a weight, allowing them to perform eight to ten repetitions before experiencing muscle fatigue. It's important to note that this fatigue threshold may vary for each exercise and each leg [11].

The TCE for group (B)

During TCE, participants were instructed to ground their feet and shift their weight smoothly from one leg to the other while performing a series of flowing movements. Each session could consist of anywhere from 7 to dozens of individual movements. The TCE is recognized as a mind-body exercise, emphasizing the integration of physical movement with mental focus and relaxation techniques. Sessions typically included a warm-up period lasting 5 to 10 minutes, followed by TCE, and concluded with another 5 to 10 minutes of cool-down exercises [12].

The conventional program implemented for groups A, B, and C, based on the protocol by Khot and Hande [13], consisted of the following components:

1. **Flexibility Exercise Phase:**

- Duration: 10 minutes
- Targeted Muscles: Calves, hamstrings, quadriceps, and adductors
- Protocol: Each stretch is held for 15 seconds with 3 repetitions.

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2. **Strengthening Exercise Phase:**
- Duration: 10 minutes
- Exercises: Abdominal and spinal extensors, hip abductors, hip extensors, hamstrings, and quadriceps.
- Protocol: Each exercise was performed 10 times.

3. **Postural Control Exercise Phase:**
- Duration: 10 minutes
- Activities:
- Stepping in all directions
- Exploring stability boundaries in various postures
- Step up and down
- Protocol: Sessions are divided into 2 sets with breaks in between.

This standardized program was applied uniformly across groups A, B, and C to enhance flexibility, strength, and postural control among participants.

Statistical analysis

Statistical analyses were performed through SPSS version 22. The demographic characteristics of the participants were analyzed utilizing one-way ANOVA, with the Kruskal-Wallis test utilized to compare sex distribution among groups. MANOVA was employed to assess differences between the three groups pre- and post-intervention. Pairwise tests were then conducted to evaluate the effects of the intervention within each group. Additionally, multiple comparisons were carried out to identify significant differences between each group and the others. $P < 0.05$ indicates statistical significance.

Results

Examination of the demographic data indicated no significant differences in age, weight, height, BMI, or sex among the three groups (**Table 1).**

Table 1. Comparison of characteristics between groups.

		Group A N=25 $\bar{x} \pm$ SD	Group B N=25 $\bar{x} \pm$ SD	Group C N=25 $\bar{x} \pm$ SD	F-value	P-value
Age (years)		69.7±3.3	69.7±3.5	70±3.4	0.749	0.476
Weight (kg)		86.5±19.7	79.1±17.1	81.4±13.7	1.251	0.292
Height (cm)		171.4±12.7	170.4±14.3	171.2±12.3	0.034	0.967
BMI (kg/m²)		29.3±5.6	26.9±4.9	27.3±2.9	1.976	0.146
		N (%)	N (%)	N (%)		
Sex	**Male**	18(72%)	16(64%)	14(56%)		0.504
	Female	7(28%)	9(36%)	11(44%)		

$\bar{x}$: Mean, SD: Standard deviation, p-value: Probability value, *: significance, N: number of participants

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Our study revealed significant alterations in the Dynamometer score for the calf muscle of both sides across all groups. However, statistical analysis showcased no significant variation between the three groups before and after the intervention (refer to Table 2). Specifically, regarding the Dynamometer score of the right leg, we observed percentage improvements of 21.3%, 22.9%, and 18.6% in groups A, B, and C, respectively. Similarly, the percentage change in the Dynamometer score of the left leg was 27.4%, 25%, and 17.9% in groups A, B, and C, respectively **(Table 2)**.

Table 2. Dynamometer score for Calf muscle comparison within and between groups.

Variables (Dynamometer score for Calf muscle)		**Group A $\bar{x}$ ± SD N=25**	**Group B $\bar{x}$ ± SD N=25**	**Group C $\bar{x}$ ± SD N=25**	**Comparison between Groups F-value**	**P-value**
Right leg	Pre-Treatment	12.7±2.9	12.2±2.9	12.9±3.4	0.464	0.630
	Post-Treatment	15.4±3.3	15±2.4	15.4±3.7	0.131	0.877
	Change %	21.3%	22.9%	18.6%		
	Comparison within Group	P<0.05*	P<0.05*	P<0.05*		
Left leg	Pre-Treatment	11.3±3	11.6±2.4	12.3±3.4	0.730	0.485
	Post-Treatment	14.4±3.6	14.5±3.5	14.4±3.8	0.004	0.996
	Change %	27.4%	25%	17.9%		
	Comparison within Group	P<0.05*	P<0.05*	P<0.05*		

$\bar{x}$: Mean, SD: Standard deviation, MD: mean difference, p-value: Probability value, *: significance, change%: percentage of change

Discussion

Our study aims to compare the effect of OEPs vs. TCEs in improving the strength of both lower limbs among older adults. The results of our investigation demonstrate a notable enhancement in the Dynamometer score of the right leg, with percentage improvements of 21.3%, 22.9%, and 18.6% observed in groups A, B, and C, respectively. Similarly, for the left leg, the percentage change in the Dynamometer score was 27.4%, 25%, and 17.9% in groups A, B, and C, respectively. Our findings highlight the significant role of OEPs in enhancing LLS, as assessed using the dynamometer. These exercises proved to be more effective than traditional strengthening exercises alone. Specifically, the OEP led to improvements in the strength of both calf muscles, with initial scores of 12.7±2.9 kg and 11.3±3 kg for the right and left legs, respectively. Following the exercise program, these scores increased to 15.4±3.3 kg and 14.4±3.6 kg for the right and left legs, respectively.

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These outcomes can be attributed to the comprehensive nature of OEPs, which incorporate resistance training targeting major muscle groups in the lower limbs. Specifically, these exercises focus on strengthening the quadriceps, hamstrings, hip abductors, calf muscles, and tibialis anterior muscles [14]. In line with our findings, OEP have been found to reduce the incidence of falls in elderly individuals by improving balance and muscular strength [11]. There was a significant correlation between group and time, suggesting that the OEP can assist in improving muscle strength ($p < .05$) [15]. Moreover, a previous study implemented the OEP three times weekly for 3 months. Their results demonstrated significant improvements in the strength of the ankle plantar flexors for both the right and left legs [7]. Specifically, the pre-treatment strength values for the ankle plantar flexors were 7.41±0.88 kg and 7.36±0.93 kg for the right and left legs, respectively. Following the intervention, strength significantly increased, with the right and left plantar flexors reaching 13.36±0.53 kg and 13.71±0.6 kg, respectively. These findings align closely with the outcomes of our investigation. In a prior investigation, the experimental group participated in a routine comprising 70 minutes of muscle strength and balance exercises derived from the OEP thrice weekly. Additionally, they engaged in 30 minutes of walking activity twice a month for a total period of 6 months. Following this intervention, significant improvements were observed, with hip flexion strength increasing from 21.7 to 22.0 kg. A previous investigation revealed that both the OEP alone and when combined with action observation training yielded positive outcomes in elderly women over a 12-week period. In both groups, improvements were observed in walking speed, cadence, step length, and stride length, as measured by the GAITRite system. Additionally, there was an increase in muscle strength of the thigh flexors, ankle dorsiflexors, and plantar flexors, as assessed using a dynamometer [16]. Unlike our results, a previous study sought to evaluate quantifiable disparities in strength and balance among a cohort of women aged over 80 who lived in the community. These women participated in the OEP for six months, whereas a control group of women of the same age was used for comparison. Remarkably, the findings revealed that there were no statistically significant disparities between the groups in relation to any of the assessed outcome indicators.

Our investigation demonstrated that TCEs effectively improved both LLS. Specifically, right and left plantar flexor strength increased from 12.2±2.9 kg and 11.6±2.4 kg to 15±2.4 kg and 14.5±3.5 kg, respectively, indicating greater efficacy compared to traditional strengthening exercises alone. An article discussing TCE's effects on the LLS and balance function of elderly individuals highlights the importance of knee and ankle joint strength in maintaining bodily balance. During TCE, the bending of the knee in various movement postures effectively activates leg muscles, providing significant stimulation to the ligaments surrounding the knee and ankle joints. This stimulation not only

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enhances muscular strength but also improves the range of motion in the knee and ankle joints. For example, it may increase the torque force for ankle plantar flexion and dorsiflexion. As a result, elderly individuals who consistently engage in prolonged physical activity, such as TCE, exhibit superior balance and walking capabilities compared to those who do not regularly participate in fitness activities [17].

Consistent with our findings, those of Chen et al. [18] revealed increased muscle strength measurements by an average of 3.1 ± 1.0 kg, with evaluations performed using a dynamometer after 8 weeks of TCE. Another previous investigation showed that after 12 weeks of a TCE program, the intervention group demonstrated improved ankle muscle strengths, with a P-value of 0.014 [19]. Traditional TCE has been manifested as not yielding significant benefits for practitioners or controls. Specifically, an 8-week traditional TCE regimen did not lead to improvements in muscle strength in all lower limbs, particularly the right and left plantar flexors (with p-values of 0.068 and 0.220, respectively) [10], which contrasts with our findings. Additionally, contrary to our results, prior research demonstrated no significant difference in lower limb muscle strength measurements, as assessed using a dynamometer, between the TCE and the control groups (with p-values exceeding 0.05) [20].

Conclusion

Our findings underscore the importance of incorporating various types of exercises, including OEPs, TCEs, and CBTs, to enhance LLS and reduce the risk of falls and injuries among the elderly population.

Limitations

Our study is limited to First, the predominantly male composition of the participants may limit the findings' generalizability to the broader older adult population. Additionally, the relatively short intervention period did not allow for an assessment of the long-term effects of TCE or OEPs. Future research with more diverse participant demographics and longer intervention durations is warranted to further elucidate the effectiveness of these exercise modalities in promoting health and reducing fall risk among the elderly.

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Authors' contributions

Nesreen G. El-Nahas, Mai R. Rageh, Magdy M. Gundi, and Gehad A. Abd-El Haseeb designed the study; Marina W. Ghattas, Mai R. Rageh, and Magdy M. Gundi collected the samples and clinicopathological data; Nesreen G. El-Nahas and Gehad A. Abd-El Haseeb conducted experiments and the data analysis; Marina W. Ghattas, Nesreen G. El-Nahas, and Gehad A. Abd-El Haseeb have contributed to the writing of the manuscript; and all authors share and approved the final version.

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Availability of data and material

The data are available upon request.

Consent for publication

Not applicable.

Conflict of interest

No conflicts of interest.

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