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Multimodal respiratory muscle training and Tai Chi intervention with healthy older adults: A double-blind randomised placebo control trial

Francesco V. Ferraro, PhD [a,*], Yutao Zhou, PhD [b], Ainoa Roldán, PhD [c], Rania Edris, PhD. [d]

[a] *Clinical Exercise and Rehabilitation Research Centre, University of Derby, Derby, United Kingdom*
[b] *Hunan Research Centre of Excellence in Physical Fitness, Health, and Performance (CEFHP), Physical Education College, Hunan University of Technology, Hunan, China*
[c] *Sport Performance and Physical Fitness Research Group (UIRFIDE), Physical Education and Sports Department, University of Valencia, Valencia, Spain*
[d] *School of Science, College of Science and Engineering, University of Derby, Derby, United Kingdom*

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ABSTRACT

Background: The World Health Organization reported that one of the major challenges for all countries in the next few years will be the development of preventive approaches to care for older adults. After COVID-19, multimodal interventions have been created to enhance older health, especially targeting respiratory muscles (e.g., inspiratory muscle training [IMT]). The following research aims to explore the combination of two interventions (IMT and Tai Chi) using a randomised, double-blind placebo approach.

Methods: A total of 30 participants were recruited from the local community in Derby (UK) and underwent an experimental (IMT + Tai Chi) or placebo (sham-IMT + Tai Chi) training protocol. Measurements of balance (i.e., mini-BEST), inspiratory muscle strength (i.e., Maximal Inspiratory Pressure) and mobility (i.e., 6 Minutes Walking Test) were collected at baseline and after 8 weeks.

Results: The results show that a combination of IMT and Tai Chi significantly improves dynamic balance ($P < 0.01$) and mobility ($P < 0.05$) when compared to Tai Chi alone, with an additional positive correlation between balance, mobility and inspiratory muscle strength ($P < 0.05$).

Conclusion: The manuscript is the first to report the combined effects of IMT and Tai Chi in older adults following rigorous methods. The results highlight the relationship between inspiratory muscle and balance, as the results demonstrate a potential link between metaboreflex and balance control, fostering multimodal practices for healthy ageing interventions.

1. Introduction

In 2022, the World Health Organization reported one of the major challenges for all countries in the next years will be to ensure that the health and socioeconomic systems are ready to make the most of the ongoing demographic shift (WHO, 2022). In 2020, the number of people aged 60 years and older outnumbered the children younger than 5 years old and between 2015 and 2050, the proportion of the world's population over 60 years is expected to increase from 12% to 22% (WHO, 2023). The increasing ageing population will consequently have a significant effect on the health systems (Rudnicka et al., 2020), increasing the costs and length of stay that will troublesome the capacity of health organisations worldwide (Harper, 2021). Hence, the National Institute for Health and Care Excellence (NICE, 2023a) recommended developing approaches to care for older adults and to prevent ageing-associated physiological declines (such as lack of mobility). Similarly, the recent EU agenda focuses on developing healthy ageing strategies to improve health, social life and well-being in the older population (Włodarczyk and Tambor, 2019; Zdunek et al.; Palermo, 2022) To what concerns balance, defined as a multidimensional concept referring to the ability of a person not to fall (Pollock et al., 2000), and mobility, defined as the physiological ability of people to move independently and safely (Forhan and Gill, 2013) a Cochrane review shows how physical activities (e.g., Pilates and Resistance Training) improve balance, mobility and general health in the older population (Howe et al., 2011). However, novel interventions have been developed that suggest adopting a multimodal approach, as in the recent review by Sheraz et al., in 2023, wherethe authors showed how an unsupervised costs-effective

* Corresponding author.
E-mail address: f.ferraro@derby.ac.uk (F.V. Ferraro).

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intervention that targets respiratory muscles, named inspiratory muscle training (IMT) can be used to improve balance and mobility in older healthy adults as well as in patient populations (e.g., diabetes) (Sheraz et al., 2023). However, other interventions that focus on respiratory muscles have been previously proposed (e.g., Tai Chi) with excellent results (Zhong et al., 2020), but IMT focuses only on inspiratory muscles and is self-administered without social interaction, Tai Chi targets expiratory muscles along with lower and upper limbs and is mostly performed with a teacher (except in the case of telemedicine). The following research explores the research highlighted by Hodges and Gandevia who initially showed the role of inspiratory muscle in balance control (Gandevia et al., 2002; Ferraro et al., 2021). More recently a systematic review (Rodrigues and McConnell, 2024), also reported lack of research that combines respiratory muscle training with other interventions. A gap that, if covered, can help in understanding the mechanism behind the positive relationship that links improvement in balance with improvement in respiratory muscle strength.

Concluding, the following research aims to explore the combination of the two interventions (IMT and Tai-Chi) using a randomised double-blind placebo approach to understand the links between improvements in inspiratory muscle strength and dynamic balance previously reported in healthy older adults and community dwellers that were not fully explained (Ferraro et al., 2020). The objectives were: i) producing an impact in the local community and sharing good practices on healthy ageing; ii) understanding the role of inspiratory muscles in balance and mobility; iii) producing recommendations to integrate multimodal inspiratory muscle training into physical training as recommended by WHO and NICE. The research team's hypothesis is that the combination of IMT + Tai Chi will produce bigger improvements in balance and respiratory muscle strengths when compared with Tai Chi or IMT intervention alone. This hypothesis is supported by a recent trend in literature that recognised the dualistic role of inspiratory muscles as breathing and balance control muscles (Ferraro et al., 2019, 2020, 2021).

2. Methods

For the purpose of this study, the research teams adopted a positivistic methodology with a double-blind randomised placebo control trial method. This manuscript reports the research following the latest CONSORT guidelines (Junqueira et al., 2023) and the Template for Intervention Description and Replication (TIDieR) (Hoffmann et al., 2014). All data were collected between June and August 2023 in Derby (UK), and full ethical approval was received by the University of Derby research ethics committee before the commencement of data collection (ETH2223-1923).

2.1. Study design

2.1.1. Participants selection

Prior to data collection, participants were screened. Those with the following exclusion criteria were not included. Younger than 60 years of age and with cognitive difficulties (Mini-Mental State Examination lower than 24 points) (Cockrell and Folstein, 2002), previous Tai Chi or IMT experiences, received a diagnosis of diabetes, chronic obstructive pulmonary disease, asthma or any other condition that might affect balance or breathing. Fallen in the previous three months (Lomas-Vega et al., 2017), vertigo in the past six months, heart conditions that prevent them from exercising, any other neuromuscular conditions (such as muscular dystrophy) that can cause harm while exercising, any medication known to effect balance (e.g. β-blockers) (Chen et al., 2023).

The sample size was calculated using G*Power software (Faul et al., 2007) based on previous studies that looked at the IMT effect of balance with healthy older adults (Ferraro et al., 2021), with α error = 0.05 and 1-β = 0.95. To test our hypothesis that healthy older adults undertaking 8 weeks of inspiratory muscle training combined with Tai Chi would improve dynamic balance outcomes to a higher magnitude than healthy older adults undertaking 8 weeks of Tai Chi combined with sham-IMT, a total sample of 25 participants were required.

In order to keep all participants blind to the interventions, IMT was portrayed as Strength Training and the sham-IMT was portrayed as Endurance Training using a previously verified protocol (Ferraro et al., 2019).

Hence, each participant was randomly allocated to Strength Training (i.e., IMT + Ta Chi) or Endurance Training (i.e., sham-IMT + Tai Chi). A simple randomisation strategy (Kang et al., 2008) was completed after initial screened. To ensure double-blindness, recruitment and screening were completed by (YZ), randomisation was carried out by (AR), and assessments were completed by one researcher expert in respiratory physiology (FVF), who was fully blinded about the type of training participants were involved in.

2.1.2. Location

The data collection took place at Dance Studio in Derby (UK), in a standardised environment with a temperature of 21.5 C. Additionally, participants were advised to wear appropriate gym clothing when arriving at the Dance studio. This location was selected because it is where participants practice Tai Chi and are familiar with the environment. Prior to their appointment, all participants received instructions not to consume any substances that could affect their assessments, such as alcohol or caffeine (Mielgo-Ayuso et al., 2019).

2.2. Intervention

All interventions described below were carried out continuously for eight weeks. For the data to be analysed, a minimum adhesion of 70% to the following intervention was required of all participants.

2.2.1. Inspiratory muscle training

The Experimental (Strength) Group was instructed to perform 30 breaths in the morning and 30 breaths in the evening, far from meals, at 50% of their Maximal Inspiratory Pressure (MIP) (Romer et al., 2002). To maintain the training stimulus for 8 consecutive weeks, each participant was instructed to increase the intensity by one level if they could achieve more than 30 breaths in two consecutive training sessions (McConnell, 2013). Each participant received a Powerbreathe Medic Plus (POWERbreathe® International Ltd, Southam, UK) to complete their training.

2.2.2. Sham-inspiratory muscle training

Using a validated protocol that reported no significant improvement in inspiratory muscle strength, the sham (Endurance) group performed 60 breathes once a day (morning or evening) at an intensity equal to 15% of their MIP (Charususin et al., 2018; Romer et al., 2002). Participants were instructed not to modify the resistance and the training valve of the Powerbreathe Medic Plus was fixed to ensure that the training intensity remained the same.

For both groups, instructions on how to use the breathing device were provided, along with a few practical trials on the day of baseline measurements. All participants also received a training diary (refer to Appendix 1) to report their training.

2.2.3. Tai Chi

The intervention was identical for both groups and was delivered by a Tai Chi master (YZ). For the purpose of the study, the Yang Style was used (Liang, 2015). Each session had a 10-min warm-up, a core session with each Tai Chi figure and 5 min cool down. Tai Chi classes were conducted once a week for 45 min. To control attendance, YZ kept a register and monitored the IMT training diary for both groups. The full structure of the Tai Chi program is reported in Appendix 2.

3. Outcomes

All anthropometric details were collected only at baseline to provide sufficient details about the cohort and screen for exclusion criteria. These included date of birth, height, weight, Mini-Mental (Cockrell and Folstein, 2002), Physical Activity Scale for Elderly (Washburn et al., 1993), forced expiratory volume in 1 second (s) (Louis et al., 2022), forced vital capacity (Hall et al., 2021), peak expiratory flow (Tsvetkova-gaberska et al., 2023), unit of alcohol per week, PAR-Q (Warburton et al., 2021) and ethnic origin.

3.1. Cardio-respiratory

The Maximal Inspiratory Pressure (MIP) was measured with a hand-held mouth pressure meter (MicroRPM, Micro Medical Ltd, Rochester, Kent, UK). Each participant performed three initial attempts and then a minimum of five and no more than eight Müller manoeuvres until variability was within 10%. This protocol has already been used and validated (Ferraro et al., 2020).

Peak Inspiratory Flow was measured using POWERbreathe® K2, with Breathe-Link 2.0 software (POWERbreathe® International Ltd, Southam, UK) using Langer and colleagues technique (Langer et al., 2013).

Systolic and diastolic blood pressure measurements were collected prior to balance and mobility assessments. A minimum of three subsequent measurements were collected, up to a maximum of five, until variability between measurements was within 10%. The highest of the three measurements was then reported.

3.2. Balance and Mobility

The mini-BEST is a shortened version of the Balance Evaluation Systems Test, which includes 14 different tasks divided into sub-groups as anticipatory, reactive, sensory, and dynamic tasks (O'Hoski et al., 2015). It also includes, as part of the dynamic tasks, the Timed Up and Go (Nightingale et al., 2019) and The Cognitive Timed Up and Go (Cardon-Verbecq et al., 2017) that were assessed within the mini-BEST and separately as an index of dynamic balance control.

The Six Minutes Walking Test (6MWT) was used as an index of activities of daily living. According to the American Thoracic Society, it is a good index of patients' blood oxygen saturation and perception of dyspnea during exertion (Enright, 2003). Following these guidelines, no encouragement was given to the patients who performed the 6MWT whilst the researcher was counting the number of laps (Enright, 2003).

For the 30 Seconds Sit to Stand, each participant sat on the edge of an armless chair (sitting height 46 cm, seat length 45 cm) with their arms folded across their chest. They were instructed to rise and then become seated as fast as possible, as many times as possible in 30 s, with both feet maintaining full contact with the floor and kept at a comfortable distance. They were also instructed to stand up completely and sit down, with the gluteus touching the chair (Jones et al., 1999).

The Activity Balance Confidence Scale was used to address participants' confidence in performing tasks that might lead to a loss of balance (Powell and Myers, 1995).

The Oswestry low back pain questionnaire was used to monitor the effect of inspiratory muscle training on low back pain with a validated protocol (Ahmadnezhad et al., 2020; Fairbank and Pynsent, 2000). The test has been included as low back pain has been reported to impair balance ability (Berenshteyn et al., 2019) and it is a condition affected by IMT (Janssens et al., 2015).

The Q5 5D 5L questionnaire was used to monitor participants' status before data collection, at baseline, and after 8 weeks of intervention. The questionnaire was administered following the latest NICE guidelines (Golicki et al., 2015; NICE, 2023b).

4. Data analysis

Within-group analysis was carried out with the Parried Sample T test, whilst between-group differences were measured using Repeated Measured ANOVA with Tukey correction. The threshold for statistical significance was determined a priori as $P \leq 0.05$, and Cohen's d effect sizes were calculated to determine the effect magnitude and non-significant tendency (small $d \leq 0.2$; medium $0.2 < d \leq 0.8$; large $d > 0.8$) (Goulet-Pelletier and Cousineau, 2018). To further explore the link between improvements in inspiratory muscle strength and balance, a Person correlation and Linear regression analysis were performed in the experimental group if significant improvement ($P < 0.05$) were reported. All data were analysed with SPSS v29.00.

5. Results

A total of 25 participants out of 30 completed the study (83%), showing excellent retention. The reason for withdrawal and participants' pathway is reported in Fig. 1.

5.1. Anthropometric

No significant differences were reported between groups in anthropometric values, except for weight and forced expiratory volumes in 1 s (FEV1), data reported in Table 1.

5.2. Cardio-respiratory

Cardiorespiratory results are reported in Table 2. Maximal inspiratory pressure improved significantly in the experimental group with a large magnitude, with no differences between groups. Peak inspiratory flow improved significantly in both groups, with a higher effect magnitude in the experimental group when compared with the placebo group, with no difference between groups. Systolic blood pressures were both not significant within and between groups whilst diastolic blood pressure was significant within group in the placebo but not in the experiential group neither in between-group analysis.

5.3. Balance and Mobility

Significant improvements were reported in dynamic balance and 6-min walking tests with the experimental group, which significantly improved compared to baseline and when compared with the placebo group. Whilst the placebo group deteriorated their balance (from 22.50 to 20.42) significantly. Additionally, Cognitive Timed Up and Go significantly improved in the experimental group with no differences between groups. Whilst the 30 s sit to stand worsened significantly in the placebo group but not in the experimental group, with no differences between groups. Data reported in Table 3.

5.4. Linear regression and correlation

Linear regression for MIP and walking distance (i.e., 6 Minutes Walking Test) follow-ups showed $F = 5.02$ $P = 0.03$ and Bootstrap $P = 0.02$ with Pearson Correlation (single-tailed) $P = 0.02$. Meanwhile, linear regression for MIP and Cognitive Timed Up and Go follow-ups showed $F = 3.69$ $P = 0.81$ and Bootstrap $P = 0.79$ with Pearson Correlation (single tailed) $P = 0.04$. Tendency line and R^2 are reported in Fig. 2.

6. Discussion

The results demonstrate that a combined IMT and Tai Chi intervention significantly improves dynamic balance, mobility, and inspiratory muscle strength in healthy older adults compared to Tai Chi alone. Participants in the experimental group showed improvements in

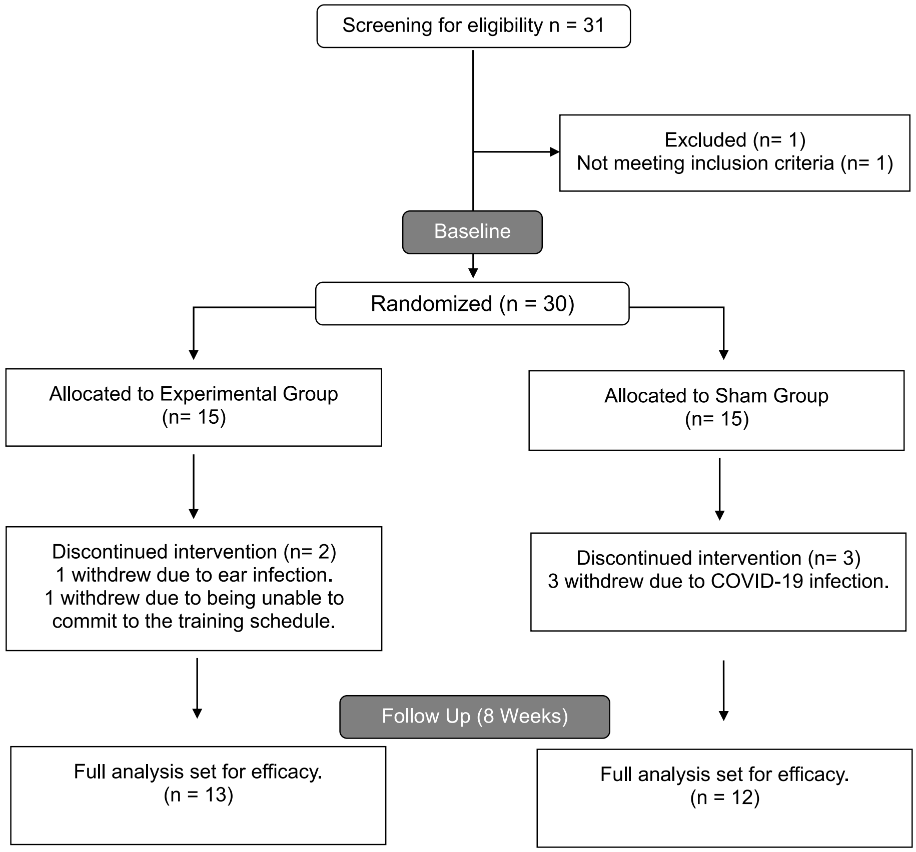

Fig. 1. – CONSORT chart modified from (Junqueira et al., 2023).

Table 1
Anthropometric values.

Outcomes	Experimental Group	Placebo Group	Between-group
	N = 13	N = 12	P
Age (years)	67.9 ± 5.52	69.0 ± 7.09	0.72
Height (meters)	1.65 ± 0.12	1.65 ± 0.12	0.87
Weight (kg)	61.35 ± 9.35	73.21 ± 14.81	0.02+
Mini-Mental (final score)	29.08 ± 1.26	27.92 ± 1.68	0.06
Physical Activity Scale for Elderly (final score)	153.76 ± 38.93	146.55 ± 35.77	0.37
Forced Expiratory Volume in 1 s (L/s)	2.27 ± 0.46	2.93 ± 0.83	0.05+
Forced Vital Capacity (L/s)	2.79 ± 0.62	3.36 ± 0.93	0.06
Peak Expiratory Flow (L/s)	371.46 ± 67.06	473.83 ± 166.50	0.06
Unit of Alcohol per week (range)+	0–15	0–30	NS
PAR-Q	33,0.33% High Blood Pressure 8.33% Gastric Reflux	25% High Blood Pressure	NS
Ethnic origin	66.67% White British 8.33% Indian 8.33% Black Caribbean 16.67% White European	83.4% White British 16.6% Chinese	N/A

NS = no significant differences measured with Chi-Square; N/A = not applicable * significant difference;+for both groups, the unit of alcohol consumption is considered as increasing risk of drinking according to Gov. UK guidelines.

Maximal Inspiratory Pressure (MIP), mini-BEST dynamic balance scores, Cognitive Timed Up and Go tests, and Six-Minute Walk Test (6MWT) outcomes. In contrast, the placebo group showed declines in balance and mobility metrics, such as mini-BEST and 30-s sit-to-stand test performance.

6.1. Interpretation of the results

It was possible to confirm the research team's hypothesis that the combination of IMT + Tai Chi will improve balance and respiratory muscle strength when compared with Tai Chi intervention alone. In particular, the experimental group (i.e., IMT + Tai Chi) significantly improved in MIP, Dynamic Balance, Cognitive Timed Up and Go and Six Minutes Walking Test. The Placebo (i.e., sham-IMT + Tai) worsened significantly in Mini-BEST, Reactive balance, 30 s Sit to Stand and showed a significant decrement in diastolic blood pressure (DBP) with low magnitude. Similar results were reported in other multimodal IMT interventions with older active women (Roldán et al., 2019). While the effect size is moderate, its statistical significance suggests the need to consider how Tai Chi alone or the overall intervention setting impacted DBP in the absence of true IMT. However, it is necessary to consider that a confounding variable can cause this result since the placebo group had a higher DBP at baseline than the experimental group (Table 2).

Both groups improved in Peak Inspiratory Flow and 5Q 5D 5L, with significant differences within groups. Differences between groups were reported in Dynamic Balance and the Six-Minute Walking Test.

6.1.1. Role of inspiratory muscle training

This study's results are in light with previous studies that looked at similarities and differences of IMT when compared to the Otago Exercises Program in healthy older adults (Ferraro et al., 2020). However, the analysis conducted above allows further speculation on the links

Table 2
Cardiorespiratory outcomes.

Variables	Experimental Group				Placebo				Between-group
	n = 13				n = 12				P
	Baseline	Follow-Up	P	d	Baseline	Follow-Up	P	d	
MIP (cmH_2O)	60.54 ± 28.68	100.85 ± 33.81	<0.001*	1.28	72.67 ± 17.61	79.33 ± 23.16	0.16	0.32	0.539
PIF (L/s)	2.91 ± 0.79	4.23 ± 0.82	<0.001*	1.64	3.41 ± 1.11	4.56 ± 1.17	<0.001*	1.00	0.206
SBP (cmH_2O)	158.92 ± 25.29	147.77 ± 21.30	0.18	0.47	159.67 ± 24.50	144.67 ± 22.61	0.004*	0.64	0.990
DPB (cmH_2O)	88.23 ± 9.71	83.77 ± 8.92	0.43	0.48	91.67 ± 15.52	84.83 ± 12.61	0.006*	0.48	0.350

Experimental Group vs Placebo Group improvements following 8 weeks of Inspiratory Muscle Training with Tai Chi and Sham-Inspiratory Muscle Training with Tai Chi; MIP = Maximal Inspiratory Pressure; PIF = Peak Inspiratory Flow; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure* *Significant difference.*

Table 3
Balance and mobility outcomes.

Variables	Experimental Group				Placebo				Between-group
	Baseline	Follow-Up	P	d	Baseline	Follow-Up	P	d	P
MBs	22.92 ± 5.19	25.15 ± 2.15	0.10	0.56	22.50 ± 5.16	20.42 ± 2.68	0.05*	0.51	0.064
As	5.08 ± 1.26	5.54 ± 0.97	0.17	0.91	4.75 ± 1.42	4.92 ± 1.16	0.36	0.13	0.316
Rs	5.00 ± 1.58	4.54 ± 0.88	0.20	0.36	5.17 ± 1.75	3.50 ± 1.73	0.01*	0.42	0.298
Ss	5.08 ± 1.66	5.85 ± 0.38	0.07	0.64	5.08 ± 1.38	5.50 ± 0.80	0.21	0.10	0.561
Ds	7.77 ± 1.36	8.92 ± 0.95	0.02*	0.98	7.75 ± 1.82	6.42 ± 1.62	0.16	0.77	0.008^{+}
TUG (seconds)	5.38 ± 0.59	5.59 ± 0.64	0.12	0.34	5.57 ± 0.80	6.33 ± 0.96	0.25	0.86	0.108
TUG_c (seconds)	7.72 ± 2.30	6.55 ± 1.26	0.02*	0.63	8.02 ± 1.43	8.79 ± 2.53	0.16	0.37	0.088
30STS	16.62 ± 4.25	18.46 ± 3.69	0.06	0.46	16.50 ± 4.15	14.25 ± 3.02	0.04*	0.62	0.160
6MWT (meters)	474.30 ± 72.29	606.18 ± 102.80	<0.001*	1.84	479.34 ± 67.11	454.06 ± 161.92	0.32	0.20	0.03^{+}
ABC	92.04 ± 10.33	93.50 ± 8.37	0.14	0.15	93.36 ± 5.95	90.24 ± 9.86	0.12	0.38	0.976
ODI	3.85 ± 4.04	5.23 ± 5.33	0.05	0.29	2.67 ± 4.62	2.67 ± 3.45	0.5	0	0.315
Q5 5D 5L (EQ Index)	0.91 ± 0.12	0.89 ± 0.12	<0.001*	0.16	0.82 ± 0.17	0.85 ± 0.10	<0.001*	0.22	0.666
Q5 5D 5L (EQ VAS)	87.69 ± 8.07	91.77 ± 7.00	<0.001*	0.54	88.83 ± 5.86	89.08 ± 12.62	<0.001*	0.02	0.518

Experimental Group vs Placebo Group improvements following 8 weeks of Inspiratory Muscle Training with Tai Chi and Sham-Inspiratory Muscle Training with Tai Chi; MBs = Mini-BEST score; As = Anticipatory score; Ss = Sensory score; Rs = Reactive score; Ds = Dynamic score; TUG = Timed Up and Go; TUGc = Cognitive Timed Up and Go; 30STS = 30 s Sit to Stand; 6MWT = 6 Minutes Walking Test; ABC = Activity Balance Confidence scale; ODI = Oswestry Disability Index; *Significant difference.

between inspiratory muscle strength and dynamic balance. Indeed, the improvements reported here are linked with gait as part of the Dynamic Balance as a subgroup of the mini-BEST, which includes gait-related tasks, such as Cognitive Timed Up and Go and 6-min walking tests. Previously, there has been speculation about the direct link between inspiratory muscle and spine stability pressure (Gandevia et al., 2002). Authors reported that improvement in balance might be linked with improvement in participants' capacity to increase intrabdominal pressure (Cholewicki et al., 1999a, 1999b), or due to anatomical links between the diaphragm muscles and the ileus-psoas complex (Raiola et al., 2020). However, as our results showed improvements in gait, more than other sub-groups of balance, might be due to improvements in metaboreflex (Witt et al., 2007; Seixas et al., 2020).

Indeed, it is possible to conceive that inspiratory muscle training, by conditioning the inspiratory muscle, decreases the sensation of fatigue and favours oxygenation. In return, better oxygenation of the respiratory muscle results in a redistribution of energy in the body, which translates in a better lower limbs performance (Callegaro et al., 2011). However, this theory needs further investigation and additional respiratory-related outcomes, such as the work of breathing. (Shei et al., 2022).

6.1.2. *Multimodal intervention*

Improvement in balance was noted only in the experimental group. The placebo group demonstrated significant decrements in overall balance, reactive balance and 30 s sit to stand. These results are similar to those reported by Huang, Mayer, Wu, Liu, Wu and Yen (Huang et al., 2022). Additionally, the effects on blood pressure were significant in the placebo group but with low-magnitude results similar to those presented in Yeh, Wang, Wayne and Phillips (Yeh et al., 2008). This study reported that the combination of IMT and Tai Chi has shown significant results with high magnitude in relation to balance gain and overall health, measured with 5Q 5D 5L. Hence, combining the interventions to enhance physiological responses to training and facilitate participation in the training program would be recommended. Multimodal interventions have also been suggested in the WHO guidelines for fall prevention and management for older adults (Montero-Odasso et al., 2022). However, as also reported by Shei et al. (2022), there were limitations in the IMT intervention. The 30 breathes morning and evening protocol initially developed for athletes (Romer et al., 2002), is assumed to be the best to produce enhancement in balance with frailer population. Previous studies have proved this assumption (Sheraz et al., 2023; Mota et al., 2023; Safei and Zulfahmidah, 2023), but future work should explore different types of inspiratory muscle training protocols (e.g., using different volumes and intensities) tailored for ageing populations. In particular, it is necessary to understand why improvements in inspiratory muscle strength are related to improvements in balance; it is possible to hypothesise three main domains for future research, focusing on increments in intrabdominal pressure, better modulation in core muscle control, and more efficient metaboreflex response. Also, additional research that includes qualitative elements is necessary. Since this intervention is people-patient lead, it is necessary to understand their perspective to enhance the training experience.

6.2. *Clinical Implications*

These results have significant clinical implications for designing future effective interventions to enhance balance, mobility, and respiratory muscle strength in older adults. Combining IMT and Tai Chi demonstrates a practical, multimodal approach that aligns with WHO and NICE guidelines. Hence, clinicians can integrate this dual intervention into rehabilitation programs for older adults at risk of falls or

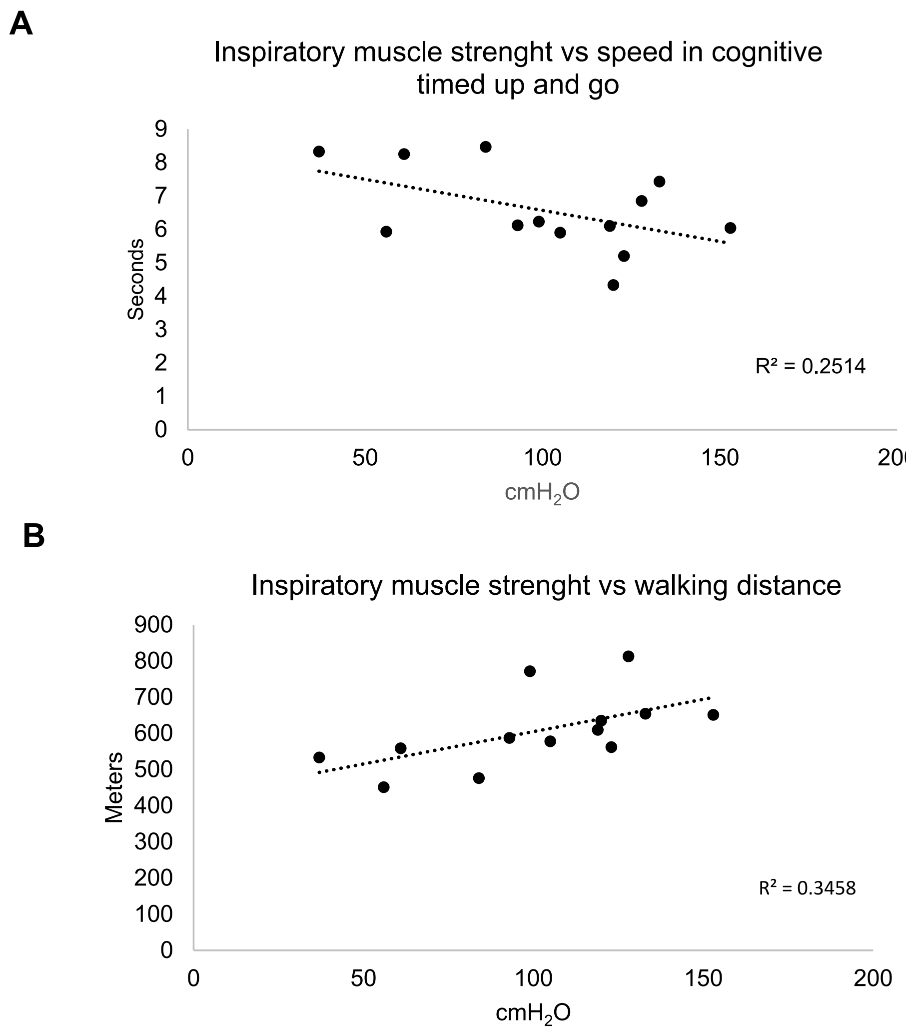

Fig. 2. The figures show the correlation between inspiratory muscle strength measured with Maximal Inspiratory Pressure (cmH_2O) and 6 m walking test (meters) (A), and Maximal Inspiratory Pressure (cmH_2O) and Cognitive Timed Up and Go (seconds) all measurements collects after 8 weeks of multimodal Inspiratory Muscle Training with Tai Chi.

those with reduced mobility. Additionally, this multimodal strategy may be particularly beneficial for patients with chronic conditions such as COPD or low back pain, where respiratory and functional mobility are often compromised. (Beeckmans et al., 2016). Future clinical practice and research should leverage these insights to develop tailored, accessible interventions that address the complex interplay of respiratory and motor functions in ageing populations.

7. Conclusion

The study provides evidence of the effect of IMT and Tai Chi in older population. The results showed that IMT + Tai Chi produces significant improvements in dynamic balance, mobility and respiratory muscle strengths when compared with Tai Chi intervention alone. These outcomes can impact the local community and hopefully will help in shaping good practices and policies for healthy ageing interventions. It can also add to the latest WHO and NICE guidelines, providing recommendations on how to integrate respiratory interventions with other gold-standard training to enhance physiological responses.

8. Limitation

Further analysis remains on the effect of inspiratory muscle on dynamic balance. While this study confirmed how improvement in inspiratory muscle strength can potentially lead to a better, faster gait, further studies should look into the work of breathing and oxygen saturation. Additional balance tests, such as the Berg Balance Test or the Tinetti Balance Test, would also help in looking at other components of balance.

This study presents other limitations, such as the age group of participants can potentially have an effect on the significance of the results. While it was previously reported that the older population presents a lower level of fitness and, therefore, can show higher improvement in balance and mobility, no effect of ageing was noted on these outcomes in this study. Therefore, future studies should recruit participants over 80 to be able to demonstrate high level of significance between and within groups as also reported in previous work (Ferraro et al., 2021).

CRediT authorship contribution statement

Francesco V. Ferraro: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yutao Zhou:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis. **Ainoa Roldán:** Writing – review & editing, Project administration, Investigation, Conceptualization. **Rania Edris:** Writing – review & editing, Validation, Formal analysis.

Impact statement

The following research aims to explore the combination of two interventions (IMT and Tai-Chi) using a randomised, double-blind placebo approach to understand the links between improvements in inspiratory muscle strength and dynamic balance previously reported in healthy older adults and community dwellers that were not fully explained. The key points were:

- producing an impact in the local community and sharing good practices on healthy ageing;
- understanding the role of inspiratory muscles in balance and mobility;
- producing recommendations to integrate multimodal inspiratory muscle training into physical training for older adults as recommended by WHO, NICE and EU.

Why does this paper matter?

Falls injuries are a major risk for older adults. According to the National Institute for Health and Care Excellence (NICE), 30% of people are at high risk of Falling between 65 and 70 years old. While 50% of people are at high risk of falling over 80 years old, with a cost to the National Health System of 2.3 billion £/yr. Moreover, fall incidence is the leading cause of death for adults aged over 75 years older and the National Institute of Health (NIH) reported that by 2050, global life expectancy will increase by almost eight years,; the global population of those over 80 is expected to grow from 126.5 million to 446.6 million, potentially leading to a higher number of people at risks of fall. For these reasons, it has become imperative to explore novel, preventive, low-cost cost, efficient balance interventions to improve health and wellness and decrease fall risks in older populations. Previous studies investigated the effects of Inspiratory Muscle Training (IMT) and Tai Chi as an intervention that will decrease the risks of falls. However, evident gaps in research remain, such as: i) why is improvement in inspiratory muscle strength related to higher balance scores? ii) how does home-based IMT compare with social training intervention such as Tai Chi? iii) would a combination of two breathing-based interventions produce a bigger improvement in balance and health-related outcomes?

To answer these questions, a random control trial approach was used to investigate IMT + Tai Chi vs sham-IMT + Tai Chi. The results will be used to shine a light on respiratory muscle effects on balance and will produce recommended high-quality outcomes following WHO, NICE and EU Healthy Ageing recommendations.

Sponsor's role

Not applicable.

Declaration of competing interest

All authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbmt.2025.01.046.

References

Ahmadnezhad, L., Yalfani, A., Borujeni, B.G., 2020. Inspiratory muscle training in rehabilitation of low back pain: a randomized controlled trial. J. Sport Rehabil. 29 (8), 1151–1158.

Beeckmans, N., Vermeersch, A., Lysens, R., et al., 2016. The presence of respiratory disorders in individuals with low back pain: a systematic review. Man. Ther. 26, 77–86.

Berenshteyn, Y., Gibson, K., Hackett, G.C., Trem, A.B., Wilhelm, M., 2019. Is standing balance altered in individuals with chronic low back pain? A systematic review. Disabil. Rehabil. 41 (13), 1514–1523.

Callegaro, C.C., Ribeiro, J.P., Tan, C.O., Taylor, J.A., 2011. Attenuated inspiratory muscle metaboreflex in endurance-trained individuals. Respir. Physiol. Neurobiol. 177 (1), 24–29.

Cardon-Verbecq, C., Loustau, M., Guitard, E., et al., 2017. Predicting falls with the cognitive timed up-and-go dual task in frail older patients. Annals of physical and rehabilitation medicine 60 (2), 83–86.

Charususin, N., Gosselink, R., Decramer, M., et al., 2018. Randomised controlled trial of adjunctive inspiratory muscle training for patients with COPD. Thorax 73 (10), 942–950.

Chen, W., Cheng, X., Ma, Y., Chen, N., 2023. Foodborne doping and supervision in sports. Food Sci. Hum. Wellness 12 (6), 1925–1936.

Cholewicki, J., Juluru, K., McGill, S.M., 1999a. Intra-abdominal pressure mechanism for stabilizing the lumbar spine. J. Biomech. 32 (1), 13–17.

Cholewicki, J., Juluru, K., Radebold, A., Panjabi, M.M., McGill, S.M., 1999b. Lumbar spine stability can be augmented with an abdominal belt and/or increased intra-abdominal pressure. Eur. Spine J. 8, 388–395.

Cockrell, J.R., Folstein, M.F., 2002. Mini-mental state examination. Principles and practice of geriatric psychiatry 140–141.

Enright, P.L., 2003. The six-minute walk test. Respir. Care 48 (8), 783–785.

Fairbank, J.C., Pynsent, P.B., 2000. The Oswestry disability index. Spine 25 (22), 2940–2953.

Faul, F., Erdfelder, E., Lang, A.-G., Buchner, A., 2007. G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39 (2), 175–191.

Ferraro, F.V., Gavin, J.P., Wainwright, T., McConnell, A., 2019. The effects of 8 weeks of inspiratory muscle training on the balance of healthy older adults: a randomized, double-blind, placebo-controlled study. Physiological reports 7 (9), e14076.

Ferraro, F.V., Gavin, J.P., Wainwright, T.W., McConnell, A.K., 2020. Comparison of balance changes after inspiratory muscle or Otago exercise training. PLoS One 15 (1), e0227379.

Ferraro, F.V., Gavin, J.P., Wainwright, T.W., McConnell, A.K., 2021. Association between inspiratory muscle function and balance ability in older people: a pooled data analysis before and after inspiratory muscle training. J. Aging Phys. Activ 30 (3), 421–433.

Forhan, M., Gill, S.V., 2013. Obesity, functional mobility and quality of life. Best Pract. Res. Clin. Endocrinol. Metabol. 27 (2), 129–137.

Gandevia, S., Butler, J., Hodges, P., Taylor, J., 2002. Balancing acts: respiratory sensations, motor control and human posture. Clin. Exp. Pharmacol. Physiol. 29 (1–2), 118–121.

Golicki, D., Niewada, M., Buczek, J., et al., 2015. Validity of EQ-5D-5L in stroke. Qual. Life Res. 24, 845–850.

Goulet-Pelletier, J.-C., Cousineau, D., 2018. A review of effect sizes and their confidence intervals, Part I: the Cohen'sd family. The Quantitative Methods for Psychology 14 (4), 242–265.

Hall, G.L., Filipow, N., Ruppel, G., et al., 2021. Official ERS technical standard: global Lung Function Initiative reference values for static lung volumes in individuals of European ancestry. Eur. Respir. J. 57 (3).

Harper, S., 2021. The impact of the Covid-19 pandemic on global population ageing. J. Population Ageing 14 (2), 137–142.

Hoffmann, T.C., Glasziou, P.P., Boutron, I., et al., 2014. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. Bmj 348.

Howe, T.E., Rochester, L., Neil, F., Skelton, D.A., Ballinger, C., 2011. Exercise for improving balance in older people. Cochrane Database Syst. Rev. 11.

Huang, C.-Y., Mayer, P.K., Wu, M.-Y., Liu, D.-H., Wu, P.-C., Yen, H.-R., 2022. The effect of tai chi in elderly individuals with sarcopenia and frailty: a systematic review and meta-analysis of randomized controlled trials. Ageing Res. Rev., 101747

Janssens, L., McConnell, A.K., Pijnenburg, M., et al., 2015. Inspiratory muscle training affects proprioceptive use and low back pain. Med. Sci. Sports Exerc. 47 (1), 12–19.

Jones, C.J., Rikli, R.E., Beam, W.C., 1999. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. Res. Q. Exerc. Sport 70 (2), 113–119.

Junqueira, D.R., Zorzela, L., Golder, S., et al., 2023. CONSORT Harms 2022 statement, explanation, and elaboration: updated guideline for the reporting of harms in randomised trials. bmj 381.

Kang, M., Ragan, B.G., Park, J.-H., 2008. Issues in outcomes research: an overview of randomization techniques for clinical trials. J. Athl. Train. 43 (2), 215–221.

Langer, D., Jacome, C., Charususin, N., et al., 2013. Measurement validity of an electronic inspiratory loading device during a loaded breathing task in patients with COPD. Respir. Med. 107 (4), 633–635.

Liang, S.Y., 2015. Simplified Tai Chi Chuan: 24 Postures with Applications and Standard 48 Postures. YMAA Publication Center, Inc.

Lomas-Vega, R., Obrero-Gaitán, E., Molina-Ortega, F.J., Del-Pino-Casado, R., 2017. Tai Chi for risk of falls. A meta-analysis. J. Am. Geriatr. Soc. 65 (9), 2037–2043.

Louis, R., Satia, I., Ojanguren, I., et al., 2022. European Respiratory Society guidelines for the diagnosis of asthma in adults. Eur. Respir. J. 60 (3).
McConnell, A., 2013. Respiratory Muscle Training: Theory and Practice. Elsevier Health Sciences.
Mielgo-Ayuso, J., Marques-Jiménez, D., Refoyo, I., Del Coso, J., León-Guereño, P., Calleja-González, J., 2019. Effect of caffeine supplementation on sports performance based on differences between sexes: a systematic review. Nutrients 11 (10), 2313.
Montero-Odasso, M., van der Velde, N., Martin, F.C., et al., 2022. World guidelines for falls prevention and management for older adults: a global initiative. Age Ageing 51 (9), afac205.
Mota, J.C., Santos, MRd, Sousa, LRd, Abdoral, P.R.G., Abdoral, L.S.R., Miranda, CJCdP., 2023. Inspiratory muscle training in people with chronic obstructive pulmonary disease (COPD): a systematic review. Fisioterapia e Pesquisa 30, e21028823en.
NICE, 2023a. Older People.
NICE, 2023b. Position Statement on Use of the EQ-5D-5L Value Set for England (updated October 2019).
Nightingale, C.J., Mitchell, S.N., Butterfield, S.A., 2019. Validation of the timed up and go test for assessing balance variables in adults aged 65 and older. J. Aging Phys. Activ 27 (2), 230–233.
O'Hoski, S., Sibley, K.M., Brooks, D., Beauchamp, M.K., 2015. Construct validity of the BESTest, mini-BESTest and briefBESTest in adults aged 50 years and older. Gait Posture 42 (3), 301–305.
Palermo, S., 2022. Serious games for promoting active and healthy ageing and monitoring frailty in the elderly. Italian J. Edu. Technol. 1–15.
Pollock, A.S., Durward, B.R., Rowe, P.J., Paul, J.P., 2000. What is balance? Clin. Rehabil. 14 (4), 402–406.
Powell, L.E., Myers, A.M., 1995. The activities-specific balance confidence (ABC) scale. J. Gerontol Series A: Biol. Sci. Med Sci. 50 (1), M28–M34.
Raiola, G., Domenico, F., Isanto, T., Altavilla, G., Elia, F., 2020. Biomechanics core. Acta Med. Mediterr. 36 (5), 3079–3083.
Rodrigues, G.D., McConnell, A.K., 2024. The Misuse of Respiratory Resistive Loading during Aerobic Exercises: Revisiting Mechanisms of "Standalone" Inspiratory Muscle Training. American Physiological Society, Rockville, MD.
Roldán, A., Cordellat, A., Monteagudo, P., et al., 2019. Beneficial effects of inspiratory muscle training combined with multicomponent training in elderly active women. Res. Q. Exerc. Sport 90 (4), 547–554.
Romer, L.M., McConnell, A.K., Jones, D.A., 2002. Effects of inspiratory muscle training on time-trial performance in trained cyclists. J. Sports Sci. 20 (7), 547–590.
Rudnicka, E., Napierała, P., Podfigurna, A., Męczekalski, B., Smolarczyk, R., Grymowicz, M., 2020. The World Health Organization (WHO) approach to healthy ageing. Maturitas 139, 6–11. https://doi.org/10.1016/j.maturitas.2020.05.018.
Safei, I., Zulfahmidah, Z., 2023. Inspiratory muscle training in chronic obstructive pulmonary disease patients: a scoping review. Green Med. J. 5 (2), 84–99.
Seixas, M.B., Almeida, L.B., Trevizan, P.F., et al., 2020. Effects of inspiratory muscle training in older adults. Respir. Care 65 (4), 535–544.
Shei, R.-J., Paris, H.L., Sogard, A.S., Mickleborough, T.D., 2022. Time to move beyond a "one-size fits all" approach to inspiratory muscle training. Front. Physiol. 12, 2452.
Sheraz, S., Ferraro, F.V., Siddiqui, F.A., Tariq, H., Anthony Faghy, M., Malik, A.N., 2023. The effects of inspiratory muscle training on balance and functional mobility: a systematic review. Postgrad. Med. 135 (7), 690–700.
Tsvetkova-gaberska, M., Kozhuharov, M., Ganeva, M., Markova, P., Pencheva, N., 2023. The effect of respiratory muscle training on young track-and-field athletes. J. Phy. Edu. Sport 23 (3), 730–737.
Warburton, D., Jamnik, V., Bredin, S., Shephard, R., Gledhill, N., 2021. The 2021 physical activity readiness questionnaire for everyone (PAR-Q+) and electronic physical activity readiness medical examination (ePARmed-X+): 2021 PAR-Q+. The Health & Fitness Journal of Canada 14 (1), 83–87.
Washburn, R.A., Smith, K.W., Jette, A.M., Janney, C.A., 1993. The physical activity scale for the elderly (PASE): development and evaluation. J. Clin. Epidemiol. 46 (2), 153–162.
WHO. WHO's work on the UN Decade of Healthy Ageing (2021–2030). https://www.who.int.2023..
WHO, 2023. Ageing and Health.
Witt, J.D., Guenette, J.A., Rupert, J.L., McKenzie, D.C., Sheel, A.W., 2007. Inspiratory muscle training attenuates the human respiratory muscle metaboreflex. J. Physiol. 584 (3), 1019–1028.
Włodarczyk, W.C., Tambor, M., 2019. EU policy on healthy ageing. Zdrowie Publiczne i Zarządzanie 2019 (Numer 3), 172–179.
Yeh, G.Y., Wang, C., Wayne, P.M., Phillips, R.S., 2008. The effect of tai chi exercise on blood pressure: a systematic review. Prev. Cardiol. 11 (2), 82–89.
Zdunek K, Kulik TB, Pacian A. Healthy Ageing-Global Crisis or Global Challenge?..
Zhong, D., Xiao, Q., Xiao, X., et al., 2020. Tai Chi for improving balance and reducing falls: an overview of 14 systematic reviews. Annals of physical and rehabilitation medicine 63 (6), 505–517.