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ORIGINAL ARTICLE

Six-month table tennis training improves body composition, bone health and physical performance in untrained older men; a randomized controlled trial

Six mois d'entraînement au tennis de table améliorent la composition corporelle, la santé osseuse et la performance physique d'hommes sédentaires de plus de 65 ans : essai contrôlé randomisé

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KEYWORDS
Bone mass;
Muscle mass;
Fat mass;
Physical performance;
Aging

Summary
Objectives. — In the present study, we aimed to investigate the effects of 6-month table tennis (TT) training on bone health, muscle mass, and physical performance in older men.
Material and methods. — Forty older men aged of ≥ 65 years were randomly assigned to an experimental group (EXP; $n = 20$) or control group (CON; $n = 20$). Before and after the intervention, dual-energy X-ray absorptiometry, a short physical performance test battery and one-leg balance tests were used to assess body composition and physical function.
Results. — TT increased whole body and regional bone mineral density (range from 2.6% to 8.7%; $p < 0.05$), and lean mass (range from 2.2% to 11.1%; $p < 0.05$), while total and regional body fat mass decreased (range from 4.8% to 24.7%; $p < 0.05$). TT also improved the performance test score, 4-m walk, 5-chair stands, 400-m walk and balance (range from 4.0% to 13.7%; $p < 0.05$).

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Conclusion. — This indicates that TT can effectively mitigate changes in bone health, muscle mass and physical performance associated with aging and a sedentary lifestyle.

MOTS CLÉS
Masse osseuse ;
Masse musculaire ;
Masse grasse ;
Performance physique ;
Vieillissement

Résumé
Objectifs. — Dans la présente étude, nous avons cherché à étudier les effets de six mois d'entraînement au tennis de table (TT) sur la santé osseuse, la masse musculaire et les performances motrices d'hommes sédentaires de plus de 65 ans.
Méthodes. — Quarante hommes âgés de $\geq$65 ans ont été assignés de façon randomisée à un groupe expérimental (EXP ; n = 20) ou groupe contrôle (CON ; n = 20). Avant et après l'intervention, une absorptiométrie biphotonique, une batterie de test de performance physique et des tests d'équilibre sur une jambe ont été utilisés pour évaluer la composition corporelle et la performance motrice.
Résultats. — TT a augmenté la densité minérale osseuse du corps entier et la densité minérale osseuse régionale (de 2,6 % à 8,7 % ; p < 0,05) ainsi que la masse maigre (de 2,2 % à 11,1 %; p < 0,05), tandis que la masse grasse corporelle totale et régionale a diminué (de 4,8 % à 24,7 %; p < 0,05). Le TT a également amélioré le résultat du test de performance de marche de 4 m, les supports de 5 chaises, la marche de 400 m et l'équilibre (de 4,0 % à 13,7 %; p < 0,05).
Conclusion. — Cela indique que le TT peut efficacement limiter le déclin de la masse osseuse, de la masse musculaire et de la performance physique du au vieillissement et à un mode de vie sédentaire.

1. Introduction

Aging is associated with significant alterations in body composition, including an increase in fat mass, and decreases in lean body mass and bone mineral density, which can occur without necessarily changing the body mass index [1,2]. There is a 13% to 24% prevalence of frank sarcopenia in 60-year-old individuals, and this increases to > 50% in people over the age of 80 years [3]. In part because initial values are larger, the absolute loss of muscle mass during aging is almost twice as great in men as in women [4]. Moreover, this muscle wasting is associated with increased disability, risk of falling and fractures and overall mortality [1,5,6], it is thus important to develop practical tactics that can prevent, delay or reverse such changes in muscle mass and function for older people.

In terms of fractures, a perhaps even more important factor than muscle weakness is osteoporosis. More than 200 million people worldwide suffer from osteoporosis [6], and it has been identified by the World Health Organization as a silent epidemic that is the world's third health problem (after cardiac disease and cancers) and the silent epidemic [7]. According to the U.S. National Osteoporosis Foundation, approximately one-fifth of men over the age of 50 years sustain one or more osteoporosis-related fractures in their remaining lifetime [8], with about half of these incidents being hip fractures. In 2050, the incidence of hip fracture in men has been predicted to increase by a further 310% worldwide [9]. Historically, education, prevention, and the treatment of osteoporosis has targeted mainly women, but recently, researchers and health care professionals have begun to redress this focus in the light of its increasing prevalence in men [10].

Musculoskeletal dysfunction predisposes older individuals to limitations of mobility, falls, fractures and frailty, posing a major challenge to continuing independent living and increasing both clinical and public health burdens [4,11]. Previous studies have shown that greater participation in physical activity, especially weight-bearing exercise, can attenuate the loss of bone mass, BMD and skeletal muscle mass normally associated with ageing [1,12,13]. Some older adults elect to participate in a range of activities, including golf, lawn bowls, swimming, dancing, indoor soccer and table tennis [14], but there is little empirical evidence on the relative merits of such activities in terms of improving the body composition, bone health and physical functioning of the older adult [13]. Given the popularity of table tennis among older adults [14], it is desirable to assess the effectiveness of TT training as a means of enhancing bone health, muscle mass, and physical functioning in older men.

Table tennis is an intermittent sport requiring short bursts of intensive physical activity [15]; it is similar in its physical demands to the intensive interval training that has been reported as improving bone mineral density and lean tissue mass, and as decreasing fat mass [15]. Data from cross-sectional studies suggest that leisure-time TT training is associated with beneficial effects for the body composition and muscular strength of older men [16,17]. Based on both these cross-sectional studies of older adults [16,17] and findings in young athletes [15] it has been suggested that TT training may be a useful tactic to maintain and increase bone mineral density and lean mass and decrease fat mass in the elderly. Thus, the aim of the present randomized control trial was to assess the effects of 6-month recreational TT training on the body composition and physical performance of older men. We hypothesized that participation in recreational TT training would reduce body fat content, while improving muscle and bone mass, and enhancing physical performance in older men.

2. Methods

2.1. Study design

A 6-month single-blind, parallel group, randomized controlled trial was conducted as described in the study flow chart. This study was approved by the Institutional Review Board of Shahrood University of Medical Sciences and the trial was registered with the Iran Registry of Clinical Trials (IRCT20170114031942N4). All participants signed their informed consent and all procedures were completed in accordance with the Declaration of Helsinki.

2.2. Participants

Forty older men aged of ≥ 65 years were recruited through presentations in the local community of Shahrood city from 24 February to 18 August 2018. Eligible participants were community-dwelling men, aged ≥ 65 years, with a score of more than 26 on the mini-mental state examination (MMSE); they had not participated in table-tennis during the last 10 years, and were able to perform physical activity safely as assessed by the physical activity readiness questionnaire (PAR-Q). They were also currently independent in terms of the activities of daily living; and had received physician's approval for participation in TT training. Volunteers were excluded if they reported a history of metabolic bone disease or took corticosteroids likely to have an effect on bone and calcium metabolism; if there was a history of severe musculoskeletal disorders (such as arthritis of the back, knee or hip) and/or previous arthroplastic surgery or implants; if there were neurological problems/injures (such as Parkinson's disease, stroke, spinal cord injury, or cerebral palsy); andendocrine disorders, such as hypothyroidism or hyperthyroidism. Other exclusion criteria were taking medication, smoking, alcohol intake, a systemic blood pressure greater than 160/100 mm Hg, diabetes mellitus, liver disease and renal disorders. Participants who had participated in other forms of physical activity (such as walking, fitness classes, supervised group exercise classes, Tai Chi, Yoga, dance or any other regular physical activity) over the past 2 years were also excluded.

2.3. Randomization

Prior to initiation of the study, an independent, blinded assessor with no further involvement in the study made a random 1:1 allocation sequence of volunteers between the experimental and control groups, using a computer-generated sequence (Random Allocation Software 2.0). A block randomization design (block size of 2, 4) was applied to ensure an equal number of participants in each group.

Participants who met the eligibility criteria signed the informed consent form before medical clearance and baseline data collection began. After randomization between experimental and control groups, participants were stratified for body mass index, total weekly physical activity and peak oxygen intake $\left(V_{O_2peak}\right)$. The control group were instructed to continue with their daily routines, leaving their lifestyle unchanged during the study. Laboratory specialists assessing the variables and the data analyst were blinded to the group allocation, although of necessity, participants and the sport science specialist providing the exercise training were aware of group allocation. Primary and secondary outcomes were re-evaluated at week 24, after completion of the last intervention session for each group.

2.4. Measurements

2.4.1. Dietary intake

A valid self-report food frequency dietary questionnaire was used to assess the calcium and vitamin D intake of participants [18].

2.4.2. Habitual physical activity level

A face-to-face guided interview, using the Iranian language version of the IPAQ was used to assess the habitual physical activity of each participant [19]. Total weekly minutes of physical activity were calculated for vigorous activities (heavy lifting, digging, aerobics, or fast bicycling), moderate activities (e.g., carrying light loads, bicycling at a regular pace, or doubles tennis), walking for occupation, and/or transportation, housework/gardening, and leisure-related activities. This data was used to match habitual physical activity (other than the TT intervention) between groups.

2.4.3. Maximal heart rate and cardiovascular fitness

The V_{O_2peak} was measured using the Young Men's Christian Association submaximal cycle ergometer test. In brief, this consists of two to four consecutive 3-min cycling stages appropriate for adults with Class A risk stratification. The initial work rate of 25 W is increased every 3 minutes until volitional fatigue, or reaching 85% of the age-predicted maximal heart rate. The recorded V_{O_2peak} and maximal heart rate are the highest values achieved during the test [20].

2.4.4. Demographic variable

Body mass was measured on a digital scale (SECA 760, Vogel & Halke GmbH & Co., Hamburg, Germany) to the nearest 0.1 kg and height (m) was measured to the nearest 1 mm. The body mass index was calculated as body mass·height^{-2} (kg·m^{-2}).

2.4.5. Blood pressure

Resting blood pressure was measured over the brachial artery using a semi-automated device (DINAMAP™ XL, Critikon, Johnson & Johnson, Tampa, Florida, USA). First and fifth Korotkov sound were defined as systolic and diastolic blood pressure, respectively. Four consecutive blood pressure readings were taken, each 2 min apart. The first reading was discarded, and the mean of the next 3 consecutive readings was used in the study.

2.4.6. Body composition

Total and regional body composition was measured using Lunar Prodigy dual-energy X-ray absorptiometry (DXA) (GE Corporate, Madison, WI, USA), as previously reported [21]. The device was calibrated daily using a lumbar spine phantom according to the manufacturer's recommendations. The enCore 2003 Version 7.0 software generated standard lines that set apart the limbs from the trunk and head; these lines were adjusted using specific anatomical points determined by a standardized segmentation protocol described elsewhere [22]. Prior to scanning, participants removed all metal-containing objects. Participants lying motionless in the supine position along the longitudinal centerline axis of the table throughout the procedure, which lasted 10 to 15 minutes. Lean mass, fat mass, and bone mineral content were calculated from analysis of the scan, and bone mineral density was calculated by dividing bone mineral content by the cross-sectional area of bone.

Sub-regional analyses were performed as described elsewhere [23]. Lean mass was assumed equivalent to the muscle mass, but only in the limbs. The arm region (including the anatomical arm, forearm, and hand) was separated from the trunk by an inclined line crossing the scapulo-humeral joint, such that the humeral head was located in the arm region. The leg region (including the upper and lower leg, and the foot) was separated from the trunk by an inclined line passing just below the pelvis. Special assessments were conducted to measure bone mass in the lumbar vertebra regions L_1—L_4, left complete proximal femur including the femur neck, trochanter-intertrochanteric region, and Ward's triangle. In our laboratory, the coefficients of variation were 0.6% for whole body bone mineral content, 0.9% for whole body bone mineral density, 1.4% for femoral regions BMD, 0.9% for lumbar spine BMD, 1.9% for whole body fat and 1.6% for whole body lean mass.

2.4.7. Physical performance

The Short Physical Performance Battery is a well-established, reliable and valid measure of functional capability for older people that comprises a hierarchical assessment of gait speed (short (4-m) usual gait pace test), chair stands (timed 5-chair stand test) and balance (feet together, semi-tandem, and tandem stands) [24].

To perform the timed 5-chair stand test, participants kept their arms folded across the chest and as quickly as possible stood up and sat down 5 times without stopping. The test was aborted if participants used their arms, could not complete 5 rises, if there were concerns about safety or after 1 minute if the test was still not completed.

Balance tests began by standing with feet next to one other, followed by a semi-tandem stand (the side of the heel of one foot touching the big toe of the other foot) and were completed with a tandem stand (the heel of one foot in front of and touching the toes of the other foot).

A total score of 0 to 12 was calculated as the sum of scores in each of the 3 tests, where top performance gave a score of 4, and inability to perform the test a score of 0.

Furthermore, participants were asked to walk 400 m as quickly as possible; times are reported as reproducible and a good indicator of mobility and ability to undertake the activities of daily living in older adults [25]. To measure balance, participants stood on their preferred leg for a maximum of 60 s, with their eyes open. Times of less than 10 s were considered as indicating poor balance and a high risk of falling [25].

2.5. Table tennis intervention

The intervention group played three to five 1.5-hour sessions of table tennis per week for 6 months. Sessions began with a 5—10 min low-intensity warm-up of light aerobic activity and general stretching exercises, and ended with a 5—10 min cooled down with general stretching exercises and slow walking.

2.6. Adherence and adverse events

The instructor, not otherwise involved in the study, recorded weekly attendance and adverse events, using a questionnaire. Participants were asked to report any unpleasant consequences such as new pain, acute and overuse injuries, etc. that appeared related to the table tennis sessions. During the 6-month intervention, attendance averaged $78 \pm 4\%$ (range: 75—120 of potential sessions). Four participants experienced adverse effects causing them to withdraw from the study; 1 for illness, 1 for an ankle sprain, and 2 for hamstring strains.

2.7. Statistical analyses

SPSS statistical software (version 18.0, SPSS Inc., Chicago, IL, USA) was used throughout. Statistical significance level was defined as $p < 0.05$. The Shapiro—Wilk and Lilliefors (used for variables with less than 50 samples) tests were used to assess normality. Descriptive statistics (mean, standard deviation, and lower/upper 95% confidence intervals were calculated. A 2×2 (group $\times$ time) mixed-model analysis of variance evaluated within-subjects comparisons of pretest and post-test data for both subject groups, as well as between-group comparisons. The software package G*Power3.1 Software calculated the minimum sample size, based on a previous study of bone mineral density in older adults [17]. For an effect size of 1.41, a 2-tailed significance level (α) of 0.05, and a power (1-β) of 0.90 a minimum sample of 15 was needed; anticipating a possible drop-out rate of 30%, we included 20 participants in each group.

3. Results

There were no significant inter-group differences in age (66.3 ± 3.6 vs. 67.0 ± 3.9, years), mini-mental state examination score (27.3 ± 1.2 vs. 27.1 ± 1.1), international physical activity questionnaire score (963 ± 550 vs. 964 ± 464), calcium (1064 ± 209 vs. 1060 ± 232 mg/day), and vitamin D (135 ± 23 vs. 144 ± 28 IU/day) intake between groups ($p > 0.05$).

3.1. Health-related variables

A significant time effect and a time $\times$ group interaction were found for the resting systolic and diastolic blood pressures,

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Table 1 Health variables, Lean mass, fat mass, and bone mass and, physical performance variables for intervention and control groups before and after the 6-month intervention.

Variables	EXP ($n = 16$)			CON ($n = 20$)			Mean inter-group difference (95%CI)	Time			Time × group interaction		
	Before	After	Delta	Before	After	Delta		$F_{(1,38)}$	p	η_p^2	$F_{(1,38)}$	p	η_p^2
Health variables													
Body mass (kg)	77.1 ± 5.7	73.5 ± 5.0	4.7	76.4 ± 5.9	76.3 ± 5.9	−0.1	−2.9 (−2.60 to −4.81)	36.8	0.001	0.49	41.1	0.001	0.52
BMI ($kg \cdot m^{-2}$)	27.1 ± 1.5	25.9 ± 1.3	4.4	26.9 ± 1.8	27.0 ± 1.9	−0.4	−1.3 (−1.71 to −0.89)	36.7	0.001	0.49	41.9	0.001	0.52
R-DBP (mmHg)	89.1 ± 6.8	85.3 ± 5.0	4.3	88.9 ± 8.0	88.7 ± 7.8	−0.2	−3.55 (−6.48 to−0.62)	14.3	0.001	0.27	5.1	0.03	0.12
R-SBP (mmHg)	138 ± 8	131 ± 7	4.3	137 ± 20	136 ± 10	0.7	−4.8 (−9.08 to −0.51)	7.8	0.01	0.17	6.1	0.02	0.14
$V_{O_2 peak}$ $\left(mL\,min^{-1}\,kg^{-1}\right)$	27.3 ± 4.1	29.9 ± 3.3	9.1	27.0 ± 4.2	27.3 ± 3.8	−1.5	2.3 (−0.39 to 4.89)	4.8	0.03	0.11	2.9	0.08	0.07
Lean mass (kg)													
UE	6.48 ± 0.39	6.86 ± 0.42	6	6.28 ± 0.60	6.31 ± 0.63	0.5	0.36 (0.26 to 0.45)	36.4	0.001	0.52	39.7	0.001	0.57
DUE	3.32 ± 0.23	3.69 ± 0.30	11.1	3.17 ± 0.35	3.19 ± 0.39	0.6	0.26 (0.14 to 0.38)	25.9	0.001	0.41	18.9	0.001	0.33
N-DUE	3.16 ± 0.30	3.26 ± 0.25	3.1	3.12 ± 0.35	3.12 ± 0.37	−0.2	0.10 (−0.3 to 0.23)	2.6	0.12	0.06	2.3	0.14	0.06
LE	17.5 ± 2.0	18.1 ± 1.9	3.3	17.7 ± 1.8	17.5 ± 1.9	−0.9	0.74 (−0.56 to 0.91)	23.1	0.001	0.38	70.4	0.001	0.65
AL	23.9 ± 1.9	24.9 ± 2.0	4.2	23.9 ± 1.8	23.8 ± 1.9	−0.5	1.11 (−0.89 to 0.34)	32.4	0.001	0.47	34.2	0.001	0.50
Trunk	27.0 ± 5.6	27.1 ± 5.5	0.5	25.9 ± 6.8	25.9 ± 6.4	−0.01	0.14 (−0.59 to 0.87)	0.1	0.74	0.01	0.2	0.7	0.01
Fat mass (kg)													
UE	2.85 ± 0.50	2.50 ± 0.46	−12.2	2.88 ± 0.55	2.87 ± 0.61	−0.3	−0.34 (−0.45 to −0.23)	44.6	0.001	0.54	38.7	0.001	0.50
DAE	1.38 ± 0.40	1.13 ± 0.39	−18.1	1.40 ± 0.37	1.39 ± 0.37	−0.4	−0.24 (−0.35 to −0.13)	22.3	0.001	0.37	20.2	0.001	0.35
N-DAE	1.47 ± 0.34	1.37 ± 0.30	−6.8	1.48 ± 0.31	1.47 ± 0.28	−0.4	−0.10 (−0.15 to −0.04)	16.5	0.001	0.30	12.8	0.001	0.25
LE	8.08 ± 1.38	7.69 ± 1.20	−4.8	8.27 ± 1.28	8.26 ± 1.28	−0.1	−0.39 (−0.68 to −0.10)	7.5	0.01	0.17	7.0	0.01	0.16
Al	10.9 ± 1.5	10.2 ± 1.3	−6.8	11.2 ± 1.6	11.1 ± 1.5	−0.2	−0.73 (−1.06 to − 0.39)	21.2	0.001	0.36	19.2	0.001	0.34
Trunk	15.2 ± 2.9	11.3 ± 3.6	−25.7	15.4 ± 1.9	15.6 ± 2.8	1.5	−4.14 (−5.42 to − 2.84)	33.2	0.001	0.47	42.1	0.001	0.53
Bone mineral density ($g \cdot cm^{1}$)													
DAE	0.79 ± 0.05	0.84 ± 0.05	6.3	0.76 ± 0.04	0.75 ± 0.04	−1.3	0.05 (−0.01 to 0.06)	45.5	0.001	0.54	84.2	0.001	0.69
N-DAE	0.75 ± 0.04	0.77 ± 0.04	2.6	0.77 ± 0.04	0.76 ± 0.04	−1.3	0.03 (−0.01 to 0.06)	4.0	0.05	0.12	22.3	0.001	0.37
TS	0.88 ± 0.06	0.92 ± 0.05	4.5	0.90 ± 0.07	0.89 ± 0.07	−0.5	0.04 (0.02 to 0.06)	13.3	0.01	0.26	20.1	0.001	0.35
LS	1.26 ± 0.11	1.32 ± 0.10	4.7	1.26 ± 0.09	1.25 ± 0.09	−0.8	0.07 (0.03 to 0.10)	7.3	0.01	0.16	15.5	0.001	0.29
FN	0.95 ± 0.10	0.99 ± 0.09	4.3	0.95 ± 0.09	0.95 ± 0.10	−1	0.04 (−0.02 to 0.10)	21.1	0.001	0.36	22.2	0.001	0.37
FT	0.77 ± 0.06	0.81 ± 0.06	3.9	0.78 ± 0.05	0.77 ± 0.05	−1.2	0.04 (0.02 to 0.07)	4.1	0.05	0.11	11.9	0.001	0.24
WT	0.83 ± 0.09	0.87 ± 0.09	3.6	0.84 ± 0.08	0.84 ± 0.09	0.5	0.03 (0.01 to 0.04)	20.9	0.001	0.36	13.3	0.001	0.26
Physical Performance													
SPPB Score	10.2 ± 1.2	11.5 ± 1.1	12.3	10.5 ± 1.0	10.3 ± 1.7	−1.9	1.8 (0.71 to 1.98)	14.5	0.001	0.29	9.6	0.001	0.44
4-m W (s)	3.42 ± 0.46	3.15 ± 0.48	7.9	3.46 ± 1.0	3.41 ± 0.42	1.1	−0.23 (−0.42 to 0.05)	11.6	0.01	0.23	6.4	0.02	0.14
5-CS (s)	11.0 ± 0.4	10.6 ± 0.5	4.0	11.0 ± 0.6	11.0 ± 0.8	−0.5	−0.49 (−0.70 to −0.26)	12.8	0.001	0.25	19.9	0.001	0.34
400-m W (s)	284 ± 17	268 ± 14	5.4	286 ± 14	286 ± 14	−0.4	−14.3 (−20.4 to −10.1)	37.3	0.001	0.49	35.4	0.001	0.48
OLS (s)	46.5 ± 4.8	52.9 ± 5.9	13.7	45.6 ± 5.4	46.1 ± 4.8	1.1	5.89 (4.24 to 7.53)	71.6	0.001	0.65	52.3	0.001	0.58

Ex: experimental group; CON: control group; R-DBP: Resting-diastolic blood pressure; R-SBP: Resting systolic blood pressure; UE: upper extremity; DUE: Dominant upper extremity-DAE: Non-dominant upper extremity; LE: Lower extremity; AL: appendicular limbs; TS: Thoracic spine; LS: lumbar spine; FN: femoral neck; FT: femur trochanter; WT: Ward's triangle. ALM: appendicular lean mass; TLM: trunk lean mass; FM: fat mass; AFM: appendicular fat mass; TFM: trunk fat mass; BMC: bone mineral content; SPPB Score: Short Physical Performance Battery Score; 4-m W: 4 meter walk; 5-CS: 5 chair stances; 400-m W: 400 meter walk; OLS: one-leg stand.

with decreases in the intervention group (%Δ = 4.3% and 4.3%), but not in the control group. There were also significant time effects and time × group interactions for body mass index (Δ = −4.4%) and $V_{O_{peak}}$ (Δ = 9.1%) (Table 1).

3.2. Total lean and fat mass and bone mineral density

A significant time effect and a time × group interaction were found for total lean mass, total fat mass, and total bone mineral density, with a significant reduction in the total fat mass (Δ = −17.6%), and a significant increases in the total lean mass (Δ = 2.2%) and total bone mineral density (Δ = 8.7%) after table tennis training (Fig. 1).

3.3. Regional lean and fat mass and bone mineral density

Significant time effects and time × group interactions were found for regional lean mass parameters ($p < 0.05$), with the intervention group showing increases of upper extremity (Δ = 6%), lower extremity (Δ = 3.3%), and dominant upper extremity values (Δ = 11.1%). However, no significant increase was seen in the non-dominant arm or trunk ($p > 0.05$) (Table 1). A significant time effect and a time × group interaction were found for regional lean mass parameters ($p < 0.05$), with the intervention group showing decreases from Δ = −4.8% for the lower limbs to Δ = −25.7% for the trunk (Table 1). Significant time effects and time × group interactions were found for regional bone mineral density parameters, with the intervention group showing an increase from Δ = 2.6% for the non-dominant arm to Δ = 6.3% for the dominant arm (Table 1).

3.4. Physical performance

Regarding physical performance variables, There were significant time effects and time × group interactions indicating improved scores for the intervention group on the overall short physical performance battery score (Δ = 12.3%), 4-m walk (Δ = 7.9%), 5-chair stands (Δ = 4%), 400-m walk (Δ = 5.4%) and one-leg stand (Δ = 13.7%).

4. Discussion

The current study is the first to investigate the effect of regular table tennis training sessions on bone health, muscle mass and physical function in initially untrained older adult men. Such training induced a reduction in whole body and regional fat mass and an increase in whole body and regional lean mass and bone mineral density, suggesting that regular table tennis playing can be an effective measure to improve health in old age.

4.1. Health-related variables

High blood pressure is a serious public health challenge, affecting more than two third of seniors and accounting for 13.5% of all deaths in those [26], confirming critical research needs regarding exercise prescription for hypertension. The table tennis program significantly decreased both systolic and diastolic pressures, a response also reported following continuous and interval aerobic training [27]. Possibly, a periodic increase of blood flow to the working muscles may stimulate the synthesis of nitric oxide by the vascular endothelial cells, thereby causing arterial and a decrease of blood pressure [27].

4.2. Fat mass

The total fat mass decreased by 17.6%, presumably mainly a loss of visceral fat, since the loss from the arms was only 12.2% and that from the legs was 4.8%, as compared with 25.7% for the trunk. Previous cross-sectional studies have also reported that regular participation in recreational table tennis practice was associated with a low body fat relative to sedentary individuals [16,17]. This probably reflects the added energy demands imposed by the table tennis sessions [15]. The decrease seen after 6 months of table tennis training was more pronounced than that reported in soccer training was performed for 3 × 40 min/week for 12 weeks [28] and swimming training were held 2 × 45 min for 14 weeks [29]. This may be in part because longer duration of experimental intervention in our study. The success in reducing body fat is an important finding, because obesity has already reached epidemic proportions among older adult [2], with many adverse medical consequences [30].

4.3. Lean mass

The intervention increased lean mass by 2.2%, in accordance with some previous observations [31], but in contrast to the absence of any significant cross-sectional effect in older table tennis players that we examined previously [17]. Andersen et al. [31] showed that 1-h recreational soccer training session twice per week for 16 weeks and three times a week for the following 36 weeks leads to an increase of lean mass, particularly in the legs, reflecting the importance of lower limb strength to success in this sport [32], but less so for table tennis [33]. Given that the loss of skeletal muscle mass is an independent risk factor for osteoporosis, falls, fractures, functional ability and mortality [1], the preservation of lean tissues may well have positive dividends in reducing the risk of such adverse events.

4.4. Bone mineral density

In the present study, the intervention increased total bone mineral density by 8.7%, with gains in the vertebrae (4.5% thoracic and 4.7% lumbar), femoral neck (4.3%) and trochanteric region (3.9%). These observations are consistent with previous cross-sectional studies in young [15] and older adult table tennis players [16,17], with benefits greater in the dominant than in the non-dominant arm. Cross-sectional studies have also reported a 20% thicker cortex around the femur neck in participants in impact sports such as soccer and squash [34]. The findings also concur with recent evidence that soccer training improves bone health in healthy older men [35], and in both youth professional tennis players [36] and tennis players with an average age

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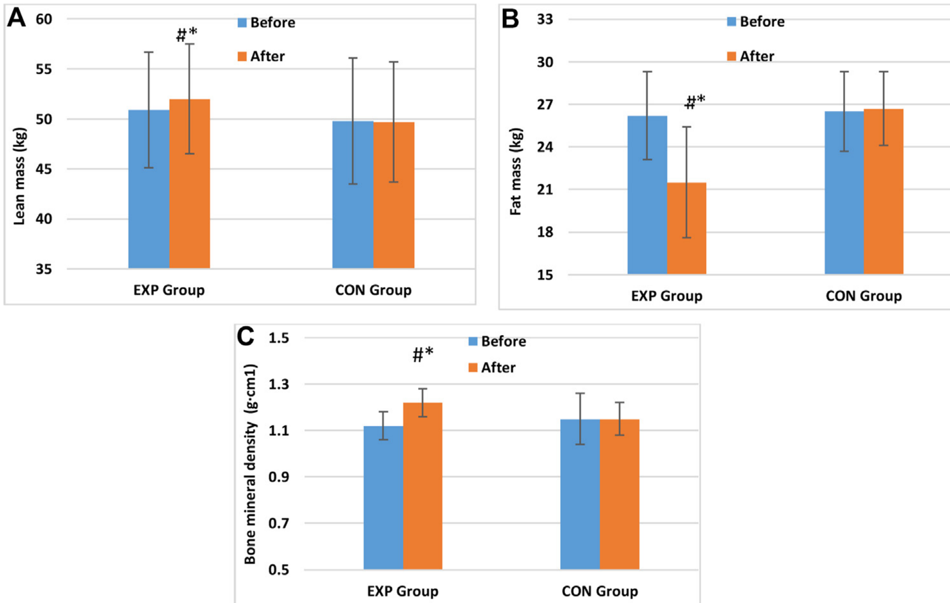

Figure 1 A) Total lean mass (mean ± SD), B) Total fat mass, and C) Total bone mineral density of control (CON) and participants before and after tennis table participation (EXP). *: Significant difference between CON and EXP groups at $p < .05$ and #: Significant within group difference at $p < .05$.

of 55 years [21]. In our study, gains were seen not only in the legs, but also in the lumbar spine.

Osteogenesis is stimulated when high-intensity strains are repeated regularly in unusual patterns and in short-term courses; there is also an association between muscle strength and bone mineral density [37]. Gains are limited to the dominant arm, as intense and rapid strains are applied uniquely to this arm [38]. The weight-bearing nature of table tennis also applies frequent and unusual impacts that promote an increase of bone mineral density and reduce the risk of fractures.

4.5. Physical performance

The intervention improved many aspects of physical performance, reducing the risk of falling and facilitating the performance of daily activities; the 1.7 point increase in performance score exceeds what has been deemed a clinically significant (1.34 points) change in older individuals [39]. The relationship between performance test scores and balance [5] underlines the potential of such gains to reduce falls and associated complications. Cross-sectional studies support the view that table tennis training enhances muscular strength and physical performance in older men [16,17].

The accelerations, decelerations, stop-and-go patterns, changes of direction, eccentric loads, and spatial orientation demanded by table tennis, suggest that it may serve as an integrative motor competency training approach for older adults. Although it is growing in popularity among seniors, deliberate walking remains the most popular leisure activity for those over the age of 60 years, and it can confer many of the same health benefits [12]. Thus, there remains a need to compare the long-term benefits, risks and adherence from a similar investment of time in these two approaches to health maintenance in seniors. Table tennis training may be the optimal solution when living in an extremely hot or cold climate, since it is usually played indoors, and it may appear if a person lives in an environment that is not ''walker-friendly.'' On the other hand, table tennis requires a partner, not easily accessible to all seniors. Often, it also requires driving to a specific facility, and many seniors lack personal transportation. The competitive nature of games may be a motivating factor for some personalities. Table tennis usually imposes greater metabolic demands than moderate walking [33], with a potential range of 4—9 METs [40]. In a healthy senor, it is thus likely to produce larger gains of fitness than moderate walking, but there is a danger that the physical demands of table tennis may become excessive for someone who has chronic health problems, particularly as the intensity of effort is determined in part by the opponent. Finally, the fast movements and jumping needed in table tennis are likely to improve agility and bone health to a greater extent than moderate walking, but they are also more likely to cause injuries, particularly in those who have some arthritic changes in the back, hips and lower limbs.

4.6. Limitations

Although we attempted to minimize potential the confounding effects of other lifestyle activities by using self-report interviews, we recommend that these variables be considered carefully in future investigations. Since the research participants were only relatively healthy senior men, the generalization of the results to other populations including women and those with various forms of chronic disease is limited. Nevertheless, this is the first study to have investigated the effects of recreational table tennis for the senior in terms of body composition and physical performance in older adult men and it demonstrates substantial benefit in terms of both overall health and bone mineral density.

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5. Conclusions

A 6-month session of table tennis training improves bone mineral density in the femur and spine, and decreases regional and total fat mass, as well as enhancing various aspects of physical performance in older adult man. It offers a potential option to prevent or reverse osteoporosis in older men, and merits careful comparison with the devotion of an equal time to brisk walking.

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Disclosure of interest

The authors declare that they have no competing interest.

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