

Original Article

A retrospective comparison of physical health in regular recreational table tennis participants and sedentary elderly men

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Abstract

Objectives: This study investigated the benefits of regular recreational table tennis games for body composition, physical performance and muscle strength of older adult men. **Methods:** We compared twenty older male regular table tennis players (RTTP) and twenty age- and weight-matched sedentary participants (SP). Body composition (LM, lean mass; FM, fat mass; BMD, bone mineral density), physical function, and muscle strength were analyzed with dual-energy X-ray absorptiometry, short physical performance battery (SPPB) and a hand-held dynamometer, respectively. **Results:** The RTTP had a higher elbow flexor, knee extensor and plantar flexor muscle strength than the SP. The RTTP had a higher total, regional (arm, leg and lumbar spine), and site-specific (trochanter and Ward's triangle) BMD, and a lower fat mass, in total and regional terms (arm, leg, and trunk) as well as percentage of body mass, than the SP. RTTP had a higher SPPB score and performed the 400-m walk in a shorter time than SP. **Conclusions:** These data suggest that regular table tennis has beneficial effects on muscle strength, physical performance and body composition, and is a potent activity to improve health in older adults.

Keywords: Body Composition, Bone Mineral Density, Muscle Strength, Ageing

Introduction

Aging is associated with reductions in the performance of most physiological systems¹. The age-related muscle weakness contributes to a number of adverse health outcomes, such as loss of mobility, frailty and social isolation^{2,3}. The weakness is at least partly a result of the loss of lean body mass and a concomitant increase in body fat percentage, and is associated with reductions in bone mineral density^{4,5}. The prevalence of non-communicable diseases (NCD), such as high blood pressure, arthritis,

cancer and diabetes also increases with increasing age⁶. The benefits of physical activity (PA) and sport as low-cost and effective means of prevention and treatment of NCDs is evident for health policymakers⁷ and recreational sports have attracted growing government attention⁸. However, few studies investigated the potential health benefits of football^{9,10}, walking¹¹, running¹², swimming^{13,14} and recreational table tennis (RTT) to prevent the age-related decline of physical function, muscle strength and changes in body composition.

Table tennis is an intermittent sport with short bursts of intensive activity^{15,16}, similar in nature to intense interval training. Accordingly it has been reported that table tennis improves bone mineral content and lean mass, and decreased fat mass in athletes¹⁷. Although there are thus beneficial effects of RTT on the health profile of athletes, the effect of RTT on the health profile of other populations, especially the older adult, is unknown. Thus, the aim of this retrospective study was to assess the effects of recreational table tennis playing on bone health, physical function and muscle strength in older adult men.

The authors have no conflict of interest.

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We hypothesized that regular participation in recreational table tennis improves bone health, physical function and muscle strength in older adult men.

Materials and methods

Participants

All participants lived in Shahrood, Semnan, Iran, and were recruited through presentations in the local community from November 2015 to May 2016. The twenty regularly recreational table tennis players (RTTP: age 68.8 ± 4.6 y; BMI 26.9 ± 2.0 kg/m²) had a training experience of 11.6 ± 3.6 years (5 to 19 y) of 3.5 ± 1.05 session (2 to 5) per week, lasting 1.5–3 hours per session. Twenty sedentary participants (SP: age 69.5 ± 3.9 y; BMI 27.6 ± 1.9 kg/m²) had not participated in any regular exercise program for at least 2 years and were age- and weight-matched to the RTTP participants.

Participants were excluded if they reported; neurological problems (such as Parkinson's disease), cardiovascular disease (CVD), bone or joint problems and/or surgery (such as back, knee, or hip arthritic diseases), hypertension, diabetes, alcohol consumption, smoking, taking medication. The study was approved by the Institution Review Board of Blinded and met the STROBE study guideline of cross-sectional studies. All procedures were in accordance with the Declaration of Helsinki and were explained to the participants before they signed an informed consent declaration.

Outcome measures

The body mass index (BMI) was calculated as body mass/height² (kg/m²). Resting blood pressure was measured using a semi-automated device (DINAMAP™ XL, Critikon, Johnson & Johnson, Tampa, Florida, USA) four times, each 2 min apart. The first reading was discarded, and data presented as the mean of the next 3 consecutive readings.

Short performance battery (SPPB)

The short physical performance battery (SPPB)¹⁸ was used as a measure of physical function and consists of assessments of standing balance, a short (4-m) usual gait-pace test and a timed 5-chair stand test. For each of the three components the score ranges from 0, being “unable to complete the task” to 4, being the “highest level of performance”. The total score thus ranges from 0 (worst performance) to 12 (best performance)¹⁹. The total score of the SPPB is related to the degree of disability, mortality and hospital admission¹⁸.

To assess static balance, participants were asked to maintain standing posture during three standing positions: side-by-side, semi-tandem and tandem stance. If the patient could maintain the side-by-side stance (feet together) for 10 s, he then performed a semi-tandem stance and if maintained for 10 s this was followed by a tandem-stance position.

The scoring was as follows: 0 points if the participant was unable to hold the side-by-side stance for >9 seconds; 1 point for a side-by-side stance of 10 sec, but unable to hold semi-

tandem for 10 s; 2 points for a semi-tandem stance for 10 s, but unable to hold tandem for >2 s; 3 points for tandem for 3–9 sec; 4 points for a 10-s tandem stance.

For the 4-m walk test, the participant was asked to walk at his comfortable speed across 4 m that was monitored by two sets of infrared photocells. Timing started on the “begin” command and ceased when one foot crossed the end of the course. If the time to cover 4 m was more than 8.70 s the score was 1 point, 6.21 to 8.70 s scored 2, 4.82 to 6.20 s scored 3, and time less than 4.82 s scored 4.

After assessment of gait speed, participants were asked to sit in a standard-height chair with feet resting on the floor and arms folded across the chest. On the command “begin”, the participant rose up as straight and as quick as possible without upper extremity assistance and sat down five times. The test was stopped if the patient became tired, short of breath, used arms, or one minute had passed without all five stands completed. A 5-chair stand time of 16.7 s or more was scored 1 point, 13.7 to 16.6 s scored 2, 11.2 to 13.6 s scored 3 and 11.1 s or less scored 4.

400-m walk test

For this test, participants were asked to walk 400 m at their usual pace without overexerting. Participants began from a standing position, walked down a 20-m track, turned around a cone, and repeated the course 10 times to complete the 400-m walk. The tester announced the number of turns completed and the number remaining. Participants were allowed to rest without sitting. Time to complete the test was recorded. If the 400 m was not covered in 15 min the test was stopped, a time that corresponds to a slow walking speed (0.45 m/s based on a 20-m track). The test has been reported to be reproducible and a good indicator of mobility limitation in older adults²⁰.

Maximal isometric muscle strength

Maximal isometric muscle strength was measured bilaterally with the ‘make’ technique, using a hand-held dynamometer (HHD: Manual Muscle Testing System; Lafayette Instruments Co, Lafayette, IN). The ‘make’ technique requires the patient to gradually increase the force, which helps the examiner to hold the dynamometer in a fixed position²¹. When maximal force was reached the participants were instructed to maintain this force for three to five seconds until the “beep” sound from the dynamometer²². Table 1 and Figure 1 illustrate the testing procedures. To measure elbow flexor muscle strength (EFMS), the experimenter placed the hand-held dynamometer (HHD) against the distal crease on the metacarpal surface of the wrist (Figure 1A). For ankle plantar flexor muscle strength (PFMS) the HHD was placed against over the metatarsal heads on the sole of the foot (Figure 1B) and for the measurement of knee extensor muscle strength (KEMS) it was held against the anterior aspect of the shank, just proximal to the ankle joint (Figure 1C).

Each test consisted of three consecutive maximal

Table 1. Description of body positions and dynamometer placement for strength testing procedure.

Muscle group	Participant position/ fixation	Joint/ limb position	Dynamometer placement	Dynamometer fixation
EFMS	Supine; lower extremity was held by co-examiner to minimize participant movement	Elbow at 90° flexion; shoulder in neutral rotation/upper arm against trunk and resting on a table	Proximal to styloid process of radius adjacent to the distal crease on the metacarpal surface of the wrist	Manually
KEMS	Seated on a test chair and thigh restrained using a belt	The hip and knee at 90° flexion, with shank perpendicular to the ground	Anterior surface of the ankle, adjacent to the most proximal crease when the foot is in dorsiflexion	Using a belt and manually
PFMS	Supine and fixed by firmly gripping the sides of the table. A co-examiner minimized any accessory movement of the lower extremity by holding the lower leg	Both feet in maximal dorsiflexion (start position of test) resting on the table with hips and knees extended	Over the metatarsal heads on the sole of the foot	Manually

EFMS, elbow flexor muscle strength; KEMS, knee extensor muscle strength; PFMS, plantar flexor muscle strength.

**Figure 1.** Subject position for A) Elbow flexor muscle strength testing, B) Knee extensor muscle strength testing and C) Ankle plantar flexor muscle strength testing.

isometric contractions of each muscle group, with 1-min rest intervals between trials and 3-min rest intervals between the tests of different muscle groups. If the difference between the highest and the lowest value was within 10%, the test was considered complete; otherwise, the test was repeated. Trials were rejected if there was excessive limb movement and/or recruitment of other muscles than the muscle group of interest.

Before each test, the participant performed two contractions to familiarize with the procedures. The participants received standardized instructions and encouragement throughout the test. The instrument was calibrated before each participant was tested. The HHD was set to read force in Newton (N), with an upper limit of 660 N, measuring to the nearest 0.1 N. The testing positions chosen minimized bias introduced by gravity. The rater

used in all tests both hands to resist the force produced by the participants and thus maximize stabilization of the HHD during the test.

Kolber, Cleland²³ reported a validity of 0.74 to 0.78 for measurement of muscle strength by HHD in healthy individuals when compared to gold standard isokinetic dynamometry. In addition, the inter- and intra-rater reliability for elbow flexor strength and knee extensor strength determination with HHD were between 0.95 to 0.98, and 0.95 to 0.97, respectively²⁴, while that for the plantar flexor strength varied between 0.84 to 0.89, and 0.80 to 0.82, respectively²⁵. In our study, we found that the ICC between three trials of muscle strength testing ranged from 0.84 for PFMS to 0.98 for EFMS. These data indicate that the 'make' test with HHD provides satisfactory indications of muscle strength.

Table 2. Demographic characteristics of study participants.

Demographic Characteristics	RTTP (n=20) Mean±SD	SP (n=20) Mean± SD	Between Group Difference Mean (95%CI)	P
Age (y)	68.8±4.6	69.5±3.9	0.6(-3.4 to 2.1)	0.25
Height (cm)	170.7±8.7	171.4±3.5	0.7 (-3.4 to 2.1)	0.91
Mass (kg)	78.4±6.8	81.1±5.1	2.7 (-6.6 to 1.6)	0.67
BMI (kg/m ²)	26.9±2.0	27.6±1.9	0.8 (-2.0 to 0.5)	0.31
BMC (kg)	2.76±0.6	2.5±0.4	0.3 (-0.58 to 0.62)	0.1
Systolic BP (mmHg)	136.5±15.7	144.6±12.8	-8.1 (-17.2 to 1.11)	0.08
Diastolic BP (mmHg)	82.2±3.9	85.1±5.6	-2.8 (-5.9 to 0.3)	0.07

Abbreviations: BMI, Body mass index; BMC, Bone mineral content; BP, Blood pressure.

Table 3. Physical Performance of study participants.

Physical Performance	RTTP (n=20) Mean± SD	SP (n=20) Mean± SD	Between Group Difference Mean (95%CI)	P
SPPB Score	10.5±1.4	9.1±1.6	1.4 (0.3 to 2.1)	0.01
5-chair stands (s)	10.7±0.5	11.3±0.7	-0.7 (-1.1 to -0.1)	0.02
4-m walk (s)	3.6±0.5	4.1±0.6	-0.4 (-0.8 to -0.1)	0.01
400-m walk (s)	268±14	286±14	-17.5 (-26.5 to -8.5)	0.001

Abbreviations: SPPB, Short Physical Performance Battery Score.

Body composition and bone mineral density (BMD)

Total and regional body composition was measured using a dual-energy X-ray absorptiometry (DXA) scan (GE, Lunar Prodigy, USA), as previously reported²⁶. Prior to scanning, participants were instructed to remove all objects containing metal. Scans were performed with the participants lying in the supine position along the table's longitudinal centerline axis. Participants remained motionless during the entire scanning procedure. The procedure lasted 10 to 15 min and was conducted by a skilled laboratory technician according to the manufacturer's recommendations and after calibration of the device using a lumbar spine phantom. The enCore 2003 Version 7.0 software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by a standardized segmentation protocol that is described elsewhere²⁷.

Lean mass (kg), fat mass (kg) and BMC (kg) were calculated from analysis of the whole body scan. BMD (g/cm²) was calculated using the formula $BMD=BMC \cdot area^{-1}$. The body fat percent (%BF) was calculated by dividing fat mass by body mass.

Additionally, total body scan sub-regions are reported. The sub-regional analysis was performed as described elsewhere²⁸. Lean mass was assumed to be equivalent to muscle mass, but only in the limbs²⁹. 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.

Bone mass was measured in the lumbar vertebra regions L₁-L₄ and left proximal femur including the femur neck, trochanter, intertrochanter region and Ward's triangle. Ward's triangle refers to a radiolucent area between principle compressive, secondary compressive and primary tensile trabeculae in the neck of femur, the region between the load-bearing trabecular patterns. In our laboratory, the coefficients of variation varied between 0.6% to 1.9% for body composition measures.

Statistical analysis

The data were analyzed using SPSS 18.0 (SPSS Inc., Chicago, IL, USA). Independent t-tests were used to assess the differences between groups or a repeated-measures ANOVA when also considering the side-to-side differences. Differences were considered significant at $p < 0.05$.

Results

Table 2 shows that there were no significant differences in age, height, body mass and BMI between the SP and RTTP group.

Table 4. Body Composition of study participants.

Variables	RTTP (n=20) Mean± SD	SP (n=20) Mean± SD	Between Group Difference Mean (95%CI)	P
Body fat percent (%)	30.3±4.7	32.9±2.0	-2.6 (-5.04 to -0.1)	0.04
Lean mass (kg)				
Total	55.1±8.1	53.1±5.2	1.9 (-2.4 to 6.31)	0.4
Arm	7.1±0.9	6.6±0.9	0.4 (-0.15 to 1.01)	0.1
Leg	17.8±2.5	17.1±1.8	0.7 (-0.74 to 2.04)	0.3
Trunk	30.8±6.4	29.2±5.4	1.5 (-2.3 to 5.3)	0.4
Fat Mass (kg)				
Total	23.8±2.9	26.9±2.8	-3.1 (-4.9 to -1.3)	0.001
Arm	2.5±0.5	3.1±0.6	-0.54 (-0.9 to -0.18)	0.004
leg	8.3±1.6	9.4±1.1	-1.1 (-1.9 to -0.19)	0.02
Trunk	12.9±2.6	14.6±2.8	-1.8 (-3.5 to -0.1)	0.04
BMD (g/cm²)				
Total	1.27±0.13	1.1±0.11	0.17 (0.09 to 0.25)	0.001
Arm	0.81±0.07	0.76±0.04	0.05 (0.02 to 0.09)	0.006
Thoracic spine	0.91±0.04	0.88±0.06	0.03 (0.002 to 0.07)	0.13
Lumbar spine	1.25±0.11	1.24±0.09	0.11 (0.05 to 0.17)	0.001
Leg	1.25±0.14	1.15±0.06	0.09 (0.03 to 0.16)	0.008
Femoral neck	0.98±0.06	0.94±0.05	0.05 (0.002 to 0.07)	0.007
Trochanter	0.83±0.07	0.79±0.05	0.04 (0.09 to 0.25)	0.03
Ward's triangle	0.91±0.05	0.84±0.04	0.07 (0.04 to 0.1)	0.001

Abbreviations: BMD, Bone mineral density.

RTTP had a higher SPPB score ($p=0.01$) and performed the 5-chair stands ($p=0.02$), 4-m ($p=0.01$) and 400-m walk ($p<0.001$) in a shorter time than the SP (Table 3).

The body fat percentage ($p=0.04$) and total ($p<0.001$), arm ($p=0.004$), leg ($p=0.02$), and trunk ($p=0.04$) fat mass were lower in RTTP than in the SP. Total ($p=0.001$), arm ($p=0.006$), lumbar spine ($p<0.001$), leg ($p=0.008$), femoral neck ($p=0.007$), trochanter ($p=0.03$), and Ward's triangle ($p<0.001$) BMD were higher in RTTP than in the SP. There were no significant differences in the total and regional lean mass between the two groups ($p>0.05$) (Table 4).

There were significant Group \times Side interactions for lean mass ($p=0.015$), fat mass ($p=0.001$), BMD ($p=0.001$) and elbow flexor muscle strength ($p<0.001$). Such an interaction indicates that the differences between the dominant and non-dominant side are not the same in SP and RTTP. Indeed, it can be seen in Table 5 that the elbow flexor muscle strength, LM and BMD were larger in the dominant than the non-dominant arm of RTTP, while no such differences between the dominant and non-dominant side were seen in the SP. In addition, the FM of the dominant arm was lower than that of the non-dominant arm in table tennis players, while there was no side difference in FM in the SP.

Discussion

To the best of our knowledge, our study is the first to investigate the effect of regular recreational table tennis in older adult men. The main observation of the study is that regular participation in table tennis playing not only results in reduced fat mass, increased strength and bone mineral density in the tennis arm, but also has beneficial effects on overall muscle strength, physical performance and body composition. This most likely is associated with a better physical health of the older adult men.

During ageing there is a loss and/or atrophy of fast-twitch fibers³⁰. It has been demonstrated that low ankle plantar flexor and knee extensor muscle strength limit the ability to prevent a fall³¹. Indeed older adults with a history of falling have smaller and slower muscles than those who don't have a history of falling³². The higher elbow flexor, knee extensor and ankle plantar flexor muscles strength we observed in the older RTTP than SP may thus be significant in reducing the risk of falling, and also underlie the better performance of daily activities. In fact, the 1.4 points difference in SPPB score between RTTP and SP far exceeds the clinically significant (1.34 points) difference in this measure in older individuals³³. The negative correlation between SPPB with fear of falling³⁴

Table 5. Body Composition and Limb Muscle Strength for the Dominant Limb (DL) and non-dominant Limb (NDL) of Older Recreational Tennis player (RTTP) and Sedentary Participants (SP).

	DL (n=20) Mean± SD	NDL (n=20) Mean± SD	Between-Arm Difference Mean (95%CI)	Group Effect	Limb Effect	Group × Limb Interaction
LM (kg)						
RTTP	3.4±0.3	3.1±0.2	0.31 (0.19 to 0.43)	0.154	0.001	0.015
SP	3.2±0.3	3.14±0.3	-0.06 (-0.12 to 0.22)			
FM (kg)						
RTTP	1.14±0.2	1.46±0.24	-0.4 (-0.25 to -0.15)	0.001	0.001	0.001
SP	1.51±0.26	1.57±0.34	-0.06 (-0.11 to -0.02)			
BMD (g/cm²)						
RTTP	0.79±0.05	0.75±0.04	0.04 (0.03 to 0.05)	0.3	0.001	0.001
SP	0.76±0.04	0.76±0.03	-0.005 (-0.02 to 0.01)			
EFMS (N)						
RTTP	24.9±2.5	22.7±2.14	2.22 (1.7 to 2.7)	0.007	0.001	0.001
SP	22.03±2.2	21.5±2.6	0.56 (0.17 to 0.96)			
KEMS (N)						
RTTP	34.6±2.2	33.9±1.8	0.59 (-0.2 to 1.2)	0.001	0.005	0.9
SP	31.6±1.4	31.02±1.5	0.57 (0.03 to 1.1)			
PFMS (N)						
RTTP	20.1±2.3	19.5±2.6	0.53 (0.2 to 1.1)	0.04	0.007	0.9
SP	18.8±1.4	18.2±1.3	0.53 (-0.01 to 1.07)			

Abbreviations: LM, lean mass; FM, fat mass; BMD, bone mineral density; EFMS, elbow flexor muscle strength; KEMS, knee extensor muscle strength; PFMS, plantar flexor muscle strength.

in older people highlights the potency of participation in RTT to reduce falls and following complications.

In line with our observation, a previous study demonstrated that regular participation in recreational tennis also reduces body fat^{35,36}. Even in older diabetic patients, 12 weeks of football⁹ was associated with a lower %BF, though less pronounced than we observed in our RTTP. Whatever the cause of the smaller differences seen in other studies, the lower body fat% is likely to have significant health benefits and societal implications as obesity, predisposing to diabetes, has become a global epidemic with more than 1.9 billion overweighted adults (BMI>25) and at least 600 million people with clinical obesity (BMI>30)³⁷.

In our study, BMD was 5.7% higher for the RTTP than the SP. This, and similar observations in football¹⁰ and tennis³⁸ support the exercise advice by the American College of Sports Medicine to perform 30-60 min of weight-bearing endurance activities such as tennis, at least three times a week for maintaining bone health in older adults³⁹. High-impact and weight-bearing exercises are particularly important for increasing or maintaining the bone mass. Another factor that could be effective in increasing BMD is the muscle force output during the exercise and increase of muscle strength over time^{38,40}.

In line with previous observations in young-adult professional table tennis players⁴¹ we show here that also

regular recreational older table tennis players had a higher LM, BMD and EFMS, and lower FM in the dominant limb than in the non-dominant limb. A similar situation has been seen in the racquet arm in veteran tennis players³⁸ and in side-to-side differences in bone strength in master jumpers and sprinters⁴². The higher BMD in the dominant arm of the older adult in the RTTP is most likely attributable to the adaptive response to the exerted mechanical load³⁸, as the environmental, nutritional, genetic, hormonal and nervous variables which affect bone are similar in both arms. Our observation and the strong relationships between muscle and bone size in both arms in elite youth tennis players⁴⁰ support the notion that regular loading of the bone is required to induce and maintain changes in bone structure.

Studies have shown that osteogenic effects occur when short high-intensity strains are repeated regularly in unusual directions^{4,43}. In addition, it has been shown that intermittent forces that produce high strains are more osteogenic than continuous forces of the same magnitude⁴³. Thus, the main cause of the larger bone mass in the dominant arm of the recreational table tennis players may well be the recurring hits in this sport activity that probably produce large and intermittent strains on the dominant arm. Another factor that can contribute to higher BMD is the higher muscle strength of the dominant arm, which may, via the larger forces it can exert on the bone, also be osteogenic⁴.

A limitation of the study is that only older men were investigated. While this may preclude generalization of the results to other populations, the effects of tennis playing on muscle and bone properties have been reported to be similar in young and old men or women^{38,44}. Accuracy of HHD measurements can be affected by inadequate strength of the tester and lack of stabilization of the subject and device²³. To minimize this bias we minimized any accessory movement of the lower extremity during measurement of knee extensor muscle strength by strapping the thigh, while during plantarflexor muscle strength measurements the participants stabilized themselves by firmly gripping the sides of the bench while a co-examiner held the lower leg in place. To measure elbow flexor muscle strength, the upper arm was held against the trunk and rested on a table.

In conclusion, regular recreational tennis playing in older men not only benefits muscle strength and bone mineral density in the tennis arm, but also overall muscle strength and body composition. It is also associated with improved performance indicators of daily life activities. This suggests that regular participation in table tennis can be used as a health-promoting activity for older adult men.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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References

1. Lord S. Aging and falls: causes and prevention. *J Musculoskelet Neuronal Interact* 2007;7(4):347-347.
2. Sai A, Gallagher JC, Smith LM, Logsdon S. Fall predictors in the community dwelling elderly: a cross sectional and prospective cohort study. *J Musculoskelet Neuronal Interact* 2010;10(2):142-150.
3. Runge M, Schacht E. Multifactorial pathogenesis of falls as a basis for multifactorial interventions. *J Musculoskelet Neuronal Interact* 2005;5(2):127-127.
4. Singh H, Kim D, Bembem M, Bembem D. Relationship between muscle performance and DXA-derived bone parameters in community-dwelling older adults. *J Musculoskelet Neuronal Interact* 2017;17(2):50-50.
5. Ke H, Crawford D, Qi H, et al. Long-term effects of aging and orchidectomy on bone and body composition in rapidly growing male rats. *J Musculoskelet Neuronal Interact* 2001;1(3):215-224.
6. Juckett DA. What determines age-related disease: do we know all the right questions? *Age* 2010;32(2):155-160.
7. Bailey R, Cope E, Parnell D. Realising the Benefits of Sports and Physical Activity: The Human Capital Model. *Retos: nuevas tendencias en educación física, deporte y recreación* 2015;28(1):147-154.
8. Parnell D, Cope E, Bailey R, Krusturup P, Curran K. Retracted article: Football and physical health: what do we know? *Sport Soci* 2016;12(1):1-21.
9. Sousa M, Fukui R, Krusturup P, et al. Positive effects of football on fitness, lipid profile, and insulin resistance in Brazilian patients with type 2 diabetes. *Scand J Med Sci Sports* 2014;24(S1):57-65.
10. Helge EW, Andersen TR, Schmidt JF, et al. Recreational football improves bone mineral density and bone turnover marker profile in elderly men. *Scand J Med Sci Sports* 2014;24(S1):98-104.
11. Lee I-M, Buchner DM. The importance of walking to public health. *Med Sci Sports Exerc* 2008;40(7 Suppl):S512-518.
12. Wolf ID, Wohlfart T. Walking, hiking and running in parks: A multidisciplinary assessment of health and well-being benefits. *Landsc Urban Plan* 2014;130(1):89-103.
13. Kemper C, Oliveira RJd, Bottaro M, et al. Effects of swimming and resistance training on bone mineral density of older women. *Revista Brasileira De Medicina Do Esporte* 2009;15(1):10-13.
14. Cox KL, Burke V, Beilin LJ, Puddey IB. A comparison of the effects of swimming and walking on body weight, fat distribution, lipids, glucose, and insulin in older women - the Sedentary Women Exercise Adherence Trial 2. *Metab* 2010;59(11):1562-1573.
15. Kondrič M, Zagatto AM, Sekulić D. The physiological demands of table tennis: a review. *J Sports Sci Med* 2013;12(3):362.
16. Zagatto AM, Morel EA, Gobatto CA. Physiological responses and characteristics of table tennis matches determined in official tournaments. *J Strength Cond Res* 2010;24(4):942-949.
17. Zagatto AM, Milioni F, Freitas IF, Arcangelo SA, Padulo J. Body composition of table tennis players: comparison between performance level and gender. *Sport Sci Health* 2016;12(1):49-54.
18. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994;49(2):M85-M94.
19. Guralnik JM, Ferrucci L, Pieper CF, et al. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol. A Biol Sci Med Sci* 2000;55(4):M221-M231.
20. Rolland YM, Cesari M, Miller ME, Penninx BW, Atkinson HH, Pahor M. Reliability of the 400-M Usual-Pace Walk Test as an Assessment of Mobility Limitation in Older Adults. *J Am Geriatr Soc* 2004;52(6):972-976.
21. Burns SP, Spanier DE. Break-technique handheld

- dynamometry: relation between angular velocity and strength measurements. *Arch Phys Med Rehabil* 2005;86(7):1420-1426.
22. Stratford PW, Balsor BE. A comparison of make and break tests using a hand-held dynamometer and the Kin-Com. *J Orthop Sports Phys Ther* 1994;19(1):28-32.
 23. Kolber MJ, Cleland JA. Strength testing using hand-held dynamometry. *Phys Ther Rev* 2005;10(2):99-112.
 24. Dowman L, McDonald CF, Hill CJ, et al. Reliability of the hand held dynamometer in measuring muscle strength in people with interstitial lung disease. *Physiotherapy* 2016;102(3):249-255.
 25. Spink MJ, Fotoohabadi MR, Menz HB. Foot and ankle strength assessment using hand-held dynamometry: reliability and age-related differences. *Gerontology* 2010;56(6):525-532.
 26. Sanchis-Moysi J, Dorado C, Olmedillas H, Serrano-Sanchez JA, Calbet JA. Bone and lean mass inter-arm asymmetries in young male tennis players depend on training frequency. *Eur J Appl Physiol* 2010;110(1):83-90.
 27. Scafoglieri A, Tresignie J, Probyn S, et al. Prediction of segmental lean mass using anthropometric variables in young adults. *J Sports Sci* 2012;30(8):777-785.
 28. Calbet JA, Dorado C, Diaz-Herrera P, Rodriguez-Rodriguez L. High femoral bone mineral content and density in male football (soccer) players. *Med Sci Sports Exerc* 2001;33(10):1682-1687.
 29. Perez-Gomez J, Olmedillas H, Delgado-Guerra S, et al. Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. *Appl Physiol Nutr Metab* 2008;33(3):501-510.
 30. Rogers MA, Evans WJ. Changes in skeletal muscle with aging: effects of exercise training. *Exerc Sport Sci Rev* 1993;21(1):65-102.
 31. Perry MC, Carville SF, Smith ICH, Rutherford OM, Newham DJ. Strength, power output and symmetry of leg muscles: effect of age and history of falling. *Eur J Appl Physiol* 2007;100(5):553-561.
 32. LaRoche DP, Cremin KA, Greenleaf B, Croce RV. Rapid torque development in older female fallers and nonfallers: a comparison across lower-extremity muscles. *J Electromyogr Kinesiol* 2010;20(3):482-488.
 33. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. *J Am Geriatr Soc* 2006;54(5):743-749.
 34. Denking MD, Lukas A, Nikolaus T, Hauer K. Factors associated with fear of falling and associated activity restriction in community-dwelling older adults: a systematic review. *Am J Geriatr Psychiatry* 2015;23(1):72-86.
 35. Laforest S, St-Pierre DM, Cyr J, Gayton D. Effects of age and regular exercise on muscle strength and endurance. *Eur J Appl Physiol Occup Physiol* 1990;60(2):104-111.
 36. Naderi A, Zagatto AM, Akbari F, Sakinepoor A. Body composition and lipid profile of regular recreational table tennis participants: a cross-sectional study of older adult men. *Sport Sci Health* 2018;14(1):1-10.
 37. World Health Organisation. Obesity and overweight, accessed 1 October 2017, <<http://www.who.int/mediacentre/factsheets/fs311/en/>>.
 38. Ireland A, Maden-Wilkinson T, Ganse B, Degens H, Rittweger J. Effects of age and starting age upon side asymmetry in the arms of veteran tennis players: a cross-sectional study. *Osteoporos Int* 2014;25(4):1389-1400.
 39. Bloomfield SA, Little KD, Nelson ME, Yingling VR. Position stand. Physical activity and bone health. *Med Sci Sports Exerc* 2004;195(9131/04):3611-3611.
 40. Ireland A, Maden-Wilkinson T, McPhee J, et al. Upper limb muscle-bone asymmetries and bone adaptation in elite youth tennis players. *Med Sci Sports Exerc* 2013;45(9):1749-1758.
 41. Calbet J, Moysi J, Dorado C, Rodriguez L. Bone mineral content and density in professional tennis players. *Calcif Tissue Int* 1998;62(6):491-496.
 42. Ireland A, Korhonen M, Heinonen A, et al. Side-to-side differences in bone strength in master jumpers and sprinters. *J Musculoskelet Neuronal Interact* 2011;11(4):298-305.
 43. Dorado C, Moysi JS, Vicente G, Serrano J, Rodriguez L, Calbet J. Bone mass, bone mineral density and muscle mass in professional golfers. *J Sports Sci* 2002;20(8):591-597.
 44. Galvão DA, Newton RU, Taaffe DR. Anabolic responses to resistance training in older men and women: a brief review. *J Aging Phys Act* 2005;13(3):343-358.