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Research article

Recreational Football Training Increases Leg-Extensor Velocity Production in 55- To 70-Year Old Adults: A Randomized Controlled Trial

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Abstract

This study investigated the effects of 10 weeks of recreational football training on the leg-extensor force-velocity (F-V) profile in 55- to 70-year-old adults. Simultaneous effects on functional capacity, body composition and endurance exercise capacity were examined. Forty participants (age 63.5 ± 3.9 years; 36♂ 4♀) were randomized in a football training (FOOT, n = 20) and a control (CON, n = 20) group. FOOT performed 45-min to 1-h of football training sessions with small-sided games twice a week. Pre- and post-intervention assessments were performed. The results revealed a greater increase in maximal velocity (d = 0.62, p_{int} = 0.043) in FOOT compared to CON. No interaction effects were found for maximal power and force (p_{int} > 0.05). 10-m fast walk improved more (d = 1.39, p_{int} < 0.001), 3-step stair ascent power (d = 0.73, p_{int} = 0.053) and body fat percentage (d = 0.61, p_{int} = 0.083) tended to improve more in FOOT than in CON. RPE and HR values at the highest speed level during a submaximal graded treadmill test decreased more in FOOT compared to CON (RPE: d = 0.96, p_{int} = 0.005; HR: d = 1.07, p_{int} = 0.004). Both the number of accelerations and decelerations as well as the distance spent in moderate- and high-speed zones increased markedly throughout the 10-week period (p < 0.05). Participants perceived the sessions as very enjoyable and feasible. In conclusion, recreational football training resulted in improved leg-extensor velocity production, which translated to a better performance on functional capacity tests that rely on a high execution velocity. Simultaneously, exercise tolerance was improved and body fat percentage tended to reduce. It appears that short-term recreational football training can induce broad-spectrum health benefits in 55- to 70-year-old adults with only 2 hours of training per week.

Key words: Small-sided games; soccer; training load; muscle power; force-velocity profile; functional capacity

Introduction

Ageing in humans is accompanied by a progressive decline in lower-limb muscle power production (Alcazar et al., 2023). This process starts around 30 years of age with an average decline of -0.6%/year and accelerates to -1.1 to -1.4%/year at middle age (40 - 60 years) and to -2.2 to -2.4% at old age (60+ years) (Alcazar et al., 2023). Lower levels of muscle power in old age are associated with reduced daily life functioning (Kuo et al., 2006), an increased risk of falls and fractures (Lee et al., 2017), cognitive impairment (Steves et al., 2016), hospitalization (Losa-Reyna et al., 2021), and even mortality (Losa-Reyna et al., 2021). While early declines in muscle power are predominantly associated with declines in force production, both a decline in force and in velocity contribute to the deterioration in muscle power at a later age (Alcazar et al., 2023). A detailed analysis of the force-velocity (F-V) relationship demonstrated a progressively blunted ability to produce force at moderate to high velocities with ageing (Alcazar et al., 2023). Therefore, improving muscle power, especially at moderate to high velocities, is a crucial target for exercise interventions in middle-aged and older adults.

In addition to a decline in musculoskeletal fitness, ageing is associated with a reduction in cardiovascular and metabolic fitness. More specifically, cardiovascular fitness declines with age at a nonlinear rate that accelerates after 45 years of age (Jackson et al., 2009). Increases in body mass index (BMI) and body fat percentage have also been reported as a consequence of ageing (Charlier et al., 2016), which in turn contribute to an accelerated decline in musculoskeletal and cardiovascular fitness. Therefore, if exercise interventions aim for a high impact on the overall health status of middle-aged and older adults, they should combine endurance, high-intensity interval training, and muscular strengthening activities (Chodzko-Zajko et al., 2009).

Recreational football training combines all these training components, which implies that it could constitute an adequate training modality for participants of all ages (Krustrup and Krustrup, 2018). Small-sided games (SSGs) have been proposed as a useful training format. SSGs are modified games played on reduced pitch areas, often using adapted rules and involving a smaller number of players than traditional football games (Hill-Haas et al., 2011). They require intense muscular actions (Milanovic et al., 2020) (i.e., external load), such as high-speed runs, shots, turns and jumps, and elicit average heart rates (HR) of 80%-85% of maximal heart rate (HRmax) (Milanovic et al., 2015) (i.e., internal load). In older men, 16% - 48% of the time in SSGs was spent in a high-intensity zone (>90% of HRmax) (Andersen et al., 2014; Randers et al., 2010b). Less is known about the external load indicators in this age group. In middle-aged men (43 ± 3 years), average distance covered during 60min of five a-side SSGs was 3375 - 3483m, with 37 - 38 number of accelerations (> 2 m s^{-2}), 35 - 36 number of decelerations (<-2 m s^{-2}), and 68.1 - 71.2

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m of high-speed runs (> 14.4 km h^{-1}) (Beato et al., 2018). More data on training load are needed to better understand the physical demands of SSG's in middle-aged to older adults.

Despite the high training load in SSG's, ratings of perceived exertion are typically lower in comparison with other activities, such as running, and incidence of severe injuries appears low (Zouhal et al., 2020). Broad-spectrum fitness effects of 2x/week recreational football training with SSG's have been documented in untrained healthy (older) adults and patient populations, i.e., positive and simultaneous effects on different aspects of cardiovascular, metabolic and musculoskeletal fitness (Krustrup et al., 2010; Krustrup and Krustrup, 2018; Milanovic et al., 2019; Mohr et al., 2023; Zouhal et al., 2020). In addition, football is perceived as highly enjoyable and strengthens social relationships, resulting in positive effects on mental and social well-being (Krustrup et al., 2010; Krustrup and Krustrup, 2018; Ottesen et al., 2010; Zouhal et al., 2020).

What remains to be investigated in more detail, is whether recreational football training can improve muscle power production in middle-aged to older adults and whether this potential improvement is present across the full F-V profile. Although a recent meta-analysis by Milanovic et al. (2019) concluded that recreational football training is very likely to induce beneficial results on countermovement jump performance, only few studies were based on middle-aged and older adults. In addition, it was suggested that training periods up to one year are required to induce gains in muscle strength and jump performance (Randers et al., 2010a; Sundstrup et al., 2016).

The current study adds to the existing literature on short-term adaptations to recreational football training in middle-aged to older adults by including a detailed analysis of the full F-V profile of the leg-extensor muscles (Alcazar et al., 2017). As adaptations to training might be non-uniform over the full F-V profile (Rodriguez-Lopez et al., 2021), such a detailed analysis allows for investigating whether changes in muscle power are mainly driven by improvements in force production or movement velocity. When power production is only assessed under a single loading condition (e.g., during an unloaded countermovement jump) early changes in the F-V profile might be missed. Next to a detailed analysis of the leg-extensor F-V profile as the primary outcome, simultaneous effects on functional capacity, body composition and endurance exercise capacity were investigated. In addition, the training program's feasibility and the physical demands (internal and external load indicators) were tracked throughout the intervention period.

Methods

Study design

This study was designed as a randomized controlled trial comparing football training to a waiting-list control group (see Figure 1). While a 12-week intervention period was planned prior to study initiation, we had to shorten this period to 10 weeks because of COVID-related restrictions. Outcome measurements were obtained at baseline (pre-intervention, April 2021) and within two weeks after the last exercise session (post-intervention, July 2021). During the intervention period, training load, adherence, drop-outs, and adverse events were monitored. The study was conducted at KU Leuven, in collaboration with the local professional football club Oud-Heverlee Leuven. It was approved by the Ethical Committee Research UZ/KU Leuven (S64926) in accordance with the Declaration of Helsinki.

Participants, sample size calculation and randomization

Community-dwelling adults aged 55 to 70 years were recruited through advertisements by the football club, which were mainly spread to the fan base of the club. Exclusion criteria were unstable cardiovascular disease, neurological disorders, cognitive malfunctioning (mini-mental state examination < 24), acute infections or fever, severe musculoskeletal problems, and systematic engagement in (resistance) exercise in the 12 months prior to participation.

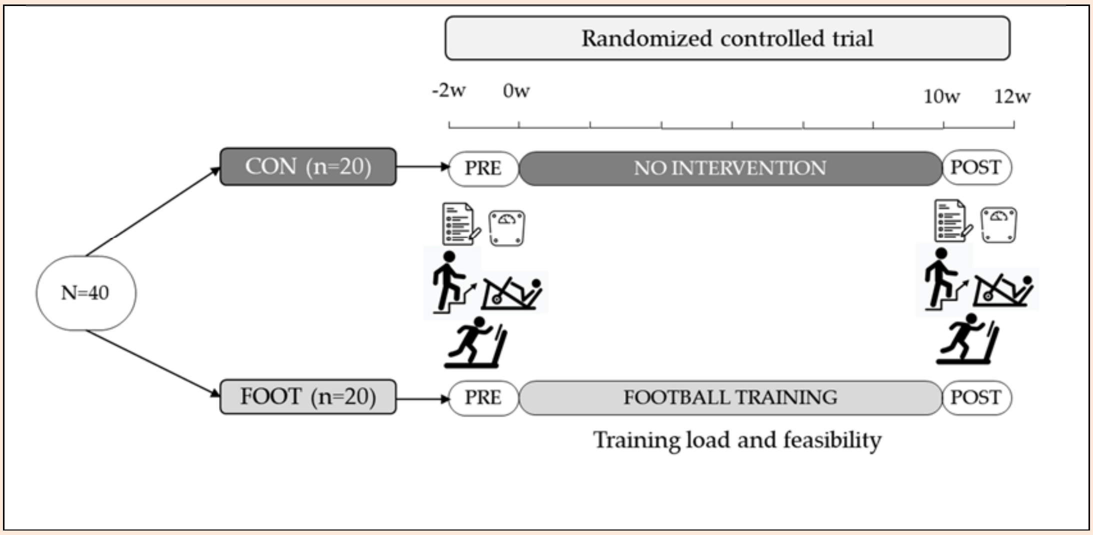

Figure 1. Design of the study. Pre and post intervention, the following outcomes were evaluated: leg-extensor force-velocity profile, functional capacity, body composition, and endurance exercise capacity. In addition, questionnaires were used to assess baseline health and demographics and satisfaction with the training sessions in FOOT. FOOT = football training group; CON = control group.

Eligible subjects were randomly assigned (allocation ratio 1:1, computer-generated random schedule) to the football training group (FOOT) or a waiting-list control group (CON) in permuted blocks of two within age strata (55 - 60, 60 - 65, 65 - 70 years) and within sex.

An a priori sample size calculation was performed in G*power (for ANOVA: repeated measures, within-between interaction). To detect a medium effect size (i.e., partial η^2 of 0.09) on the primary outcome (i.e., maximal leg-extensor power), a total sample size of N = 30 was needed (α = 0.05, power = 0.95, correlation among repeated measures = 0.6). Considering a potential drop-out of 25%, N = 40 participants were recruited for the study. Although more people were found eligible to participate, COVID-related restrictions did not allow to an increase the group size for the training sessions. All participants in FOOT were recreationally active. All participants provided written informed consent. A flow chart can be found in Figure 2.

Intervention

Participants of CON were asked not to change their lifestyle during the 10-week intervention period. They were given the opportunity to engage in the football training program after the end of the study. Participants of FOOT performed 45-min to 1-h training sessions twice a week (Mondays and Thursdays) for 10 weeks at the facilities of football club Oud-Heverlee Leuven.

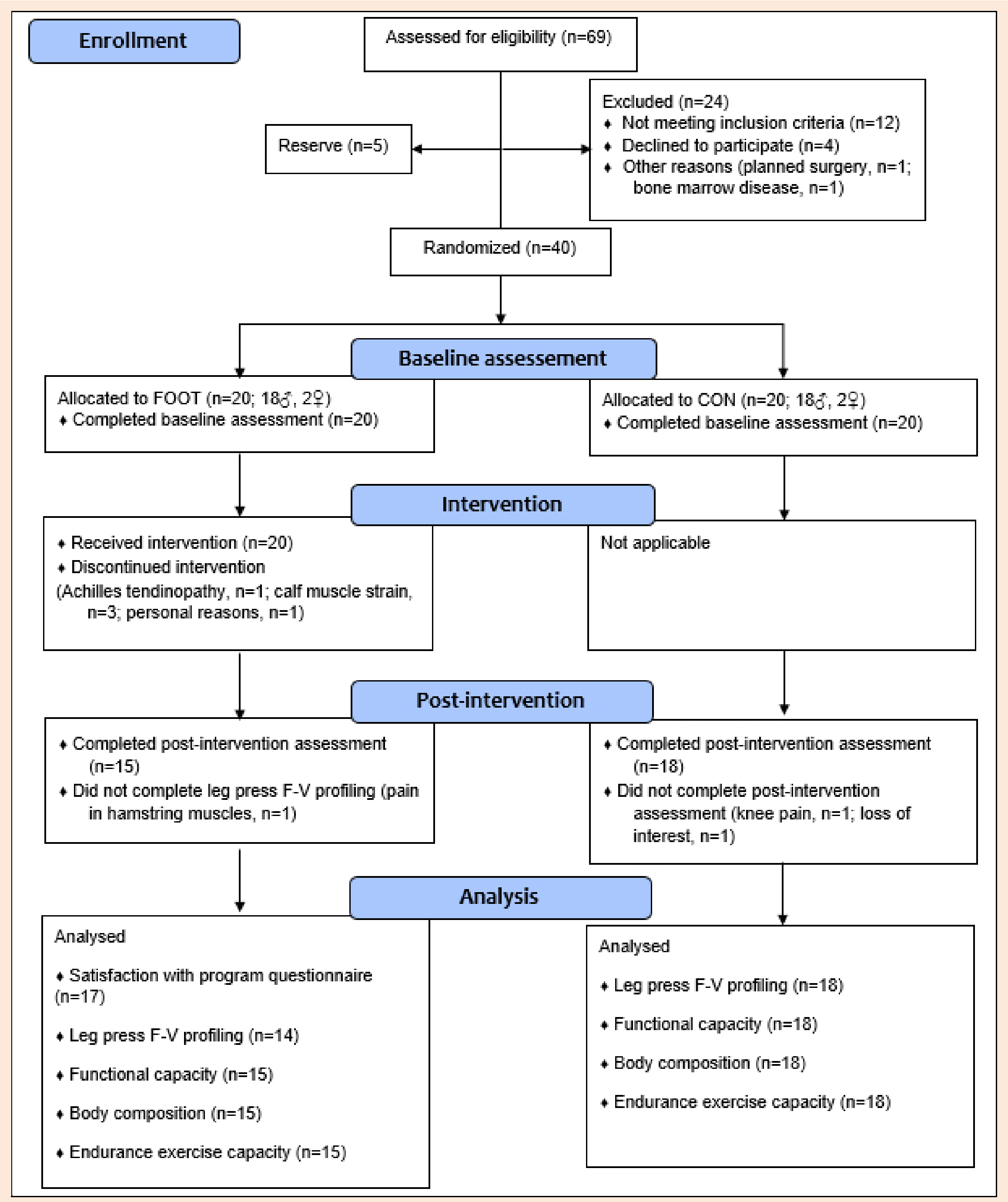

Figure 2. Flow chart of the study.

All training sessions were supervised by qualified coaches and were performed on an artificial football pitch. The sessions consisted of a standardized warming-up with running drills and ball exercises, followed by small-sided games (4-a-side or 5-a-side, pitch size 20 x 30m (for 4 vs 4) or 20 x 35m (for 5 vs 5), no goalkeeper) that were progressively built up in duration, based on prior research in similar populations (Andersen et al., 2014; Randers et al., 2010a). Week 1 was considered a try-out week so that the coaches were able to judge the skills and physical capacity of the participants, with 1 x 10min 5-a-side game. Small-sided games increased to 2 x 10min in week 2 to 4, 2 x 12.5min in week 5 to 7 and 2 x 15min in week 8 to 10, with 3-min rest in between.

Outcomes

Feasibility and training load (internal and external load indicators) were tracked throughout the intervention period. Pre and post intervention, the following outcomes were assessed: leg-extensor power and its F-V profile (primary outcome), functional capacity, body composition, and endurance exercise capacity (secondary outcomes).

Demographics and feasibility

Demographic variables (education and professional status), as well as the presence of chronic conditions, were collected by means of a questionnaire. The feasibility of the intervention was assessed by the following criteria: exercise session adherence, number of drop-outs, adverse events and satisfaction with the program. Exercise adherence was calculated as the number of training sessions attended over the total number of training sessions (i.e., 20). The number and reasons of drop-out were recorded, as well as any adverse events during the intervention. Satisfaction with the program was evaluated by means of a short questionnaire completed after the 10-week intervention. This survey consisted of three questions and were answered on an 11-point Likert scale (ranging from 0 = 'not at all…' to 10 = 'very…'): (1) How much did you enjoy the training program? (2) How feasible was the training program for you? (3) How high is the chance that you subscribe to a new sequence of training sessions? Participants in CON were also asked to answer the third question. If participants did not intend to subscribe to additional training sessions, they were asked to provide a reason.

Training load

Training load was analyzed through GPS metrics collected using WIMU Pro™ devices (RealTrack System, Almeria, Spain). Once weekly during the training session (from week 2 to 10), participants wore specially designed garments provided by the manufacturer with a pocket to hold the GPS unit between the scapulae and a compatible heart rate (HR) band (Garmin International, Inc., Kansas, USA). The software SPRO™ (RealTrack System, Almeria, Spain) was used to extract external and internal load indicators. External load indicators were total distance covered (m), meters, and time (in %) in different speed zones (low (0-6 km h^{-1}), moderate (6-12 km h^{-1}) and high speed (> 12 km h^{-1})), and the number of accelerations (> 2 m s^{-2}) and decelerations (< -2 m s^{-2}). Internal load indicators were average HR (% HRmax) and time (in %) in different HR zones (<70%, 70 - 80%, 80 - 90%, >90% of HRmax). Participants' HRmax was estimated with the formula of Ilmarinen, i.e., $\text{HRmax} = 220 - (0.9 \times \text{age})$.

Leg-extensor F-V profile

Before the baseline measurement, a familiarization session was performed, in which the participants were acquainted with the equipment and the test protocol. Force-velocity profiling was carried out unilaterally (dominant leg) on a pneumatic horizontal leg press device (Leg Press CC, HUR, Kokkola, Finland). The inclination of the apparatus was 5° to horizontal and the seat was inclined backwards (130°). Four built-in load cells register instantaneous force at the foot plate, while a built-in potentiometer measures displacement, and thus movement velocity, of the seat. Prior to all tests, a standardized warm-up and practice trials were performed. After a 5-min warm-up on a cycle ergometer at self-selected load, participants performed three sets of leg extension movements with 1-min. rest intervals. The first set was performed at controlled, slow speed with a fixed load of 5 kg for women and 10 kg for men, the second set consisted of 10 repetitions at 15% body mass and the third set of 6 repetitions at 30% of body mass. In the second and third set, the last 2 - 3 repetitions were performed at maximal concentric speed.

The test protocol consisted of a maximal isometric test (knee joint angle = 85°, hip angle = 55°; 3 attempts of 3s), followed by explosive concentric leg extensions at gradually increasing loads (unloaded, 15%, 30%, 45%, 60% of the maximal isometric force, 2 (for 45% and 60%) to 3 (for unloaded, 15% and 30%) attempts per load, and additional single repetitions until the one-repetition maximum (1-RM) was reached). Standardized rest periods were provided, as described by Alcazar et al. (2017).

All data were relayed to a pc via an AD converter, recorded using Labview and processed offline using Matlab. Data (time and position) were sampled at 1000Hz and filtered by a fourth-order low-pass Butterworth filter with a 70 Hz cut-off frequency. In the explosive concentric tests, the mean velocity of all trials was calculated as the change in position over time (from the start of the movement until full extension (knee angle 180°), the potential flight phase during light loads was discarded). The start of the movement was defined as a 1.5% change in position compared to the baseline. Mean velocity and the corresponding force of the best trial per load (i.e., highest mean velocity value) were used to estimate the individual F-V relationship through a linear equation. It should be noted that the total system load was calculated (i.e., external load + body mass + weight of seat corrected for inclination) as a proxy to force. The 'unloaded' test indicates that no external load was added, not that load was zero. If a data point deviated from the expected linear regression with more than 0.03 m s^{-1}, it was excluded. From the F-V regression line, the following variables were extracted: force at zero velocity (F_0, theoretical maximal isometric force, N), the velocity at zero loads (V_0, maximal velocity, m/s) and the slope divided by F_0 (S_{FV}/F_0). The latter variable represents the decline in force as a function of contraction velocity. Maximal muscle power (P_{max}, W) was calculated using the following formula:

$$Pmax = \frac{F0 \; x \; V0}{4}$$

On average, 5.0 ± 1.1 data points were used to estimate the F-V relationship. Individual R^2 values of the linear regression were all higher than 0.98. For an overview and reliability values of the F-V procedure, see Alcazar et al. (2017).

Functional capacity

Functional capacity was assessed by a test battery, consisting of 10-m fast walk, countermovement jump (CMJ), 5-repetition sit-to-stand (5xSTS) test and a 3-step stair ascent test. For the 10-m fast walk, participants were instructed to walk as fast as possible, and time (s) were registered through timing gates (Racetime2 Light Radio, Microgate, IT). A maximal CMJ was performed on a contact mat with the hands on the hips and jump height (CMJheight) was calculated based on previous procedures(Kennis et al., 2013). During the 5xSTS and stair ascent test, data were collected using a body-fixed sensor positioned at the lower back (DynaPort MoveTest, McRoberts, The Hague, NL). The sampling rate was 100Hz and data were analyzed using commercially available software (DynaPort MoveTest, McRoberts, The Hague, NL). In the 5xSTS test, participants performed five sit-to-stand cycles as fast as possible with the arms crossed over the chest. From the sensor data, the total STS duration (s) (from the start until the fifth standing position) was calculated. Mean power (W) was calculated for each of the five sit-to-stand transition phases and averaged over the five repetitions. In the stair ascent test, participants ascended a flight of 3 stairs as fast as possible without using the handrail. Total stair ascent duration (s) and mean power (W) during the rising phase (defined as vertical velocity > 0.1 m/s) of each step were calculated. The highest mean power out of the three steps was used in the analyses. For more information on the procedure, see previous work (Van Roie et al., 2019).

The 10-m fast walk test and 5xSTS were performed twice; CMJ and stair ascent were performed three times; and the best trial (based on duration parameter or jump height) of each test was used in the analyses.

Anthropometry and body composition

Body height and mass were determined using a stadiometer and a digital scale (Seca, GmbH & Co. KG, Germany), respectively. All participants wore minimal clothing and were barefoot. Body mass index (BMI) was calculated as body mass (kg) divided by squared body height (m). Body fat percentage (BF%) was assessed using bio-electrical impedance (BIA) (BODYSTAT® 1500 MDD) according to standardized procedures. To calculate whole-body skeletal muscle mass (SMM), the BIA equation of Janssen et al. (2000) was used.

Endurance exercise capacity

The endurance exercise capacity of the participants was assessed during a submaximal graded exercise test on a motorized treadmill (h/p/cosmos Saturn®, Nussdorf-Traunstein, Germany) set at a 1% uphill gradient. Initial velocity was set at 4 km h^{-1}, followed by increments of 1.5 km h^{-1} every three minutes. At the end of each intensity block, a capillary blood sample was obtained from a hyperaemic earlobe to assess the blood lactate of the participant (Lactate Pro2, Arkray, Japan). The exercise test was stopped when participants reached blood lactate values ≥ 4 mM. Ratings of perceived exertion (RPE) were assessed at the end of each intensity block using a 6 - 20 Borg Scale. Speed (x-axis) and corresponding blood lactate (y-axis) data were plotted and a polynomial 4th order trend line was drawn to estimate the speed at 2 mM and 4 mM lactate values. In addition, RPE, HR and lactate values of the common highest intensity block, completed in the pre- and post-intervention test, were reported (i.e., values at the same speed level in both tests).

Statistical analyses

Data were presented as mean ± standard deviation (SD) unless otherwise stated. Independent samples T-test was used to test for baseline differences between groups. To investigate whether external and internal training load indicators changed over time, linear mixed-effects models with a random factor (participant ID) and time as a repeated factor (three time periods: week 2 - 4, week 5 - 7, week 8 - 10) were used.

The intervention effects were tested by linear mixed-effects models with a random factor (participant ID) and three terms: intervention group (FOOT [code = 1] vs CON [code = 2]), time (baseline and post-intervention) and time-by-group interaction. Beta coefficients (including 95% confidence intervals (CI)) of linear mixed-effects models and Cohen's d effect sizes for between-group differences in absolute changes from baseline to post-intervention were reported for all variables that showed at least a trend towards significance for the time-by-group interaction effect ($p < 0.1$). Thresholds 0.20, 0.50 and 0.80 were used to interpret small, moderate and large effect sizes (Cohen, 1992). Post-hoc analyses were conducted for within-group changes when the time-by-group interaction effect was significant.

To test the normality assumption for multilevel regression models, we checked whether the models' residuals were normally distributed, both by visual inspection of the Q-Q plots and histogram, as well as by Shapiro-Wilk tests. If the residuals were non-normally distributed, a log or square root transformation was performed and tested on normality. When these transformations did not result in normality, non-parametric tests were used as alternatives. In that case, time effects from baseline to post were analyzed with Wilcoxon Singed Rank tests. Percent changes from baseline to post were calculated and then used in Mann-Whitney U tests to determine differences in changes between groups. The following parameters were not normally distributed: P_{max} (log transformed), body mass (non-parametric tests), stair ascent duration (non-parametric tests), average HR for the training session (non-parametric tests) and SSG (non-parametric tests), time in HR zone <70% HRmax for the training session (square root transformed).

To examine whether adherence and training load

Table 1. Means ± SD for baseline characteristics of the subjects.

Characteristic		FOOT (♂18;♀2)	CON (♂18;♀2)	p-value
Age (years)		63.7 ± 4.1	63.2 ± 3.7	0.724
Body height (cm)		174.0 ± 6.6	175.9 ± 8.3	0.430
Body mass (kg)		81.8 ± 11.7	81.4 ± 11.6	0.901
BMI (kg m-²)		27.0 ± 2.9	26.3 ± 2.9	0.453
Experience with football (n)	Competitive	13	11	
	Recreational	5	4	
	None	2	5	
Education (n)	Primary education	1	1	
	Upper secondary education	7	3	
	Bachelor's or master's degree	12	16	
Professionally active (n)	Yes	8	9	
	No	12	11	
Chronic conditions (n)	Hypercholesterolemia	2	3	
	Hypertension	8	9	
	(Rheumatoid) Arthritis	0	2	
	Thyroid problems	0	1	
	Gastro-intestinal problems	2	1	
	Depression	1	0	
	Hemochromatosis	1	0	

p-values of independent samples T-test; BMI = body mass index

affected the training adaptations, Spearman Rank correlation coefficients were calculated between (percent) changes in all outcome variables, adherence and training load indicators.

All statistical tests were conducted in R (version 4.2.1). The multilevel models were fit using the lmer-function of the lme4 package. The level of significance was set at $p < 0.05$.

Results

Participants' characteristics are described in Table 1. Only one outcome variable showed a baseline difference between groups: 10-m fast walk was performed at a slower pace in FOOT compared to CON ($p = 0.034$). HR registration during the endurance exercise capacity test failed in two participants of FOOT (one at baseline, one post-intervention), so these data points were missing in the analyses. Likewise, we were unable to calculate the post-intervention running speed at 2 mM lactate in one participant in FOOT because of a measurement error for lactate.

Feasibility and adherence

In total, 5 participants (25%) of FOOT and 2 (10%) of CON discontinued participation (Figure 2). One female and one male participant in FOOT dropped out after the first training session due to personal reasons and recurrent Achilles tendinopathy, respectively. The other three male drop-outs suffered from a calf muscle strain, caused by the training sessions (in week 1, week 3 and week 8, respectively). Minor adverse events during the intervention included muscle soreness (n = 6), mild muscle strain in calves, quadriceps or hamstrings (n = 4), pain in the knee (n = 4) and hip (n = 2), and rib contusion (n = 1). Adherence to the program, excluding drop-outs, was 83.7 ± 12.1 %. Eleven participants were considered high adherers (≥ 80% adherence). All participants in FOOT considered the training program to be 'very enjoyable' (score of 8 - 10 out of 10) and 'very feasible' (score of 7 - 10 out of 10). 70.6% in FOOT and 55.6% in CON indicated that they were 'very likely' (score of 8 - 10 out of 10) to subscribe for a new sequence of training sessions, while 17.6% in FOOT and 22.2% in CON gave a neutral answer (score of 4 - 6 out of 10) and 11.8% in FOOT and 22.2% in CON indicated that they were 'not likely' to subscribe (score <4 out of 10). Reasons for not willing to subscribe, where lack of time (n = 7, mainly because of the job), fear of injury (n = 1) and no interest (n = 2).

Training load

External and internal training load indicators are reported in Table 2. The total distance covered during the training session increased by 29.2 ± 15.4% from week 2 - 4 to week 8 - 10 ($p < 0.001$). The percentage of distance decreased in the low-speed run and increased in the high-speed run zone from week 2 - 4 to week 8 - 10 (all $p < 0.05$). The number of accelerations (> 2m s^{-1}) and decelerations (< -2m s^{-1}) increased with 41.4 ± 46.8% and 50.8 ± 49.2%, respectively, from week 2 - 4 to week 8-10 (all $p < 0.001$). No time effect was found for average HR, or the percentage of time spent in the different HR zones.

Leg-extensor F-V profile

A greater increase in V_0 (β = -0.07 [95% CI - 0.130 - -0.003], $d = 0.62$, $p_{int} = 0.043$) and a trend towards a greater increase in S_{FV}/F_0 (β = -0.04 [95% CI -0.079 - -0.002], $d = 0.50$, $p_{int} = 0.065$, respectively) was apparent in FOOT compared to CON. No time-by-group interaction effects were found for P_{max} ($p_{int} = 0.221$) nor for F_0 ($p_{int} = 0.922$). (Table 3 and Figure 3 and Figure 4).

Functional capacity, body composition and endurance exercise capacity

Performance duration on 10-m fast walk improved significantly more in FOOT (-12.4 ± 10.9%) than in CON (1.1 ± 9.3%) (β = 0.64 [95% CI 0.30 - 0.96], $d = 1.39$, $p_{int} < 0.001$). Moreover, a trend towards a significant time-by-group interaction effect was found for stair ascent power (β = -65.7 [95% CI - 131 - 0.88], $d = 0.73$, $p_{int} = 0.053$). No time-by-group interaction effect was found for any of the other functional capacity outcomes (all $p_{int} > 0.05$) (Table 4 and Figure 4).

Table 2. Estimated means (SE) for external and internal training load variables, for the total training session and the small-sided games separately in the football training group.

Load indicator		Total Session					Small-sided games				
		Mean	Week 2-4	Week 5-7	Week 8-10	p-value	Mean	Week 2-4	Week 5-7	Week 8-10	p-value
External load	**Distance**										
	Total Distance (m)	2935 (71)	2591 (93)	2869 (94)	3360 (94)	<0.001	879 (25)	764 (37)	889 (37)	982 (37)	<0.001
	Low-speed run (<6 km h^{-1}) (m)	1974 (38)	1765 (49)	1987 (50)	2198 (50)	<0.001	591 (13)	518 (18)	625 (19)	633 (19)	0.002[a]
	Mod-speed run (6-12 km h^{-1}) (m)	850 (37)	747 (57)	782 (57)	1010 (57)	<0.001	241 (14)	211 (22)	220 (22)	286 (22)	<0.001
	High-speed run (>12 km h^{-1}) (m)	110 (11)	80 (18)	97 (18)	149 (18)	<0.001	48 (5)	35 (8)	43 (8)	63 (8)	<0.001
	Low-speed run (<6 km h^{-1}) (%)	67.9 (0.9)	68.8 (1.6)	69.8 (1.6)	66.2 (1.6)	0.005	68.3 (1.3)	69.2 (2.1)	71.1 (2.1)	65.7 (2.1)	0.007
	Mod-speed run (6-12 km h^{-1}) (%)	28.5 (0.7)	28.3 (1.2)	27.0 (1.2)	29.6 (1.2)	0.043	26.6 (0.9)	26.5 (1.5)	24.3 (1.5)	28.3 (1.5)	0.071
	High-speed run (>12 km h^{-1}) (%)	3.6 (0.3)	2.9 (0.5)	3.3 (0.5)	4.3 (0.5)	<0.001	5.1 (0.4)	4.3 (0.8)	4.6 (0.8)	6.1 (0.8)	<0.001
	Accelerations - decelerations										
	Accelerations (>2m s^{-2}) (n)	30.7 (2.1)	27.1 (3.4)	27.3 (3.5)	36.5 (3.5)	<0.001	12.1 (0.9)	11.1 (1.6)	11.4 (1.6)	13.2 (1.6)	0.062
	Decelerations (<-2m s^{-2}) (n)	27.8 (2.1)	23.1 (3.5)	25.9 (3.5)	33.3 (3.5)	<0.001	12.6 (0.9)	10.8 (1.6)	12.1 (1.6)	14.2 (1.6)	0.001
Internal load	**Heart rate**										
	Average HR (% HRmax)	78.0 (1.0)	76.9 (1.8)	80.3 (1.8)	78.4 (1.7)	0.625a	85.7 (1.0)	86.8 (1.8)	86.4 (1.8)	85.6 (1.8)	0.194[a]
	HR <70% HRmax (% of time)	33.5 (2.7)	34.0 (4.9)	25.1 (4.9)	33.2 (4.8)	0.810	12.1 (1.9)	13.4 (3.2)	8.2 (3.2)	13.5 (3.1)	0.945[b]
	HR 70 - 80% HRmax (% of time)	21.5 (9.0)	22.6 (2.3)	22.7 (2.4)	19.2 (2.3)	0.151	16.3 (1.6)	14.9 (2.9)	17.8 (2.9)	14.8 (2.8)	0.964
	HR 80 - 90% HRmax (% of time)	22.7 (1.3)	19.9 (2.2)	26.2 (2.3)	23.2 (2.2)	0.166	31.1 (2.1)	28.2 (3.7)	33.4 (3.7)	30.7 (3.4)	0.465
	HR >90% HRmax (% of time)	22.3 (2.3)	23.7 (4.3)	26.0 (4.3)	24.3 (4.2)	0.809	40.5 (3.8)	44.0 (6.6)	41.0 (6.6)	40.9 (6.5)	0.574

p-values of time effect (week 2-4 vs week 8-10) based on Linear Mixed-Effects Models analyses (significant values in bold); [a]not normally distributed and non-parametric tests were performed and reported; [b]not normally distributed and square root transformation was performed for the analyses. For easier interpretation, non-transformed data means were reported for all variables. For the small-sided games (SSG's): average values for one SSG were reported (not a summation of the two SSG's). HR = heart rate; HRmax = maximal heart rate

Table 3. Estimated means and SE at baseline (pre-) and posttest and % change (±SD) for leg-extensor force-velocity profile in the football training (FOOT) and the control (CON) group.

		FOOT			CON				
		Mean	SE	%	Mean	SE	%	Time	Time x group
F_0 (N)	Pre	876	42		827	42			
	Post	904	43	3.4 ± 9.2	858	42	4.3 ± 9.3	0.558	0.922
V_0 (m s^{-1})	Pre	1.12	0.03		1.13	0.03			
	Post	1.22	0.03	7.6 ± 8.7*	1.17	0.03	2.8 ± 6.7	**0.003**	**0.043**
S_{FV}/F_0 (%F_0 m s^{-1})	Pre	-0.903	0.025		-0.892	0.025			
	Post	-0.845	0.027	-6.5 ± 7.4	-0.872	0.026	-2.3 ± 6.4	**0.006**	0.065
P_{max} (W)	Pre	249	17		236	17			
	Post	284	18	11.0 ± 10.5	251	17	7.0 ± 9.1	**0.009**[b]	0.221[a]

p-values of Linear Mixed-Effects Models analyses (significant values in bold); * significant within-group change from Pre to Post, [a]not normally distributed and log transformed for the analyses. For easier interpretation, non-transformed data means were reported for all variables. F_0 = theoretical maximal isometric force; V_0 = maximal velocity; S_{FV}/F_0 = the slope of the force-velocity relationship relative to F_0; P_{max} = maximal muscle power

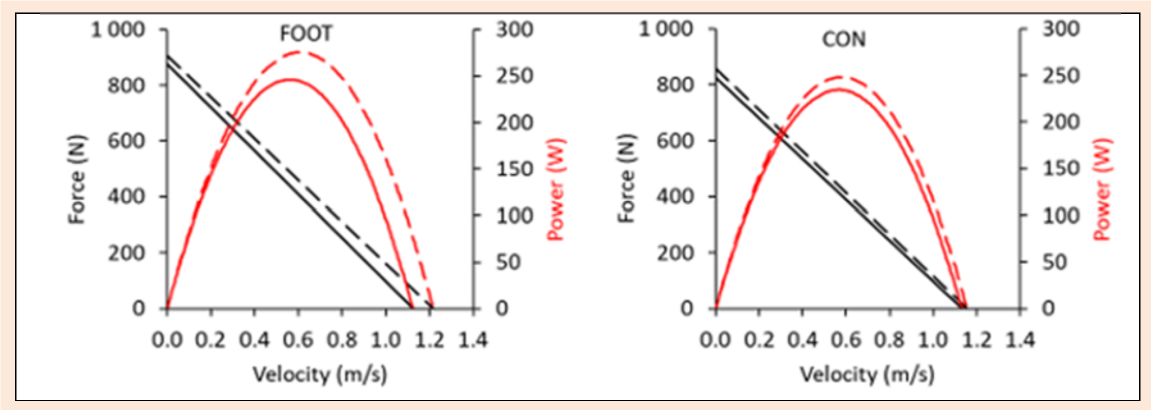

Figure 3. **Leg-extensor force-velocity (black) and power-velocity (red) profile at baseline (solid line) and post intervention (dashed line) in the football training group (FOOT, left) and the control group (CON, right). Error bars were removed to improve visibility of the figure, but can be viewed in Table 3.**

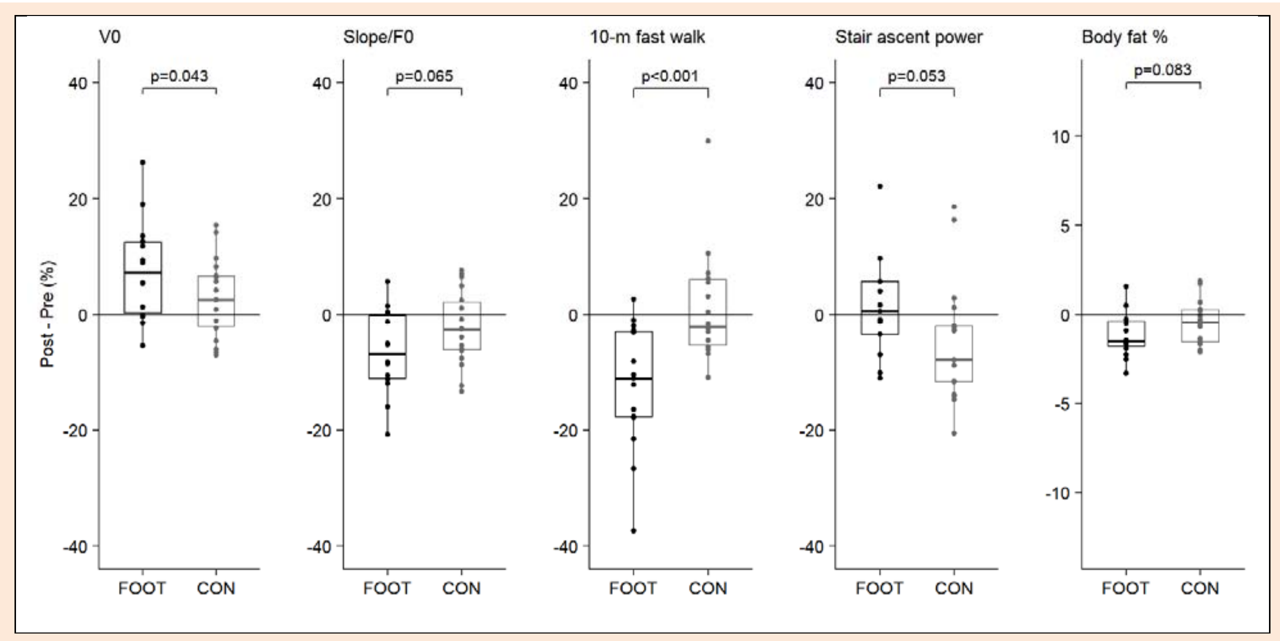

Figure 4. **Boxplots of percent changes from baseline to post intervention for the football training group (FOOT, black) and the control group (CON, grey) for leg-extensor force-velocity variables, functional capacity tests and body fat percentage. P-values of time-by-group interaction effects of linear mixed-effects models were added.**

Neither body mass nor skeletal muscle mass showed a significant time-by-group interaction effect ($p_{int} > 0.05$). Body fat percentage tended to decrease more in FOOT compared to CON ($\beta = 0.75$ [95% CI -0.10 - 1.59], $d = 0.61$, $p_{int} = 0.083$) (Table 4 and Figure 4). For RPE and HR values at the highest speed level, a greater decrease was found in FOOT compared to CON (RPE: $\beta = 1.5$ [95% CI 0.49 - 2.57], $d = 0.96$, $p_{int} = 0.005$; HR: $\beta = 10.3$ [95% CI 3.58 - 16.99], $d = 1.07$, $p_{int} = 0.004$). In addition, running speed at 2mM lactate tended to increase more in FOOT compared with CON ($\beta = -0.12$ [95% CI -0.25 - -0.001], $d = 0.66$, $p_{int} = 0.050$) . (Table 5).

Relationship between training adaptations and training load

No clear associations were found between training load and adaptations in F-V profile, functional capacity, or body composition. The running speed at 4mM lactate increased more in participants who experienced a higher increase in high-speed run distance (% relative to total distance) ($\rho = 0.518$, $p = 0.048$), in the number of decelerations per SSG ($\rho = 0.579$, $p = 0.024$) and average HR per SSG ($\rho = 0.659$, $p = 0.014$) throughout the training sessions. RPE at the highest speed level decreased more with a higher increase in total distance covered per SSG ($\rho = -0.571$, $p = 0.033$).

Discussion

The current study investigated adaptations to a 10-week recreational football training program in middle-aged to older adults. Throughout the intervention period, the feasibility and physical demands of the program were tracked. Compared to a control group, recreational football training induced the following effects: 1) leg-extensor gains that were non-uniform over the full F-V profile, with moderate gains in maximal velocity but not in maximal force; and

Table 4. Estimated means and SE at baseline (pre-) and posttest and % change (±SD) for functional capacity and body composition in the football training (FOOT) and the control (CON) group.

		FOOT			CON				
		Mean	SE	%	Mean	SE	%	Time	Time x group
Functional capacity									
10m fast walk (s)	Pre	4.74	0.16		4.24	0.16			
	Post	4.12	0.17	-12.4 ± 10.9*	4.26	0.17	1.1 ± 9.3	**<0.001**	**<0.001**
5xSTS duration (s)	Pre	8.34	0.21		7.85	0.22			
	Post	7.66	0.24	-8.5 ± 11.5	7.44	0.23	-4.2 ± 9.3	0.063	0.382
5xSTS power (W)	Pre	357	16		362	16			
	Post	359	17	0.6 ± 11.3	351	17	-1.0 ± 13.4	0.576	0.409
Stair ascent duration (s)	Pre	0.76	0.02		0.77	0.02			
	Post	0.72	0.02	-4.9 ± 6.3	0.76	0.02	-0.4 ± 8.5	**0.022**[a]	0.184[a]
Stair ascent power (W)	Pre	878	48		831	48			
	Post	907	49	4.5 ± 14.1	793	48	-5.0 ± 10.6	0.085	0.053
CMJ jump height (cm)	Pre	23.4	1.1		22.4	1.1			
	Post	24.2	1.2	4.0 ± 8.9	22.1	1.1	-1.3 ± 11.1	0.122	0.138
Body composition									
Body mass (kg)	Pre	81.8	2.6		81.4	2.6			
	Post	81.6	2.6	-0.3 ± 2.0	81.2	2.6	-0.2 ± 2.5	0.172[a]	0.929[a]
Body fat (%)	Pre	26.3	1.1		25.4	1.1			
	Post	25.1	1.1	-1.2 ± 1.2	25.0	1.1	-0.4 ± 1.2	**0.007**	0.083
Skeletal muscle mass (kg)	Pre	30.5	1.1		30.7	1.1			
	Post	31.5	1.1	3.4 ± 3.1	31.2	1.1	1.7 ± 4.2	**0.024**	0.225

p-values of Linear Mixed-Effects Models analyses (significant values in bold); * significant within-group change from Pre to Post, [a]not normally distributed and non-parametric tests were performed and reported. For easier interpretation, non-transformed data means were reported for all variables. STS = sit-to-stand; CMJ = countermovement jump.

Table 5. Estimated means and SE at baseline (pre-) and posttest and absolute change (±SD) for endurance exercise capacity in the football training (FOOT) and the control (CON) group.

		FOOT			CON				
		Mean	SE	Change	Mean	SE	Change	Time	Time x group
Speed at 2 mM lactate (km h^{-1})	Pre	6.09	0.31		6.51	0.28			
	Post	7.26	0.32	1.17 ± 1.27	6.85	0.28	0.34 ± 1.24	**0.006**[a]	0.050[a]
Speed at 4 mM lactate (km h^{-1})	Pre	8.15	0.43		8.52	0.40			
	Post	9.25	0.43	1.10 ± 0.48	9.26	0.40	0.74 ± 1.06	**0.004**	0.214
RPE	Pre	15.3	0.5		14.7	0.5			
	Post	13.4	0.5	-1.7 ± 1.0*	14.3	0.5	-0.3 ± 1.8	**<0.001**	**0.005**
Heart rate (bpm)	Pre	155	3.2		149	2.9			
	Post	139	3.2	-14.6 ± 6.7*	144	2.9	-4.9 ± 10.8*	**<0.001**	**0.004**
Lactate (mM)	Pre	5.49	0.38		5.51	0.35			
	Post	3.50	0.38	-1.99 ± 1.16	4.12	0.35	-1.38 ± 1.87	**0.001**[a]	0.142[a]

p-values of Linear Mixed-Effects Models analyses (significant values in bold); * significant within-group change from Pre to Post, [a]not normally distributed and log transformed for the analyses. For easier interpretation, non-transformed data means were reported for all variables. RPE = rating of perceived exertion. RPE, heart rate and lactate values of the common highest intensity block, completed in the pre- as well as post-intervention test were reported (i.e., values at the same speed level in both tests).

2) simultaneous improvements in musculoskeletal fitness (V_0, walking speed, stair-climbing performance) and cardiovascular fitness (endurance exercise capacity), and a trend towards improved metabolic fitness (fat percentage). The training sessions, in particular the SSG's, elicited intense muscular actions and both the number of accelerations and decelerations, as well as the distance spent in moderate- and high-speed zones, increased markedly throughout the 10-week period. High average heart rates of 85.7% of HRmax were reached during the SSG's. Despite the high external and internal load, participants perceived the training sessions as very enjoyable and feasible. These results indicate that recreational football with SSG's is a feasible training tool to induce broad-spectrum health benefits in middle-aged to older adults.

Lower-limb muscle power is a key component in activities of daily living (Kuo et al., 2006). To improve muscle power, international guidelines have recommended to perform resistance exercises, with a specific focus on performing the concentric phase of the movement as fast as possible (Fragala et al., 2019). However, many older adults are reluctant to initiate an exercise program in a traditional fitness center. As a result, the number of older adults that engage in these types of exercise programs is limited. Recreational football training with SSG's might be a valuable alternative, given that intense muscular actions are required (Milanovic et al., 2020), which were hypothesized to induce gains in muscle strength and power.

Contrary to these expectations, the current study did not find a larger improvement in F_0 (+3.4% vs +4.3%), P_{max} (+11.0% vs +7.0%), nor in CMJ jump height (+4.0% vs -1.3%) in FOOT compared to CON, which is in line with the previous suggestion that longer training periods (i.e., up to 12 months) might be needed to induce gains in lower-limb strength and power (Randers et al., 2010a; Sundstrup et al., 2016). However, adaptations to exercise are typically velocity-specific (Lopez et al., 2022; Rodriguez-Lopez et al., 2021). Therefore, we assessed the full F-V profile instead of a single loading condition. A greater improvement in maximal velocity of the leg-extensor muscles was found in FOOT compared to CON (moderate effect size). The slope of the F-V curve relative to F_0 also tended to change in FOOT, which was less steep at post-intervention compared to baseline (see Figure 3, moderate effect size). Even though this change was not significantly different from CON, it might be an important benefit to be obtained from recreational football, considering that ageing results in a more compromised muscle function when the required movement velocity increases (Alcazar et al., 2023). Studies in larger samples are needed to replicate these findings.

In line with the change in maximal velocity of the leg-extensor muscles, larger gains in FOOT compared to CON were found for functional capacity tests that rely on high execution velocities, such as 10-m fast walk (large effect size) and 3-step stair ascent (moderate effect size, trend towards significance). Changes in V_0 were highly related to changes in 10-m fast walk in FOOT ($\rho = -0.732$, $p = 0.003$, data not shown in the results). Combined with results from previous studies in older (male) adults, it seems that recreational football training can induce gains in functional capacity tests with either a high execution velocity (e.g., fast walking, stair climbing (Sundstrup et al., 2016), TUG (Duncan et al., 2022)) or an endurance component (e.g., 6-minute walk test (Duncan et al., 2022), 30s chair stand test (Andersen et al., 2014; Duncan et al., 2022; Sundstrup et al., 2016)).

Next to the changes in musculoskeletal fitness, the current study also investigated changes in metabolic and cardiovascular fitness after recreational football training. More specifically, body composition and endurance exercise capacity were assessed using BIA and a submaximal graded exercise test, respectively. The results showed that a short intervention period of 10 weeks tended to reduce body fat percentage in middle-aged to older adults (moderate effect size). This is in line with previous studies (Bjerre et al., 2019; Duncan et al., 2022; Skoradal et al., 2018) and review papers (Bangsbo et al., 2015; Mohr et al., 2023), which concluded that regular recreational football training lowers body fat percentage in untrained (older) adults. In addition, recreational football can induce large improvements in maximal oxygen uptake, regardless of age, sex and health status of the participants (for a review, see Milanovic et al. (2015)). Although we did not find a significant difference between FOOT and CON in running speed at 2mM or 4mM lactate, the decrease in heart rate and RPE at the highest intensity block of the exercise test is indicative of an enhanced exercise tolerance in FOOT (large effect size).

An important consideration in recreational football training is the physical loading that the players' experience and its potential risk for injury. Therefore, we closely monitored external and internal loads and documented all injuries throughout the training period. SSG's were progressively built up in duration and the number of players (4vs4, 5vs5) were chosen to specifically target power-related football actions (Rebelo et al., 2016). In line with the progressive increase in duration of the SSG's (i.e., from 2 x 10min to 2 x 15min), total distance per SSG increased from 764m to 982m, with an increasing amount of time spent in the moderate- and high-speed zone (from 26.5% to 28.3% and from 4.3% to 6.1%, respectively) and an increasing number of accelerations and decelerations (from 11.1 to 13.2 and from 10.8 to 14.2). Although external load gradually increased, internal load did not change throughout the intervention period, with an average HR of 85.7% of HRmax and 40.5% of time spent in a high-intensity zone (>90% of HRmax). This is in line with our finding of improved exercise tolerance during the submaximal treadmill test. Our results also indicate that the increase in training load throughout the intervention period is related to improved endurance exercise capacity, stressing the added value of load monitoring during training sessions.

Internal load indicators are in line with previous literature in middle-aged to older adults, indicating average HR of 80-85% in SSG's (Beato et al., 2018) and up to 48% of time spent in a high-intensity zone (>90% HRmax) (Randers et al., 2010b). It is difficult to compare external training load with previous studies given the methodological differences, such as age and health status of the study sample, duration of SSG's, pitch size, number of players in SSG's, and definition of high-speed run or accelerations/decelerations. Beato et al. (2018) reported external training load indicators in middle-aged men (43 ± 3 years) playing SSG's 5-a-side for 60min on a pitch size of 36 x 18.5m. In week 8-10 of the current study, the total session duration was around 60min, and similar external load indicators were found when compared to Beato et al. (2018), i.e., total distance (3360m vs 3375 - 3483m), number of accelerations > 2 m s^{-2} (36.5 vs 37 - 38) and number of decelerations <-2 m s^{-2} (33.3 vs 35 - 36). Uth et al.(Uth et al., 2016) reported slightly lower distances covered during SSG's of 15min (839 – 916.5m vs 982m) and a similar number of accelerations and decelerations, albeit performed at a lower intensity (>1.4 m s^{-2} vs >2 m s^{-2}), in men with prostate cancer compared to the current study. Overall, we can conclude that recreational football training with SSG's is a highly intense and intermittent activity, with numerous high-speed runs, accelerations and decelerations.

It could be questioned whether these high physical loadings also imply a high risk for injury. In the current study, the following minor adverse events, which did not result in missed participation time, were reported: mild muscle soreness (n = 6), knee pain (n = 4), hip pain (n = 2), and rib contusion (n = 1). Eight injuries were recorded in 20 participants, of which 4 resulted in drop-out (1 Achilles tendinopathy, 3 calf muscle strain). The other 4 injuries were mild muscle strains (calf, hamstrings, quadriceps), which resulted in a missed participation time of 1 to 7 sessions. All injuries could be grouped according to their severity as mild to moderate (Fuller, 2006). Overall injury incidence per 1000 player-hours was 27, which is similar to the injury report by Duncan et al. in a sample of older men (60 - 80 years) during a 12-week recreational football training intervention (Duncan et al., 2022). Nevertheless, it is higher than previous estimations of injury incidence in football in a Finnish cohort (15 - 74 years), namely 7.8 per 1000 player-hours (Parkkari et al., 2004). From a public health perspective, the health benefits due to participation in football have to be balanced with the possible health risks involved. Previously untrained women and men may be exposed to an increased risk of injuries, albeit mostly minor ones (Oja et al., 2015). This suggests that effective injury prevention measures should be built in as an integral part of the intervention programs (Oja et al., 2015). To note, most injuries occur in the initial phase of a training period, so the incidence rate of injuries would probably be lower if longer training periods are included.

Although the risk for injuries was increased, all participants in FOOT, including two of the five drop-outs, experienced the training sessions as very enjoyable and very feasible. Data of the three other drop-outs were unavailable, but those individuals already dropped out after the first week and would not have been able to properly score the training sessions. Even though we have previously shown that participants in a resistance exercise intervention also indicated to enjoy the exercise (Van Roie et al., 2015), the social connectedness and cohesion that is more present in interactive team sports compared to resistance training might result in higher intrinsic motivation (Pedersen et al., 2017). 70.6% in FOOT and 55.6% in CON indicated their willingness to engage in a new sequence of training sessions. The most important barrier to engagement was lack of time, mainly because of job obligations (as training sessions were performed in the afternoon, during regular office hours). As we have previously shown that the intention to continue with an exercise intervention after the end of an RCT is not synonymous with the actual behavior (Van Roie et al., 2015), further research is necessary to investigate long-term adherence.

We acknowledge a selection bias in the recruitment strategy, as the recruitment was initiated by the local football club and mainly directed to the fan base of the club. Therefore, the study sample was not representative for the overall population of people aged between 55 and 70 years. Most of the participants were previous football players, who are certainly more intrinsically motivated to play football than individuals who have never played football. This may also have influenced the risk for injury, as former players immediately want to play at the intensity level that they used to play when they were younger. As such, the coaches had to slow down the participants in their enthusiasm to perform at a high level, instead of motivating them.

Apart from the recruitment strategy, the following limitations of the study should be acknowledged. Firstly, the intervention period had to be shortened because of COVID-related restrictions. More specifically, kick-off date of the training sessions had to be postponed by two weeks, because training in groups of more than four people was not allowed. This may have resulted in smaller overall effects. Future research should investigate the long-term effects of such intervention on health benefits while tracking adherence to the program and injuries. Secondly, the sample size in this study might be considered small, although it was similar to previous reports on recreational football training in middle-aged to older adults (Andersen et al., 2014; Duncan et al., 2022).

Conclusion

A 10-week recreational football training program with SSG's in middle-aged to older adults resulted in improved leg-extensor velocity production, which translated into better performance on functional capacity tests that rely on high execution velocity, such as fast walking and stair climbing. A simultaneous improvement in endurance exercise capacity and a trend towards a decrease in body fat percentage were found. Although training intensity was high and the incidence of muscle strains was substantial, all participants experienced the training sessions as very enjoyable and feasible. Future studies need to address the question whether these findings lead to a high adherence rate in the long term.

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Key points

- A 10-week recreational football training program with small-sided games improved leg-extensor velocity production in 55- to 70-year old adults, which translated into better performance on functional capacity tests that rely on high execution velocity, such as fast walking and stair climbing.
- External load of the training sessions (i.e., distance, high-speed runs, number of accelerations and decelerations) gradually increased throughout the training program without changes in average HR, which indicates improved exercise tolerance. This is in line with the lower RPE and HR values in the submaximal graded exercise test.
- Despite the high training intensity, participants experienced the training sessions as very enjoyable and feasible.

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