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ORIGINAL ARTICLE

Influence of a brisk walking program on isokinetic muscular capacities of knee in sedentary older women

P. L. Bernard[1] · G. Tallon[1] · G. Ninot[2] · A. Jaussent[3] · S. Ramdani[1] · O. Coste[4] · M. C. Picot[3] · H. Blain[1,5]

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Abstract This study analyzed the evolution in peak torque (PT) and mean power (MP) isokinetic parameters in the quadriceps and hamstring muscles of elderly sedentary women who were randomly selected to participate in a brisk walking program for 6 months. The 121 sedentary women of this study presented a mean score of 5.3 (±1.7) on the Physical Activity Questionnaire for the Elderly and covered 86 % of the theoretical distance on the 6-min walk test. The isokinetic evaluation was performed on both sides at 60°/s and 180°/s. PT and MP were selected for analysis. Women in the trained group ($n = 61$) participated in a program of 78 sessions over 6 months with three sets of 60 min of exercise per week. For this group, heart rate, time and distance were, respectively, 125.2 bt/min (±10), 37.9 min (±4.2) and 3756.3 m (±445.4). The analysis of the group × time interaction demonstrated an increase in the PT of the dominant-side hamstrings ($p < 0.001$). In the trained group, we observed a significant increase in PT at 60°/s for the hamstrings on both sides ($0.01 < p < 0.02$) and a significant increase in MP for the hamstrings at 60°/s on the nondominant side ($p < 0.05$). The study indicates a minor, though significant, influence of a brisk walking program on the peak torque and mean power of the quadriceps and hamstring muscles in sedentary women over 60 years.

Keywords Elderly · Isokinetic · Knee · Brisk walking · Training program

Introduction

Preventing the loss of autonomy and maintaining health are major priorities for the elderly population. Aerobic capacities decrease with aging. At age 80–85 years, 18 ml/min/kg of maximal oxygen uptake (VO_{2max}) is necessary for independent living and it is assumed that an increase of 5–10 ml/min/kg of VO_{2max} would delay dependency by 10–20 years [1]. The current recommendation is for 30 min of continuous physical activity, five to seven times per week. Moderate, progressive and individualized activities are recommended, based on the control of heart rate during the exercise.

Muscular function is influenced by age and the loss of strength is associated with reduced walking speed and losses in autonomy and functional capabilities [2, 3]. Nevertheless, it has been demonstrated that physical exercise might make these losses more moderate. Meta-analysis has shown that muscular training improves the capacity to rise from a chair and climb stairs, locomotion capacity, and quality of life [4, 5]. Many of the physical training studies have been based on strength measurements using monoarticular exercise. These variables indicate the trainability of neuromuscular function, the gains in

✉ P. L. Bernard
pierre-louis.bernard@umontpellier.fr

1 Euromov, University de Montpellier, avenue du Pic Saint Loup, 700, 34090 Montpellier, France

2 EA 4556 Epsylon, University de Montpellier, 4 boulevard Henri IV, Montpellier, France

3 Department of Medical Information, University Hospital of Montpellier, University de Montpellier 1, Montpellier, France

4 DRJSCS, 3 avenue C. Flahault, Montpellier, France

5 Department of Internal Medicine and Geriatrics, Antonin Balmes Center, University Hospital of Montpellier, Montpellier, France

maximal strength, in trophicity and the improvements in activation and strength control [6–8].

Another approach to physical training programs for elderly people targets the whole body rather than centering on a specific musculo-articular complex. Mobilizing functional capacities and optimizing the physical fitness dimensions (strength, endurance, flexibility, balance, coordination) are usually the objectives in these types of program and introduced the potential concurrent effects [9–11]. Isokinetic methods have been used to examine the muscular benefits of some of the global physical reconditioning programs, including tai-chi [12, 13] and whole-body vibration [14, 15]. Moreover, some studies have examined the influence of combined training programs, often composed of muscular and aerobic exercises [16–19] and others still have included balance and flexibility exercises [20–22]. Last, some of the physical reconditioning programs focus on aerobic function and an increasing number of studies have focused on the effects of brisk walking or nordic walking [23–25]. Most of these studies have included participants with cardiovascular disabilities or have examined programs to prevent cardiovascular disease, diabetes or obesity [26, 27]. Others have investigated the influence of brisk walking on muscular function, particularly in elderly people [28–30]. The whole-body approach makes it more difficult to improve muscular function capacity, especially in the musculo-articular area, because of the less-specific nature of the exercise. Walking, however, may address this issue. It is consistently cited in the international recommendations for physical activity as a preferential method for optimizing physical fitness and maintaining health. Although it is a full-body approach to physical fitness, we investigated whether walking could significantly improve the muscular function of knee joints in elderly people.

We found few studies on the effects of brisk walking on lower limb muscular function and even fewer on the impact of an exercise program evaluated by an isokinetic method. The benefits of muscular reconditioning programs have been tested for the muscular function of disabled people, and the benefits of aerobic programs have been tested for obese, cardiovascular and respiratory risk populations. The aim of this study was to determine the evolution in the isokinetic parameters of peak torque and mean power in the quadriceps and hamstring muscles of older sedentary women.

Method

Study design

The present study was part of a single-blind pilot RCT with two parallel arms registered with ClinicalTrials.gov (NCT02094144). The trial aimed to determine the efficacy of a brisk walking program on endurance parameters. These concurrent effects included effects on bone metabolism (main outcome) and muscle strength, balance, depression, and quality of life (secondary outcomes). All study participants provided written informed consent. This study was ethically approved by the Regional Committee for the Protection of Human Subjects (CPP Sud-Méditerranée III, Number: 2008.07.04). Participants selection and data collection were performed at the Euromov center of the University of Montpellier's School of Sport Sciences and at University of Montpellier Hospital. The manuscript reports on the efficacy of a brisk walking program on lower extremity isokinetic strength.

Setting and sample

Community-dwelling women aged 60–76 years were recruited at public meetings aimed to promote exercise for postmenopausal women. Participants were recruited over a 36-month period (between June 2008 and June 2011). The ads briefly described the study (i.e., a 26-week study to define the effects of brisk walking on functional capacities). Women were eligible and enrolled in the study if they met the following criteria: (1) not diagnosed with any of the following conditions: rheumatoid arthritis, osteoarthritis, ischemic heart disease, previous joint replacement surgery, cerebrovascular disease affecting lower limb function, or malignant tumors, and (2) without pain and not under medication known to alter physical performance (e.g., corticosteroids, estrogens, statins, or anti-estrogen drugs).

To recruit a sample of asymptomatic sedentary postmenopausal women that adequately represent the target population, women with a score value above 9.4 on the Physical Activity Questionnaire for the Elderly (PASE) [31] and a 6-min walk distance (6MWD) lower than 105 % of the predicted 6MWD based on Troosters' reference equation were excluded [32]. The Troosters' reference equation is: predicted 6MWD $= 218 + [5.14 \times$ height (cm) $- 5.32 \times$ age (years)] – [$1.8 \times$ height (cm)] $+ (51.31 \times$ sex).

Each woman was evaluated on two 6-min walk tests (6MWT). The 6MWT is a rectangular, continuous and submaximal field test to evaluate exercise tolerance [33]. Participants were equipped with a heart rate monitor to assess the physiological adaptations to exercise and prevent potential complications. After a 3-min warm-up of walking and leg stretching (quadriceps, hamstring, ilio-psoas and triceps surae), they performed the 6MWT over 30 m with markers every 10 m. No verbal encouragement was given. The participants rested for 20 min between the two tests, which was assumed to be adequate physiological recovery.

Intervention

Before the isokinetic evaluation, each subject warmed up by ergocycling for 5 min with 60 W of resistance and 90 rotations per minute, followed by 5 min of quadriceps and hamstring stretching.

We used the Biodex System 3® isokinetic dynamometer (Biodex Medical, Inc., Shirley, NY) from the Technological Platform of Euromov Center of Montpellier, France. The quadriceps and hamstring muscles were evaluated in concentric/concentric modality with a 70° range of motion (ROM). The distal shin pad of the dynamometer lever arm was attached 10 cm proximal to the lateral malleolus and motion ranged from 60° to −10° of knee extension in the sagittal plane to limit hamstring resistance during the extension. The cushion setting on the control panel for the hands of the ROM was set to the lowest (hard) setting during the evaluation in order to reduce the effect of limb deceleration on the reciprocal motion. Tests were performed in the seated position with a hip flexion angle of 110°. Velcro straps stabilized the trunk and the thigh of the tested leg. The contralateral limb was not strapped. The dynamometer's axis of rotation was aligned with that of the knee joint. The hands were crossed over the trunk during testing.

The cycling warm-up was followed by a warm-up on the dynamometer consisting of two sets of five submaximal repetitions of knee extensors and flexors at 180°/s separated by 1 min of recovery. A period of 3 min then separated the end of this warm-up and the test. The experimental protocol began by the evaluation of the dominant side with five repetitions at 60°/s. We then imposed 60 s of recovery time and began a second set of five repetitions at 180°/s. Five minutes was needed for the preparation of the controlateral side. After the same protocol of isokinetic warm-up as for the dominant side, the same test protocol was imposed. The parameters of peak torque (PT, N m) and mean power (MP, W) were selected for analysis. The data were normalized by body mass. During the test, each subject received verbal encouragement from the same investigator.

Exercise

Women in the training group participated in a program of 78 sessions over 6 months, with three sessions of 60 min per week. Two weekly sessions were supervised (52 sessions) and one individual session was unsupervised (26 sessions). Each walking group in the training program was composed of ten women. The program was carried out on flat ground and participant behaviors were controlled:

- The maximal heart rate (MHR) was calculated with the equation of Tanaka [$FC_{max} = 208 - (0.7 \times \text{age})$] and the program was designed to progress from 60 % of MHR at the beginning to 80 % of MHR at the end of the program,
- Walking distance was expected to be three times greater at the end of the program with a total distance of 1500 at the beginning and 4700 m at the end of the program,
- The time of actual exercise effort per session was expected to rise from 25 to 45 min over the course of the program.

This information was collected during each session to assess the level achieved by the 61 women composing the training group, with heart rate, time and distance, respectively, 125.2 bt/min (±10), 37.9 min (±4.2) and 3756.3 m (±445.4).

Randomisation

After the public meetings, 121 women were included and randomized in the study at a 1:1 ratio, blocked in groups of four (Table 1). The random allocation sequences were computer-generated using SAS software.

Statistical analyses

Sample size

The sample's size was calculated according to the main criterion, i.e., variation of areal bone mineral density (aBMD). The expected BMD variation difference between the two groups was 2.8 %. The mean BMD of the femur was 0.806 g/cm^2 (mean difference of 0.024) with a standard deviation of 0.047 for a 1-year variation. Under a bilateral hypothesis, a minimal number of 70 subjects per group was required, with an alpha risk of 5 % and a power of 80 %. Based on an expected loss to follow-up rate of about 10 %, 77 subjects had to be included in each group.

Data analysis

Patient characteristics are described using means and standard deviation (SD) for quantitative variables. The distribution of continuous variables was assessed with the Shapiro–Wilk test. Linear mixed models for repeated measures were used to examine the effect of training on the strength measures at 6 months. Time treatment group (training versus control) and group × time interactions were modeled as fixed effects with strength measures as

Table 1 Anthropometric and physiological characteristics of the population

	Control		Trained	
	m	SD	m	SD
Years (years)	65.54	4.04	65.46	4.37
Weight (kg)	70.06	11.57	64.14	12.06
Height (cm)	162.53	6.6	161.25	6.29
BMI	26.53	4.27	24.68	4.34
Lean mass/fat mass	1.76	0.39	1.89	0.6
Waist circumference/hip circumference	0.87	0.1	0.85	0.09
Systolic blood pressure (mmHg)	123.67	22.16	122.23	14.28
Diastolic blood pressure (mmHg)	76.4	9.77	73.07	9.73
Heart rate rest (bt min)	74.88	10.49	74.7	10.61
Grip test (kg)	22.66	5.77	22.03	6.4
6MWT (mt)	444.92	47.83	448.9	56.14

dependent variables. The group × time interaction was tested to evaluate the differences in strength between group at 6 months. Tests of the group × time interactions are also reported separately for each group (within-group variations). Values were considered statistically significant at $p < 0.05$. Statistical analyses were performed using SAS version 11 (SAS Institute, Cary, NC).

Results

The tables present the evaluation of the isokinetic parameters of peak torque (PT) and mean power (MP) of the knee muscles at 6 months for the two groups of trained (T) and control (C) participants. Each parameter was tested in flexion (Fl) (hamstring) and extension (Ext) (quadriceps), on the dominant (do) and nondominant (nd) sides and for the two test speeds of 60°/s and 180°/s.

Peak torque

At study inclusion, the two groups were similar for all isokinetic parameters except PT60doEx and PT180doEx, which were higher in the T group (respectively, $p = 0.04$ and $p = 0.05$) (Table 2). We observed a significant increase in PT60doFl, PT60ndFl and PT180doFl in the T group at 6 months (respectively, $p = 0.02$, $p = 0.01$, $p = 0.01$), whereas the C group showed no significant variation. However, only PT180doFl varied significantly between the two groups ($p = 0.01$). PT180doFl increased significantly in the T group but showed no significant variation in the C group. Similarly, PT60doFl tended to change in different ways between the two groups ($p = 0.07$) (Table 2).

Mean power

At study inclusion, the two groups were similar for all isokinetic parameters except MP60doEx, which was higher in the T group ($p = 0.04$) (Table 3). We observed a significant increase in MP60ndFl in the T group at 6 months ($p = 0.04$), whereas a significant decrease was observed in the C group for MP180doEx, MP180ndEx and MP180ndFl (respectively, $p = 0.02$, $p = 0.01$ and $p = 0.02$). However, only MP180ndFl tended to change in different ways between the two groups ($p = 0.10$). We observed a significant decrease in MP180ndFl in the C group but this parameter did not vary in the T group (Table 3).

Discussion

The interactions between the training time and the two groups indicated a minor but significant influence of the brisk walking program on the peak torque and mean power of the quadriceps and hamstring muscles of sedentary women over 60 years old. This training program particularly increased the peak torque of the dominant-side hamstrings at high speed did not significantly affect mean power.

Although significant effects of the brisk walking training program were not observed, this merits examination. The principal aim of our training program was to improve overall physical fitness and especially cardioventilatory function. Walking was considered a pertinent exercise to mobilize cardioventilatory capacities and the heart rate management during the training period was a way to control the physiological adaptations and the effort level. Therefore, the intensity was progressively increased from

Table 2 Means, standard deviations and significant levels of peak torque (PT) of the flexor (Fl) and extensor (Ex) muscles on the dominant (do) and the nondominant (nd) sides for the two test speeds of 60°/s and 180°/s for the two groups of trained and control groups

	Trained					Control					Between group evolution	Between group difference	
	M0		M6		Within group evolution	M0		M6		Within group evolution	Gr × time	At Baseline	At 6 month
	m	sd	m	sd	p	m	sd	m	sd	p	p	p	p
PT60doEx	1.36	0.29	1.38	0.29	0.77	1.24	0.29	1.26	0.33	0.69	0.94	0.04	0.05
PT60ndEx	1.26	0.30	1.29	0.33	0.45	1.23	0.30	1.25	0.32	0.70	0.42	0.83	0.65
PT60doF1	0.68	0.15	0.72	0.17	0.02	0.67	0.15	0.67	0.15	0.82	0.07	0.88	0.10
PT60ndF1	0.67	0.15	0.72	0.20	0.01	0.63	0.15	0.67	0.14	0.49	0.20	0.69	0.13
PT180doEx	0.91	0.23	0.89	0.20	0.58	0.82	0.22	0.82	0.20	0.79	0.74	0.05	0.08
PT180ndEx	0.84	0.20	0.82	0.22	0.28	0.83	0.18	0.81	0.20	0.41	0.76	0.72	0.83
PT180doF1	0.57	0.15	0.61	0.15	0.01	0.58	0.14	0.57	0.13	0.27	0.01	0.70	0.09
PT180ndF1	0.56	0.15	0.59	0.16	0.12	0.57	0.15	0.58	0.14	0.70	0.40	0.62	0.81

Table 3 Means, standard deviations and significant levels of mean power (MP) of the flexor (Fl) and extensor (Ex) muscles on the dominant (do) and the nondominant (nd) sides for the two test speeds of 60°/s and 180°/s for the two groups of trained and control groups

	Trained					Control					Between group evolution	Between group difference	
	M0		M6		Within group evolution	M0		M6		Within group evolution	Gr × time	At Baseline	At 6 month
	m	sd	m	sd	p	m	sd	m	sd	p	p	p	p
MP60doEx	0.78	0.18	0.79	0.23	0.51	0.70	0.21	0.69	0.18	0.76	0.49	0.04	0.01
MP60ndEx	0.73	0.20	0.73	0.24	0.78	0.72	0.19	0.69	0.22	0.34	0.63	0.66	0.40
MP60doF1	0.42	0.12	0.44	0.12	0.36	0.41	0.12	0.40	0.14	0.69	0.35	0.50	0.15
MP60ndF1	0.41	0.13	0.43	0.15	0.04	0.40	0.11	0.39	0.11	0.69	0.09	0.79	0.07
MP180doEx	0.88	0.33	0.89	0.40	0.80	0.84	0.35	0.77	0.33	0.02	0.14	0.55	0.08
MP180ndEx	0.84	0.36	0.81	0.40	0.35	0.87	0.34	0.77	0.40	0.01	0.24	0.63	0.66
MP180doF1	0.49	0.22	0.51	0.24	0.76	0.50	0.23	0.46	0.21	0.07	0.13	0.77	0.32
MP180ndF1	0.48	0.24	0.48	0.25	0.93	0.51	0.24	0.46	0.23	0.02	0.10	0.50	0.55

60 % of MHR at the beginning to 80 % of MHR at the end of the program, with a mean MHR of 77.07 % (±9.04) for all the sessions. This approach most likely places a limit on optimizing muscular function. The program was carried on flat ground in order to reach a stable heart rate for a fixed time. As the goal was to achieve a certain heart rate, and given the relationship between heart rate and movement frequency, the observed tendency was to increase the gait cadence and not the step length. To optimize muscular function, it might have been better to insist on the beneficial affect of longer step length and greater musculo-articular solicitations to improve the muscular torque and power of the lower limbs. Nevertheless, some studies have shown the positive effects of walking exercise on the muscular function of elderly people and have suggested the benefits of restricted blood flow during walking exercise. Abe et al. [28] studied the influence of a walk training program at low speed with restricted blood flow to the leg muscles on the muscular and aerobic capacities of 19 men and women with ages ranging from 60 to 78 years. The walk training group combined restricted blood flow to the leg muscles with 20-min of treadmill walking (67 m/min), 5 days a week for 6 weeks. Isokinetic knee extension and flexion torques, muscle–bone cross-sectional area, and ultrasound-estimated skeletal muscle mass significantly increased ($p < 0.05$) in the walk group but not in the control group. Ozaki et al. [30] studied the effects of walk training with BFR on muscle trophicity and VO_{2peak} in older women. The walk training group with BFR performed 20 min of treadmill walking at an exercise intensity

of 45 % of heart rate reserve, 4 days per week, for 10 weeks. BFR walk training improved VO_{2peak} ($p < 0.05$), muscle volume ($p < 0.01$), maximal isometric ($p < 0.05$) and maximal isokinetic strength ($p < 0.01$) in the older women. Ozaki et al. [29] confirmed these data in a brief review and they discussed whether ambulatory exercise elicits leg muscle hypertrophy in older adults.

Our study was carried out on flat ground to maintain a steady and stable heart rate. This is a reasonable option to prevent the cardiorespiratory overload observed during uphill walking or the muscular overload of excentric contraction, such as occurs in the quadriceps during downhill movement. The interest of walking on flat ground associated with heart rate control is well-known, but this approach needs to be adapted when the goal is specifically muscular optimisation. Our study demonstrated the small but significant effects of this kind of training on the muscular capacities of sedentary older women. One option in programming could make use of the recovery time. Although passive recovery and hydration between sets are important, isometric and/or plyometric exercises could be introduced at low-intensity contractions to prevent excessive fatigue.

Some studies have been conducted with programs of combined aerobic and specific muscular solicitation in older populations [13, 14, 16, 18]. Lee et al. [17] showed the significant effect of a combined exercise program (aerobic and resistance) versus aerobic exercise on the isokinetic strength of older women after 8 weeks of training. Marzolini and Brooks [19] performed a meta-analysis comparing the effects of aerobic programs versus combined programs of aerobic and resistance exercise. In the cardiovascular rehabilitation field, they selected 12 major studies and concluded that the combined programs were more efficient with regard to body composition, muscular strength and cardioventilatory health parameters. When the goal is specifically to improve muscular function, however, other studies have insisted that major specific exercises need to be included. Carvalho et al. [21] showed the limited effects of a biweekly global training program on isokinetic strength and they insisted on the significant influence of added resistance exercises to improve muscular function. Fatouros et al. [16] studied the effects of aerobic training, muscular training and their combination over 16 weeks on musculo-articular function in 32 sedentary older men. The muscular training program and the combined program resulted in a significant increase in isokinetic concentric peak torque measured at the hip and ankle joints. The aerobic training program significantly improved ($p < 0.05$) the flexion and extension movements of the hip. The interest of combined training programs has often been cited for disabled people. Nevertheless, the principle of exercise specificity seems inescapable and mandatory to optimize a specific function such as muscular function. Various studies emphasize the concepts of concurrent effects, and the difficulty to articulate endurance and resistance on the necessary contents [9–11]. Further studies are needed to define the most optimal combinations. This principle of specificity is especially the case for people without a high level of disability, as opposed to populations with high levels of chronic disabilities who greatly improve in proportion to their low physical fitness. Our population was considered sedentary (6MWT at 86 % of the theoretical distance), but not disabled. In the context of aerobic training, an interval training model was another option. Based on the variation between low- and high-intensity levels, this type of training would have placed greater demand on the muscles. Although this type of training is underused for elderly people, some studies have shown its interest for populations with cardiovascular, ventilatory and metabolic disease [34, 35].

In line with our physiological goal of muscular optimization, this study takes a promotional approach to health. As previously mentioned, the public information meeting we held aimed to select participants as well as promote healthful behaviors. Encouraging regular physical activities and presenting the risks of a sedentary lifestyle were major objectives. Therefore, despite our recommendation to the control group to maintain their regular activity level for the 6 months of the study, we observed a change in the behaviors of some of them through their PASE responses. Although none of them joined a walking group, which was prohibited, some intensified their physical activities, which might have affected their muscular profile. This was a great attitude in terms of personal health, but a real methodological difficulty in a study attempting to demonstrate the influence of a specific training program. Removing these women was an option but at the risk of lowering the power of the statistical analysis, and a further difficulty was defining a cutoff value for the change in activity level that would signal exclusion.

Conclusion

Our study showed a minor but significant influence of a brisk walking program on the peak torque and mean power of the quadriceps and hamstring muscles in sedentary women over 60 years old. The analysis of the interaction between groups and time demonstrated an increase specifically in the peak torque of the hamstrings on the dominant side. We also observed in the trained group a significant increase in the peak torque for the hamstrings on both sides and a significant increase in the mean power for the hamstrings on the nondominant side.

Moreover, our study raises questions about the recommendations for physical activities favoring health. The international recommendations, which are broadly communicated by the major medical societies, are to engage in 150 min of physical activity per week, with five sessions of 30 min apiece. Walking is often cited as a good exercise to optimize functional capabilities and health. Our study did not refute this, but we think it is necessary to move from general recommendations to individualized prescription, which means the selection of appropriate activities, the selection of adapted training methods for a given population, accurate management of the duration, intensity and frequency of the session, and management of work time and recovery time during the different sets of a training session. In addition to analytic efficiency programs focused on specific joints or muscular groups, more research is needed on specific training programs for older people to ensure appropriate levels of physical fitness and well-being along the aging process.

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Compliance with ethical standards

Conflict of interest None.

Human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research comittee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

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

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