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ORIGINAL ARTICLE

Lower limb muscular strength and power characteristics of Masters road cyclists and age-matched sedentary adults

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ABSTRACT

BACKGROUND: Endurance exercise is known to promote healthy aging of cardiovascular system, but the effects on muscle characteristics are still unclear. Some evidence suggests that endurance running provides insufficient stimulus to prevent age-related losses in muscle mass and muscular strength. However, few studies have evaluated the muscular adaptations to high-volume road cycling. The purpose of the present study was to compare thigh muscle volume, muscular strength, and muscular power of Masters cyclists and sedentary controls.
METHODS: Ten competitive road cyclists (57.8±6.1 years) and 10 age- and body mass-matched sedentary males (54.3±3.7 years) were studied. Thigh muscle volume was determined from thigh circumference, age and body mass using a validated equation. Maximal isometric leg strength was measured with a leg and back dynamometer. Relative dynamic force and leg power was measured using a countermovement jump.
RESULTS: No significant differences ($P>0.05$) were observed between sedentary older males and Masters road cyclists for body mass (83.1±9.5 *vs.* 84.0±6.7 kg), BMI (27.6±2.7 *vs.* 27.0±2.1 kg/m^2), absolute isometric strength (143.2±20.9 *vs.* 132.9±21.2 kg), relative dynamic power (28.6±6.6 *vs.* 32.5±8.7 W/kg) or thigh muscle volume (8007±651 *vs.* 8052±505 cm^3) groups.
CONCLUSIONS: These findings suggest competitive endurance cycling training does not enhance muscular strength and power compared to age-matched sedentary older adults.

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The aging process is accompanied by a gradual loss of muscle mass and strength.[1] Recent research has suggested a strong inverse association between quadriceps strength, mobility and morbidity in a normal aging population.[2] This relationship is becoming increasingly important as the world's population ages with the average life span expected to extend another ten years by 2050,[3] thus posing a significant future challenge for medical and aged-care resources.[4]

Age is also associated with a significant reduction in muscle mass.[1, 2] Moreover, the age-related loss of muscle mass is associated with the age-related decline in both muscular strength and muscular power, leading to a reduced ability to perform activities of daily living.[5-7] Furthermore, Stephen and Jansen [8] have reported a maintenance of muscular strength into older age may lead to a reduction of cardiovascular disease risk factors in older age. Moreover, other researchers have suggested the loss of muscle mass with age increases the risk of several chronic conditions including diabetes and dyslipidemia.[5, 7, 9] Taken together, the above research suggest the importance of maintaining muscle mass, strength and power into older age. The number of older adults participating in road cycling, as competitive and recreational cyclists are growing at a rapid rate in Australia and internationally.[10, 11] Despite these increasing in participation in road cycling, the effectiveness of endurance cycling in preserving muscle mass, strength and power in Masters road cyclists in comparison to sedentary age and body mass-matched older adults is unknown.

Previous research [12] has demonstrated that younger road cyclists possess greater thigh muscle mass compared to aged-matched normally active individuals. These findings suggest that road cycling may induce increases in muscle mass and therefore strength in younger road cyclists.[12] However, cross-sectional studies comparing Masters endurance runners (N.=15, 79.0±9.0 years) and sedentary, age and body mass-matched older adults (76.0±9.0 years) suggest no significant differences in thigh muscle mass, strength and power exist between these two groups.[13, 14]

In contrast, other studies suggest Masters endurance runners and swimmers demonstrate greater muscular strength and muscle mass in comparison to sedentary age-matched controls (15,16,17). For example, Zampieri *et al.*,[17] although not reporting the influence of additional strength training, observed senior sportsmen (70.2±5.2 years) who routinely participate in competitive sporting activity demonstrated greater maximal thigh isometric force and muscle mass compared to healthy but untrained age-matched controls.

No studies to date have examined the effect of competitive road cycling may have on muscular mass, strength and power in Masters road cyclists compared to sedentary, age and body mass-matched older adults. Therefore, the purpose of the present investigation was to compare the differences in thigh muscle volume, muscular strength and muscular power of Masters road cyclists and age matched sedentary adults.

Materials and methods

Ten Masters road cyclists (57.8±6.1 years) and 10 age and body mass matched, sedentary males (54.3±3.7 years) volunteered for the study. The Masters road cyclists were members of the Waratahs Masters Cycling Club who train regularly (120 km per week) and competed in monthly road cycling races. The sedentary male participants were included if they were not involved in any organized or competitive sport and excluded if they had any prior resistance training experience or reported completing more than 150 minutes a week of physical activity as assessed by stage 2 of the Exercise and Sports Science Australia/Sports Medicine Australia adult pre-exercise screening system.[18] All participants were screened for any health or injury concerns which would limit participation using the same pre-screening tool.[18] Participants were provided with a written, plain language information sheet outlining the risks and benefits associated with participation in the research and provided written informed consent. The project was approved by the CQ University Human Research Ethics Committee.

Upon arrival at the testing session, anthropometric measurements (stature, body mass and thigh circumference) were conducted trained anthropometrist according to International Society for the Advancement of Kinanthropometry (ISAK) protocols.[19] Participants were weighed (kg) in minimal clothing on a previously-calibrated weighing scale (Seca model 803, GMBH, Hamburg, Germany). Stretch stature (cm) was measured using a portable stadiometer (Seca model 213, GMBH, Hamburg, Germany). Mid-thigh girth (cm) was measured using a flexible steel tape (Lufkin W606PM Apex Tool Group, New York, NY, USA).

Thigh muscle volume was determined from

midthigh circumference, age and body mass according to the method previously described by Chen *et al.*,[20] using the following formula:

Muscle volume (cm^3) = 5226.3 − 52.5 × age (years) − 955.7 × gender (male=1, female=2) + 55.9 × body weight (kg) + 60.0 × thigh circumference (cm).

This method has been validated in older adults against magnetic resonance imaging (r^2=0.755, P<0.001; standard error of the estimate 581.6 cm^3).[20]

Relative dynamic leg force and power was measured using a Myotest™ unit (MYOTEST Inc. Durango, CO, USA). The Myotest unit is a light weight (<200 g) commercial, tri-axial accelerometer which has been shown to be give valid and reliable measurements of lower body strength and power.[21-24] The Myotest unit was secured via a waist band over the superior aspect of the iliac crest in accordance with the manufacturer's instructions and using standardized protocols.[23, 24] The participants performed a standardized warm-up consisting of five minutes of low intensity aerobic exercise (jogging) followed by a series of trunk stability exercises (one set of sit ups or crunches, 20 repetitions), before moving on to a specific warm up by performing jump squats (two sets of five repetitions) followed by five minutes passive seated rest. Following the Myotest devices countermovement jump (CMJ) test protocol, five maximal CMJ were then performed separated by five minutes of passive seated rest. The Myotest unit recorded participant's relative dynamic strength (N/kg), power (W/kg), jump height (cm), and take off velocity (m/s). The highest of five trials was recorded for subsequent data analysis.

Following a further five minute passive rest, participant's maximal isometric leg strength (kg) was measured using a leg and back dynamometer (Takei, Niigata, Japan) (Figure 1). The participant held the bar with both hands in the centre, both palms down, so that the bar rested superior to the patella, participants were also instructed to keep their back straight, head erect and chest held up. The knees of the subject were flexed to an angle of 130° to 140° [25] and then instructed to slowly start to apply force to the dynamometer by attempting to straighten the knees whilst pulling up on the bar.[25, 26] The best of 3 trials (kg) was recorded for subsequent data analysis.

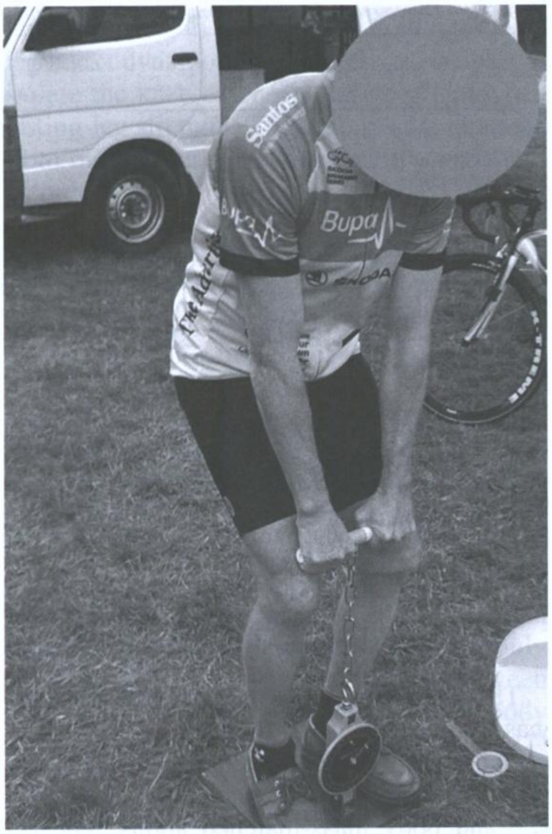

Figure 1.—Participant in the Masters road-cyclist group performing the maximal isometric leg strength test.

Data are reported as means and standard deviations (mean ± SD). Between group differences were determined using independent samples *t*-test. Statistical significance was accepted alpha level of P<0.05. All analyses were conducted using the SPSS v.20 (IBM Corporation, New York, NY, USA).

Results

Demographic, anthropometric and functional performance measures are shown in Table I.

No significant difference were observed between the sedentary older males and Masters road cyclists for body mass index, relative dynamic force, relative dynamic power, take

TABLE I.—*Demographic, anthropometric and functional characteristics of participants.*

Parameter	Sedentary controls (N.=15) (mean ± SD)	Masters road cyclists (N.=13) (mean ± SD)	P value
Age (years)	53.3±3.5	54.6±3.0	0.31
Stature (cm)	1.77±0.6	1.73±0.0	0.19
Body mass (kg)	95.8±15.5	77.3±11.1	0.001
Body mass index (kg/m²)	30.6±4.2	25.7±2.7	0.001
Thigh girth (cm)	60.4±15.9	54.7±3.6	0.219
Maximal isometric leg strength (kg)	152.6±25.4	133.5±18.6	0.001
Relative isometric leg strength (kg/kg)	1.6±0.4	1.7±0.2	0.41
Relative dynamic strength (N/kg)	19.1±1.8	23.6±4.2	0.001
Relative dynamic power (W/kg)	30.4±8.4	35.5±8.2	0.12
Take off velocity (m/s)	181.7±60.9	199.0±29.2	0.36
Jump height (cm)	24.0±4.7	24.5±3.8	0.94
Thigh muscle volume (cm³)	9027.2±1536.2	7780.6±636.5	0.011

off velocity, jump height, absolute isometric strength, relative isometric strength, or thigh muscle volume (P>0.05).

Discussion

The purpose of the present investigation was to compare the differences in thigh muscle volume, muscular strength and muscular power of Masters road cyclists and sedentary, age and body mass-matched adults. The results of the present study suggest there were no significant differences in relative dynamic force, relative dynamic power, take off velocity and jump height between sedentary older males and Masters road cyclists. Moreover, the present results suggest no significant between group differences for absolute and relative leg strength, or estimated thigh muscle volume.

The present finding of no significant between group differences in isometric strength are consistent with previous studies examining muscular strength in Masters athletes and sedentary controls.[13, 14, 25] For example, Harridge *et al.*[13] and Tarpenning *et al.*[14] reported no significant differences in both absolute isometric and isokinetic thigh strength as measured by strain gauge and dynamomometry between Masters endurance runners (N.=15, 79.0±9.0 years) (N.=62, age range 43-69 years) and sedentary age-matched controls (N.=18, 76.0±9.0 years) (N.=33, age range 43-69 years). Similarly, an earlier study by Klitgaard *et al.*[25] reported no significant differences in absolute isometric thigh muscle strength between Masters swimmers (N.=6, 69±1.9 years) and sedentary age-matched controls (N.=8, 68.0±0.5 years). Futhermore, Marcell *et al.*[27] in their longitundinal study, investigated absolute isometric knee extension strength in male (N.=59, 58.6±7.3 years) and female (N.=35, 57.1±8.2 years) Masters runners. They reported that, despite maintaining a high volume of endurance training, muscle strength was lost at a rate of 5% per year. The results of the current study demonstrate a similar trend to these studies which suggest that endurance training may not enhance absolute isometric thigh strength in Masters endurance athletes.

The current study found no statistically significant difference between Masters road cyclists and sedentary age and body mass-matched males for relative isometric thigh strength. Previous research [15-17] has suggested the relative isometric strength of endurance-trained Masters athletes is greater than that of sedentary, age-matched controls. For example, Zampieri *et al.*[17] recently reported the relative isometric strength of the knee extensors in senior sports men (N.=15, 70.2±2.0 years) who routinely practiced lifelong sport more than three days per week, was significantly greater than healthy, sedentary age-matched controls (N.=9, 71.5±3.0 years). In an earlier study, Alway *et al.*[15] reported that endurance-trained older runners, swimmers and cyclists (N.=6, 62.0±1.0 years) who had not engaged in any form of resistance training for the last ten years demonstrated greater relative isometric strength, but lower absolute isometric strength and muscle volume than sedentary age-matched men (N.=6, 63.0±1.0 years). In a more recent study, McCrory *et al.*[16] reported relative isometric thigh strength was greater in male and female endurance-trained Masters runners, swimmers and cyclists (N.=95, 72.6±6.5 years) than sedentary, age-matched controls. However, the results of the current study suggest competitive road cycling does not reduce the age-related decline in relative isometic strength. Masters road cyclists did not display significantly greater relative isometric thigh strength than sedentary age and body mass-matched males. Alway *et al.*[15] and Zampieri *et al.*[17] in their studies, reported endurance-trained Masters athletes who demonstrate significantly greater relative isometric strength also demonstrated significantly greater lean muscle mass. Thus, it could be argued, that maintained relative isometric strength reflects maintained muscle mass. However, there was no significant difference in estimated thigh volume between the two groups, which may also explain why we did not see a significant difference in relative isometric thigh strength.

Taken together, these results suggest competitive Masters road cyclists may lose relative isometric strength and thigh muscle volume at the same rate as their sedentary, aged-matched peers.

There are a number of limitations of these previous studies.[13, 14, 16, 17, 25, 27] Firstly, it is possible that concurrent strength training was performed by the Masters athletes in these previous studies since this was not stated as being used to screen out participants in the previous studies. Thus, it is difficult to identify if the greater relative thigh strength was the result of endurance training or the concurrent resistance training that may have been undertaken by the Masters athletes in these studies. In contrast, we deliberately controlled for resistance training to eliminate any influence this may have had on not only thigh strength measures but all other performance variables. Secondly, other previous studies [13, 14, 16, 17, 25, 27] used isolated (single joint), laboratory-based measures of thigh strength. In contrast, we used a portable leg/back dynamometer which is unable to isolate the knee extensor muscle group when testing leg strength. Thus the results obtained from our measures of knee extension strength includes the contribution of other muscle groups such as the hip extensors and plantar flexors and this may explain why we were unable to find a significant difference in relative or absolute thigh isometric muscle strength.

Another major finding of the present study was that there was no significant difference found between the relative leg power of Masters road cyclists and sedentary, age and body mass-matched controls. Most of the previous research comparing performance measures in Masters endurance athletes and sedentary older adults has concentrated on the measurement of both thigh muscle cross-sectional area and muscular strength [14, 16, 26] with only one study comparing muscle power between Masters athletes and sedentary, age and body mass-matched controls.[27] Sundstrup *et al.*[28] investigated elderly men (N.=*15,* 69.6±1.5 years) exposed to lifelong football training and observed a significantly greater rate of force development than sedentary, age and body mass-matched controls. In addition to these findings, other researchers [29, 30] have suggested vigorous exercise into older age may prevent motor unit denervation. For example, Power *et al.*[29] compared the number of motor units in Masters endurance runners (N.=9, 65.0±1.0 years) with age-matched, sedentary older adults. The researchers concluded that Masters runners had significantly more motor units in trained lower limbs than the age-matched sedentary controls. However, the results of the current study suggest endurance cycling does not influence leg power. It may be that endurance cycling training does not regularly involve rapid, explosive muscular contractions necessary for the stimulation of fast twitch motor units, and thus may not provide high enough stimulation for high threshold type II motor units necessary for maintenance of muscular power.[31] This maintenance of muscular power with increasing age in Masters road cyclists has important health implications as it is well documented the age-related loss of muscular power is a risk factor for the loss of mobility, independence and quality of life.[31-33]

We acknowledge several limitations to the current study. Firstly, we only estimated thigh muscle volume using the valid and reliable method by Chen *et al.*[20] Direct measurement of muscle mass or muscle cross-sectional area using magnetic resonance imaging or computer tomography may have revealed different findings. The use of the Chen *et al.*[20] equation relies on limited anthropometric measurements (height, mass, age and thigh circumference) and thus is of high value for use in the clinical or field setting. Thus, despite being a validated measure of thigh muscle volume in sedentary older individuals, the present results may not be as accurate as the more sensitive measures of thigh muscle cross-sectional area. Furthermore, this equation has only been validated in sedentary, older adults, not Masters athletes and does not differentiate between fat mass and lean muscle mass. However in the absence of laboratory equipment and use in the field, the Chen *et al.*[20] method allowed for comparison of thigh muscle volume between the Masters road cyclists and sedentary, age and body mass-matched groups in the present study. A second limitation of our study was it was cross-sectional in nature. Thus, we cannot make inferences on longitudinal, age-related changes in any variable of the Masters athletes and sedentary controls. Finally, we acknowledge the relatively small sample size used in the current study.

Notwithstanding these limitations, the importance of the current study includes the use of field-based measures that can be replicated by practitioners such as strength and conditioning coaches and exercise professionals who commonly work with Masters athletes and sedentary, older adults in the field. Secondly, unlike previous studies, we controlled for the inclusion of subjects who undertake strength training, thus reducing the likelihood that differences in thigh muscle strength and power that could be attributed to resistance training, rather than endurance training alone.

Conclusions

The present findings suggest Masters road cyclists do not possess superior absolute or relative isometric strength, leg power and thigh muscle volume compared to sedentary aged-matched controls. Thus, it appears that endurance cycling training alone does not prevent age-related declines in isometric knee strength, leg power or muscle mass commonly observed in sedentary aged populations.

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