Bicycling Exercise Helps Maintain a Youthful Metabolic Cost of Walking in Older Adults

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The decline of walking performance is a key determinant of morbidity among older adults. Healthy older adults have been shown to have a 15–20% lower walking economy compared with young adults. However, older adults who run for exercise have a higher walking economy compared with older adults who walk for exercise. Yet, it remains unclear if other aerobic exercises yield similar improvements on walking economy. The purpose of this study was to determine if regular bicycling exercise affects walking economy in older adults. We measured metabolic rate while 33 older adult “bicyclists” or “walkers” and 16 young adults walked on a level treadmill at four speeds between (0.75–1.75 m/s). Across the range of speeds, older bicyclists had a 9–17% greater walking economy compared with older walkers ($p = .009$). In conclusion, bicycling exercise mitigates the age-related deterioration of walking economy, whereas walking for exercise has a minimal effect on improving walking economy.

Keywords: aging, cycling, walking economy

Impaired walking performance is a key determinant of morbidity among older adults (Studenski et al., 2011). Around the age of 65 years, a decline in walking performance begins to occur. A subtle but noticeable impairment that has been observed is an increased metabolic cost of walking (lower economy) in older adults (Mian, Thom, Ardigò, Narici, & Minetti, 2006). Healthy older adults have been shown to have a 15–20% greater metabolic cost during walking, across a range of speeds in comparison with young adults (Martin, Rothstein, & Larish, 1992). Approximately 20% of U.S. citizens will be over the age of 65 by the year 2030. As the percentage of adults over the age of 65 continues to grow, the obligation for mitigating age-related deteriorations in mobility will continue to become a key element of preventative health care. However, age alone is a less accurate predictor of mortality than overall health and fitness (FitzGerald et al., 2004; Mitnitski, Graham, Mogilner, & Rockwood, 2002). Ortega, Beck, Roby, Turney, and Kram (2014) showed that older adults who consistently run for exercise have a considerably lower metabolic cost of walking relative to average healthy older adults. Their findings might suggest that consistent running can reduce early onset of fatigue during walking and improve functional independence later in life (Malatesta et al., 2004). Interestingly, the same study showed that older adults who walk for exercise do not yield similar improvements in walking performance. While other studies that implemented vigorous walking interventions showed a reduction in the metabolic cost of walking, contrarily, less vigorous exercise interventions did not yield improvements in walking energetics (Malatesta, Simar, Saad, Préfaut, & Caillaud, 2010; Mian et al., 2007; Thomas, Vito, & Macaluso, 2007). These differences in finding may be due to the intensity of the exercises prescribed; vigorous aerobic exercise may improve walking economy more than other forms of exercise (Ortega et al., 2014). Yet, it remains unclear if other forms of aerobic exercises have a similar effect as running on the metabolic cost of walking in older adults.

Walking is an effective and essential human motor task, necessary for activities of daily living. While walking, over 200 muscles generate forces by consuming metabolic energy to perform the mechanical work, support the weight of the body, laterally stabilize the body, and swing the leg forward (Gottschall & Kram, 2005; Ortega & Farley, 2005, 2007; Ortega, Fehlmann, & Farley, 2008). These are considered the four main biomechanical determinants of the metabolic cost of walking (Cavagna & Franzetti, 1986). Researchers that have looked at age-related biomechanical differences of walking found that older adults are performing nearly equal or even less mechanical work as young adults (Mian et al., 2006; Ortega & Farley, 2007) and have a similar ability to conserve mechanical energy via an inverted pendulum exchange of kinetic and potential energy.

Even though older adults may perform a similar amount of mechanical work as young adults, prior research suggest that older adults including healthy older walkers perform that work using a lower muscular efficiency (Ortega & Farley, 2007, 2015). In contrast, older runners have been shown to consume less metabolic energy for walking but have similar biomechanics as older walkers (Ortega et al., 2014). These studies suggest that the improvements in walking economy (lower metabolic cost) associated with running exercise are likely due, not to changes in walking biomechanics, but to other factors that contribute to the metabolic cost of walking, such as impaired muscular efficiency (Hortobágyi, Finch, Solnik, Rider, & DeVita, 2011; Peterson & Martin, 2010). Research from Conley, Coen, and others support this hypothesis. Specifically, mitochondrial coupling efficiency, a component of muscular efficiency, has been shown to become less efficient with normal aging (Conley, Jubrias, Cress, & Esselman, 2013b) but can be maintained or partially maintained in older adults who participate in vigorous exercise (Broskey et al., 2015; Coen et al., 2012; Conley, Jubrias, Cress, & Esselman, 2013a).

Although previous research suggests running can mitigate the age-related decline in walking economy, alternative aerobic exercises that can be performed at a high aerobic exercise intensity, such as bicycling, may elicit a similar metabolic response with less mechanical joint loads and risk of orthopedic injury. Because bicycling is a low-impact activity, it may be a safer alternative

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to running while offering the same benefit of improving walking economy (Ericson & Nisell, 1987). It is worth noting that older bicyclists have been shown to have a lower metabolic cost of cycling compared with untrained young adults and older sedentary adults (Hopker et al., 2013; Peiffer, Abbiss, Chapman, Laursen, & Parker, 2008; Sacchetti, Lenti, Di Palumbo, & De Vito, 2010). These studies suggest that participation in regular bicycling exercise may provide a similar metabolic stimulus as running exercise, in that it may help to prevent normal age-related declines in muscular efficiency.

The purpose of this study is to determine if regular bicycling exercise affects walking metabolic costs in older adults. We hypothesize that older bicyclists will have a lower metabolic cost of walking compared with older walkers and a similar metabolic cost of walking to healthy young adults.

Materials and Methods

Subjects

Forty-nine healthy adults participated; including 16 young adults (nine males and seven females), 16 healthy older adults who walk for exercise (seven males and nine females) and 17 healthy older adults who bicycle for exercise (13 males and four females; Table 1). All of the older adults were a minimum of 65 years of age with no self-reported walking impairments. Young adults were 18–35 years of age with no self-reported walking impairments. All subjects were free of major neurological, cardiovascular, and orthopedic problems. Older bicyclists and older walkers self-reported their average intensities and durations of their past 6-month respected exercise routines, based on American College of Sports Medicine (ACSM) guideline definitions of relative intensity (Ainsworth et al., 1993; American College of Sports Medicine, 2017; Piercy et al., 2018). All subjects gave written informed consent prior to participation of the study. The Humboldt State University Institutional Review Board approved this protocol prior to any subject participation.

Protocol

Subjects completed two sessions. Prior to the first session, subjects underwent a brief medical and exercise screening. For all qualified participants, the first session consisted of informed consent, a more in-depth medical screening based on previously stated inclusion criteria and familiarization to treadmill walking for 6 min at four speeds (0.75, 1.25, 1.60, and 1.75 m/s). This 24-min familiarization period exceeded the recommended minimum treadmill habituation time of 10 min (Van de Putte, Hagemester, St-Onge, Parent, & de Guise, 2006; Wall & Charteris, 1981).

Following a minimum of 3 days rest and at the start of the second session, we measured each participant's anthropometrics (height, mass, and leg length). Height was measured in centimeters using a stadiometer, mass was measured in kilograms using a digital scale, and leg length was measured in centimeters from anterior superior iliac spine (ASIS) to medial malleolus using a Gulick tape measurer and then normalized to body height (%body height). We then measured resting metabolic rate and heart rate as each subject stood quietly for 6 min. For the experimental trials, participants walked at each of the four speeds (0.75, 1.25, 1.60, and 1.75 m/s) separated by at least 5 min of rest. Within the last 3 min of each 6-min trial, we collected data to determine stride frequency/length, heart rate, and the rate of O_2 consumption and CO_2 production.

Measures

Metabolic cost. Using open circuit expired gas analysis system, we measured oxygen consumption $\dot{V}O_2$ (ml O_2 /min) and carbon dioxide expiration $\dot{V}CO_2$ (ml CO_2 /min). To make sure oxidative metabolism was the main pathway, we measured the collected data over a 2-min period during the last 3 min of each trial when $\dot{V}O_2$, $\dot{V}CO_2$, and respiratory exchange rate maintained steady state (Ferretti, Fagoni, Taboni, Bruseghini, & Vinetti, 2017; Whipp, Ward, Lamarra, Davis, & Wasserman, 1982; Whipp & Wasserman, 1972) and respiratory exchange rate stayed below 1.0. Using a standard equation (Brockway, 1987), we calculated the rate of metabolic energy consumption as

$$\text{Gross metabolic power (W/kg)} = 16.58 \dot{V}O_2 + 4.51 \dot{V}CO_2. \quad (1)$$

We subtracted resting standing metabolic power from exercise gross metabolic power to determine net metabolic power (in watts per kilogram), and then calculated net cost of transport (CoT) by taking net metabolic power and dividing by the speed to determine energy cost per meter traveled (in joules per kilogram per meter). We then used quadratic least-squared regression to identify the curve of best fit for the CoT versus speed relation and to identify the speed at which CoT was minimized for each group.

Heart rate. A PolarTM heart rate monitor (H10; Polar Electro Inc., Bethpage, NY) was placed according to manufacturer's instruction, "below chest muscles," approximately 1-cm inferior to the subjects' sternum. Heart rate was recorded in the last minute of each exercise, as well as during standing metabolic collection. We estimated maximal heart rate ($HR_{\max}$) using the formula (Tanaka, Monahan, & Seals, 2001):

$$HR_{\max} = 208 - (0.7 \times \text{age}), \quad (2)$$

Table 1 Subject Characteristics

Demographics	Young adults	Older walkers	Older bicyclists
Age (years)	23.6 ± 2.0	70.8 ± 4.9	68.4 ± 2.9
Height (m)	1.69 ± 0.09	1.62 ± 0.09	1.73 ± 0.07*
Leg length (%body height)	0.52 ± 0.02	0.54 ± 0.02	0.54 ± 0.02
Body mass (kg)	71.4 ± 15.9	69.1 ± 11.4	74.0 ± 9.0
Exercise duration (min/week)		155 ± 46	156 ± 36
Exercise intensity (a.u.)		1.8 ± 0.4	2.4 ± 0.5

Note. Values are presented as mean ± SD. a.u. = arbitrary units.

*Significant differences between older bicyclists and older walkers.

and then determined the percentage of HR_{max} at each walking speed.

Stride length and frequency. In the last minute at each walking speed, we measured the time to complete 20 strides in order to determine stride frequency (in Hertz). Using the treadmill speed, we measured stride frequency and subjects' leg length, we calculated normalized stride length (arbitrary units, a.u.) using the formula:

$$\text{Normalized stride length (a.u.)} = \frac{\text{Speed (m/s)}}{\text{Stride frequency (Hz)}} / [\text{Leg length (m)}]. \quad (3)$$

Statistical analyses. We used two-way mixed repeated-measure analysis of variance ($p < .05$) to control for body height while determining the effect groups on dependent variables. When an analysis of variance was significant, we used post hoc analysis to determine individual group differences (older bicyclists vs. older walkers vs. young adults). When a significant group by speed interaction effect was found, we performed independent-samples t tests with Bonferroni correction to determine at which speed(s) the differences occurred. We also performed paired two-tailed t tests to compare $\dot{V}O_2$, $\dot{V}CO_2$, and respiratory exchange rate from minutes 3.0 to 4.0 to respective variables from minutes 5.0 to 6.0 to ensure participants achieved a metabolic steady state. We performed all statistical analysis using SPSS (version 23.0; SPSS Inc., Chicago, IL).

Results

Overall, the three groups did not differ in mass (in kilograms) or leg length (in arbitrary units) ($p = .522$ and $p = .123$, respectively; Table 1). While young adults had similar body height as older walkers and older bicyclists ($p = .336$ and $p = .383$, respectively), older bicyclists were an average ~9-cm taller in body height as older walkers ($p = .008$). All three groups had a similar body mass ($p = .522$). Both older walkers and older bicyclists reported that they participated in a similar amount of walking exercise ($\sim 155 \pm 46$ min/week) and bicycling exercise per week ($\sim 156 \pm 36$ min/week), respectively ($p = .940$; Table 1). However, older bicyclists self-reported exercising at a 28.4% greater intensity than older walkers ($p < .0005$; Table 1).

While controlling for body height as a covariate, net metabolic cost differed between groups across all walking speeds, $F(2, 46) = 6.775$, $p = .003$ (Figure 1). In support of our hypothesis, older bicyclists had a 9–17% lower net metabolic cost of walking compared with older walkers across the range of level walking speeds ($p = .009$). Moreover, young adults and older bicyclists consumed an almost identical amount of metabolic energy for walking across the range of speeds ($p > .999$). Because there was a significant group by speed interaction effect on net metabolic cost, $F(2, 46) = 6.00$, $p = .024$ (Figure 1), we investigated differences in net metabolic cost between groups at each speed. In agreement with previous studies, pairwise comparisons identified that older walkers consumed metabolic energy for walking at an 11–24% faster rate compared with young adults across speeds ($p = .006$). Figure 1 shows differences between groups at individual speeds. For all groups, net metabolic cost increased across the range of walking speeds. Despite these group differences in walking economy, there

Figure 1 — Mean (SE) net metabolic cost as a function of walking speed in young adults ($\diamond$), older walkers ($\bullet$), and older bicyclists ($\square$). *Significant differences between older bicyclists and older walkers. †Significant difference between older bicyclists and young adults. There was a significant difference at all speeds, between young adults and older walkers ($p < .05$).

Figure 2 — Mean (SE) net metabolic cost of transport as a function of walking speed in young adults ($\diamond$), older walkers ($\bullet$), and older bicyclists ($\square$) (metabolic energy per kilogram of body weight to travel a given distance). *Significant differences between older bicyclists and older walkers. †Significant difference between older bicyclists and young adults. There was a significant difference at all speeds, between young adults and older walkers ($p < .05$).

were no group differences in standing resting metabolic cost, $F(2, 46) = .333$, $p = .72$.

When normalizing the metabolic cost of walking to distance traveled as CoT (in joules per kilogram per meter), all groups presented a quadratic U-shape relation between net CoT and walking speed (Figure 2). Although the measured CoT was lowest at the intermediate walking speed of 1.25 m/s for all groups, the results of our quadratic regression suggest that CoT is optimized at speeds slightly less than 1.25 m/s for young adults (1.17 m/s) but at speeds slightly greater than 1.25 m/s for older walkers (1.30 m/s)

Table 2 Resting Heart Rate, Estimated Maximum Heart Rate, and Percentage of Estimated Maximum Heart Rate Across the Range of Walking Speeds

Variable	Young adults	Older walkers	Older bicyclists
Resting heart rate (bpm)	86 ± 14	80 ± 12	71 ± 13****
Estimated max heart rate (bpm)	192 ± 1	159 ± 3	160 ± 2
Heart rate (% of maximum)			
0.75 m/s	46.0 ± 0.1	57.9 ± 0.1**	46.9 ± 0.1*
1.25 m/s	49.7 ± 0.1	63.9 ± 0.1**	51.0 ± 0.1*
1.60 m/s	56.4 ± 0.1	74.2 ± 0.1**	58.0 ± 0.1*
1.75 m/s	61.3 ± 0.1	81.0 ± 0.1**	64.9 ± 0.1*

Note. Values are presented as mean ± SD. bpm = beats per minute.

*Significant differences between older bicyclists and older walkers. **Significant difference between older walkers and young adults. ***Significant difference between young adults and older bicyclists ($p < .05$). There was no significant difference at all walking speeds, between young adults and older bicyclists ($p > .05$).

Table 3 Mean Values for Normalized Stride Length ± SD

Speed (m/s)	Stride length (a.u.)		
	Young adults	Older walkers	Older bicyclists
0.75	1.15 ± 0.08	1.13 ± 0.13	1.05 ± 0.10
1.25	1.55 ± 0.08	1.51 ± 0.11	1.51 ± 0.10
1.60	1.80 ± 0.09	1.73 ± 0.15	1.75 ± 0.11
1.75	1.87 ± 0.10	1.81 ± 0.11	1.84 ± 0.11

Note. There was no significant difference for normalized stride length between the three groups across the range of speeds. a.u. = arbitrary units.

and older bicyclists (1.28 m/s) (Figure 2). There were significant differences in CoT between groups across all walking speeds, $F(2, 46) = 7.336$, $p = .005$ (Figure 2). Similar to the results of net metabolic power, we observed no significant difference in CoT across the range of walking speeds between young adults and older bicyclists ($p = .807$). However, young adults had an 18% and older bicyclists 15% lower CoT across the range of speeds as compared with older walkers ($p = .005$ and $p = .012$, respectively). Differences between groups at individual speeds are shown in Figure 2.

Percentage of estimated HR_{max} followed a similar trend as walking economy and was significantly different between groups across all walking speeds $F(2, 46) = 15.827$, $p < .001$ (Table 2). Across the range of walking speeds, young adults and older bicyclists used a similar percentage of estimated HR_{max} ($p > .999$). However, older walkers were at a 20–23% higher percentage of estimated HR_{max} across the range of speeds compared with the young adults and older bicyclists ($p < .001$).

Despite all groups having a similar rate of metabolic energy consumption at rest, we observed significant differences between groups for standing resting heart rate, $F(2, 46) = 5.665$, $p = .006$ (Table 3). At rest, older bicyclists had a 7–18% lower heart rate than the older walkers and the young adults ($p = .024$ and $p = .003$, respectively). There was no statistical difference between older walkers and young adults resting heart rates ($p = .294$).

In this study, we also measured spatiotemporal parameters (stride length and frequency). We observed that when normalized to leg length, there was no significant difference in stride length between the three groups across the range of speeds, $F(2, 46) = 1.646$, $p = .204$ (Table 3).

Discussion

This study investigated the effect of bicycling and walking for exercise on the metabolic cost of walking in older adults. In support of our initial hypothesis, older bicyclists consumed less metabolic energy for walking compared with older walkers and a similar amount of metabolic energy as young adults. Furthermore, older walkers consumed an average of 16% more metabolic energy for walking compared with young adults. Although the older bicyclist consumed less metabolic energy for walking than the older walkers, the two groups used similar stride frequencies and stride lengths at each of the tested speeds.

One possible explanation for the improved walking economy observed in older bicyclist may be improved muscle efficiency associated with increased participation in more vigorous aerobic activity. Aging is typically associated with reduced muscle efficiency (Amara et al., 2007; Conley et al., 2013a; Mian et al., 2006). More specifically, impaired mitochondrial function associated with the uncoupling of oxidative phosphorylation (less ATP production per O_2 uptake) reduces muscle efficiency and increases the energetic cost of muscle activation (Amara et al., 2007). While a reduction in muscular efficiency associated with mitochondrial uncoupling may increase the cost of walking in older adults, recent evidence suggests that vigorous aerobic exercise may help repair mitochondrial function in older adults by increasing mitochondrial protein turnover within the muscle cell (Conley et al., 2013b; Conley, Jubrias, & Esselman, 2000; Jubrias, Esselman, Price, Cress, & Conley, 2001; Mogensen, Bagger, Pedersen, Fernström, & Sahlin, 2006), thus, improving muscular efficiency. Interestingly, evidence suggests that as little as 6 months of vigorous aerobic exercise training may improve mitochondrial coupling and muscular efficiency in older adults (Conley et al., 2013b). While both groups of older adults in the present study reported that they participated in a similar amount of exercise each week, older bicyclists reported participating in ~28% more intense (vigorous) aerobic exercise compared with older walkers. Possibly, the greater intensity of aerobic cycling exercise mitigated the decrease in muscular efficiency typically associated with age. This hypothesis was substantiated by Ortega et al.'s (2014) findings that older adults who participate in more vigorous running exercise consumed ~15% less metabolic energy for walking compared with older walkers.

Because the metabolic cost of walking is heavily dependent on the external and internal mechanic work required for walking

(Donelan, Kram, & Kuo, 2002; Minetti, Capelli, Zamparo, & Saibene, 1995), it is possible that the reduced cost of walking in older bicyclists is related to using more efficient biomechanics. Prior research has shown that the characteristic U-shaped relation of walking speed and CoT is closely tied to changes in internal and external mechanical work associated with increasing speed (Minetti & Saibene, 1992; Minetti et al., 1995). In the present study, all groups displayed a similar U-shaped relation between CoT and speed and used similar stride frequency and stride length across the range of speeds. Although suggestive, our results do not definitively show that older walkers performed the same amount of mechanical work as young adults or older bicyclists. Nonetheless, these results are in agreement with prior research that show that healthy older walkers, despite having a greater cost of walking, maintain similar walking biomechanics as healthy young adults and more energetically efficient older runners (Franz & Kram, 2013; Ortega et al., 2014; Ortega & Farley, 2007). More specifically, prior studies have shown that, healthy older walkers perform a similar amount of external mechanical work (Franz & Kram, 2013; Ortega & Farley, 2007) and use a similar inverted pendulum mechanics as young adults (Ortega & Farley, 2007). Similarly, older runners that have a 7–10% better walking economy than older walkers have been shown to use similar stride frequencies and exert similar ground reaction forces as older walkers across a range of speeds (Ortega et al., 2014). Despite the compelling evidence of prior research, future studies of the effect of age and bicycling exercise on walking biomechanics and economy are warranted.

When the energetic cost of a task increases, the heart must pump more oxygenated rich blood to the muscle to meet muscle mitochondrial oxygen requirements (Green, 2011). In agreement with our metabolic results, to reach these higher energetic needs, older walkers estimated HR_{max} percentages were higher across the range of speeds compared with young adults and older bicyclists. To quantify a correlation between heart rate and walking economy a larger sample size must be assessed. However, the results showing that older walkers use a higher percentage of estimated HR_{max} may provide an alternative low-tech method for future investigators, trainers, and therapists to estimate walking economy in older adults. Although using estimated HR_{max} presents a limitation to our study, we used a prediction equation that has a stronger correlation to actual HR values than other traditional equations (Tanaka et al., 2001).

What is clear from our findings and those of prior research, is that aging muscles without moderate to vigorous aerobic exercise may not be able to properly maintain efficiency, leading to higher metabolic costs of walking (Martin et al., 1992), and a possible progression of further physiological declines (Carmeli, Coleman, & Reznick, 2002). Unfortunately, when older adults use more energy for walking, they may be more easily fatigued and less inclined to walk as much or participate in other physical activities (Malatesta et al., 2004). The increased metabolic cost of walking may indirectly contribute to an increased risk of degenerative diseases and declines in activities of daily living that typically occur in the last 15% of life (Studenski et al., 2011). The results of this study as well as prior studies, propose that participation in vigorous aerobic exercise, such as running or bicycling, may help improve or maintain muscle efficiency and walking economy in older adults. While running is a wonderful exercise for maintaining or even improving cardiovascular, bone, and muscle health (Kusy & Zielinski, 2015), many older adults with existing orthopedic conditions, such as joint arthritis, may not be able to participate in running without pain, due to the large forces experienced by the

body (Buist et al., 2010; Dugan & Bhat, 2005). However, many older adults may be able to achieve similar health benefits from less impactful, yet vigorous bicycling exercise (Ericson & Nisell, 1987). Our results suggest that if performed consistently, bicycling can improve walking economy, thus likely improving or retaining mobility and the ability to achieve desired activities of daily living. Regardless of which aerobic exercise a person chooses, the body of literature which this study contributes to advises older adults to stay active throughout life in order to help maintain health and mobility.

An important limitation of this study is that exercise participation was self-reported and questions regarding exercise participation (duration and intensity) were focused on their primary mode of exercise, that is walking or bicycling. We did not exclude any subject if they participated in additional activities such as strength training. Nonetheless, we recruited “older walkers” and “older bicyclists,” thus delimiting older participants in our study to those who self-reported walking or bicycling as their main form of aerobic exercise, respectively. Another limitation of this study is that subject’s average exercise intensity was self-reported on a scale of 1 to 3 (1 = *low*, 2 = *moderate*, and 3 = *vigorous*) based on the definition of exercise intensity according to The Centers for Disease Control and Prevention (CDC) and ACSM guidelines. Although we observed clear physiological differences in heart rate and metabolic cost during walking between the older walkers and older bicyclists groups, future research investigating the effects of aerobic exercise on walking energetics or muscle efficiency that more specifically identifies exercise volume and intensity of participants or prescribes specific levels of exercise intensity is warranted.

To better understand the potential mechanisms for the observed effect of aerobic exercise on walking energetics, future research should also explore the relation between mitochondrial coupling efficiency and the metabolic cost of walking in older adults, who are sedentary and aerobically trained. Although we identified that bicycling for exercise is more beneficial to the metabolic cost of walking than walking itself; from a practitioner’s standpoint, it would be useful to know more precisely what intensity and frequencies of exercise are needed to benefit the metabolic cost of walking in older adults. It may be that swimming and more vigorous walking exercises such as hiking or walking interval training (Malatesta et al., 2010; Thomas et al., 2007), can also be prescribed to older adults who want to lower their metabolic cost of walking and maintain a healthy lifestyle.

Conclusion

In conclusion, regular moderate to vigorous bicycling exercise maintains a more youthful metabolic cost of walking in older adults. However, the normal age-related decline in walking economy still exists in older walkers. It is possible that factors that affect metabolic energy consumption, such as muscular efficiency, may be improved by participation in vigorous aerobic exercise and therefore, explain the improved walking economy observed in older bicyclists.

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