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RESPIRATORY SYSTEM

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Aerobic determinants of the decline in preferred walking speed in healthy, active 65- and 80-year-olds

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Abstract The preferred walking speed is a common measure of mobility that declines with age and has been related to maximal oxygen uptake ($\dot{V}O_{2,max}$). The present study determined whether this decline is associated with a higher percentage of the ventilatory threshold in older adults walking at their preferred speed. We compared the preferred walking speed and $\dot{V}O_2$ at this speed in relation to both $\dot{V}O_{2,max}$ and $\dot{V}O_2$ corresponding to the ventilatory threshold (T_{VE}) in healthy, physically active sexagenarians (G65, n=10) and octogenarians (G80, n=10) walking on a treadmill. The preferred walking speed was lower in G80 (1.16±0.09 m·s^{-1}) than in G65 (1.38±0.09 m·s^{-1}; P<0.001). Energy expenditure and the energy cost of walking at the preferred walking speed were not significantly different between the two groups. G80 subjects exhibited significantly higher fractions of $\dot{V}O_{2,max}$ (60.8±8.0%) and T_{VE} (74.2±7.9%) at the preferred walking speed than G65 (42.9±5.0 and 53.2 ±5.7% respectively; P<0.001). Multiple regression analysis showed that the fraction of T_{VE} was the main determinant, with a small contribution of height, in the decline in the preferred walking speed in healthy and active elderly subjects (R^2=64%; P<0.001). These findings show that with age, walking at the preferred speed requires a higher fraction of T_{VE}. This increase in the relative physiological effort at preferred walking speed could explain the reduction in this gait speed in healthy older subjects.

Keywords Elderly · Gait · Maximal oxygen uptake · Ventilatory threshold

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Introduction

Aerobic fitness is one of the major contributors to maintaining independent living in the elderly [18, 21]. The two most reliable parameters of aerobic fitness are maximal oxygen uptake ($\dot{V}O_{2,max}$) and the ventilatory threshold (T_{VE}), reflecting maximal and submaximal aerobic function, respectively [27]. T_{VE} is an effort-independent physiological marker of the ability to perform submaximal, prolonged activity. Working at intensities above T_{VE} results in metabolic acidosis, hyperventilation and an inability to sustain performance [34]. T_{VE} declines with age, but more slowly than $\dot{V}O_{2,max}$ (i.e. there is a progressively smaller difference between T_{VE} and $\dot{V}O_{2,max}$) [26, 27, 31]. This slower decline in T_{VE} may reflect a preserved metabolic function of muscle oxidation [27]. In elderly subjects, T_{VE} appears to be maintained by normal everyday activities and may define endurance capacity more closely in these subjects [13, 27, 39].

Another common performance measure of mobility in elderly subjects is the preferred walking speed, also called comfortable gait speed [9]. This gait speed is an indicator of general physical health and is associated with independent living in older adults [1]. The preferred walking speed declines with age, with the rate of decline increasing after the critical age of 62 years [19]. Although the decline is age-related [4, 5, 25], maximal aerobic power has been shown to be a more important determinant of walking speed [9, 12].

Despite the slower preferred walking speed in elderly subjects, the energy expenditure at this speed is similar to that in younger subjects and, consequently, the energy cost of walking (C_w), i.e. the energy expenditure per unit distance, is increased [38]. This suggests that older adults moving at their preferred walking speed are at a higher percentage of both $\dot{V}O_{2,max}$ and T_{VE} and thus may be limited in the performance of customary activities by earlier onset of fatigue. The reduced aerobic function and decreased gait efficiency may explain why the elderly prefer to walk more slowly. Although T_{VE} is the parameter of aerobic function that defines endurance capacity and is closely related to the intensity of daily living activities [13, 34, 39], the relationship between preferred walking speed and T_{VE} has never been investigated in healthy elderly subjects. We hypothesized that the decline in preferred walking speed observed in older adults is associated with a higher T_{VE} at this gait speed. To test this, we measured preferred treadmill walking speed, the energy expenditure at this gait speed, and $\dot{V}O_{2,max}$ and T_{VE} in healthy elderly subjects aged 65 or 80 years.

Materials and methods

Subjects

Two groups of subjects participated in the study: G65 (n=10, 66.9 ±2.6 years, range 62–70 years) and G80 (n=10, 82.8±2.6 years, range 79–87 years). The subjects were living independently and were recruited from associations that offer different activities for the elderly, including regular country walks, gymnastics and cultural activities. A neurologist, who was aware of the study objectives, screened each older subject extensively with a complete medical history, physical examination and the Mini Mental State Examination [14]. A score below 26 on this test was an exclusion criterion, as diminished function may result in difficulty in adhering to instructions. All subjects were ambulatory and free from any limiting orthopaedic, neurological, cardiovascular or respiratory problems that might otherwise affect economy and gait mechanics. The protocol and consent form were approved by the local ethics committee and all study subjects provided informed written consent.

Experimental Design

The subjects completed two test sessions. In the first session, a physician took the medical histories and performed physical examinations, and the subjects were then introduced to the experimental procedures. After 30 min treadmill accommodation across several walking speeds (0.67, 0.89, 1.11, 1.33, 1.56 m s^{-1}) [23, 24] and a brief rest period, the preferred walking speed of each subject was determined according to the procedure proposed by Martin et al. [24]. One week later, the subjects returned for the experimental session. After 3 min of resting measurements in the standing position, the subjects walked for 5 min at the preferred walking speed on the treadmill at 0% grade; this was referred to as submaximal exercise. They then completed a maximal incremental exercise test on the treadmill to determine individual parameters of aerobic function ($\dot{V}O_{2,max}$ and T_{VE}).

Assessments

Physical activity level

Physical activity level was estimated from a physical activity questionnaire for the elderly [36]. Different scores were used to quantify household activities, sports activities and other physically active leisure time activities, together resulting in a total activity score. The questionnaire provided a method for classifying elderly subjects into categories of high, medium and low physical activity, with cut-off points of 16.5 and 9.4, respectively, as proposed by Voorips et al. [36]. These scores have been shown to be associated positively with repeated 24-h activity recalls, pedometer measurements and test-retest reliability [36].

Preferred walking speed

Subjects began treadmill walking at the lowest familiarization speed (0.67 m s^{-1}), which was then slowly increased until each subject subjectively identified his or her preferred walking speed. This speed was maintained for 1 min and was then modified slightly. The subject was again asked to evaluate the speed and adjustments were made according to the subject's directives. This procedure was repeated starting with the highest familiarization speed (1.56 m s^{-1}) and gradually reducing to the preferred speed. The final preferred walking speed was considered to be the mean of the two speeds selected by the subject during both the increasing and decreasing speed trials [23, 24]. During this session and the exercise tests, the subjects were secured continuously by a cross-belt fixed to the handrails such that arm swing was not impeded.

Submaximal exercise test

After 4 min rest without measurement, expired gases were collected and analysed for 3 min in standing position. Subjects were then asked to complete 5 min of level walking at the preferred walking speed. Subjects were allowed to establish their own preferred stride rate combination. All subjects walked on the treadmill (LE 200 CE, Jaeger, Hoechberg, Germany) without using handrail support. During submaximal exercise, $\dot{V}O_2$, CO_2 output ($\dot{V}CO_2$) and ventilation ($\dot{V}_E$) were analysed breath-by-breath using an on-line system (Oxycon Pro, Jaeger) and the calibration was checked before each exercise test. Metabolic data were averaged over 20-s intervals and cardiac activity monitored continuously using a 12-lead electrocardiogram integrated into an on-line system. $\dot{V}O_2$ values from the last 2 min were averaged and normalized to body mass. Data were normalized subsequently with respect to walking speed to produce the desired descriptor of energy cost of walking (C_w), i.e. aerobic demand per unit distance walked [24].

Maximal exercise test

The maximal incremental test on the treadmill was performed at the individually determined preferred walking speed [35]. After a warm-up at preferred walking speed (submaximal exercise), the speed was then held constant and elevation increased progressively every minute until exhaustion. The grade increase was 1–2%, according to subject age and physical activity level (G80: 1–1.5%; G65: 1.5–2%), to ensure that the test lasted 8–12 min [8]. During maximal testing, $\dot{V}O_2$, $\dot{V}CO_2$ and $\dot{V}_E$ were measured continuously and averaged every 20 s, and cardiac activity was monitored continuously. $\dot{V}O_{2,max}$ was considered attained when the subject reported feeling fatigued and one of the following criteria was met: (1) a plateau in $\dot{V}O_2$ concurrent with continuing increase in exercise intensity or (2) respiratory exchange ratio (RER) of greater than 1.0 and the heart rate (HR) within 5 bpm of the age-specific maximal heart rate (HR_{max}=220−age) [27].

T_{VE} was determined as described in the literature using the gas exchange threshold of Beaver et al. [6], which consists of visually determining the inflection point of $\dot{V}CO_2$ with respect to $\dot{V}O_2$ [6]. To support this estimate of T_{VE}, we then used Wasserman's ventilatory method of determining the point at which the $\dot{V}O_2$ respiratory equivalent ($\dot{V}_E/\dot{V}O_2$) increases while the $\dot{V}CO_2$ ventilatory equivalent ($\dot{V}_E/\dot{V}CO_2$) remains stable [37]. Two blinded and independent investigators determined T_{VE}.

$\dot{V}O_{2,max}$ and T_{VE} were compared with the values obtained from the predictive equations of Paterson et al. [27]. This latter provides "normative" cardiorespiratory function data of a random sample of independently living men and women aged 55–86 years.

Fraction of $\dot{V}O_{2,max}$ and fraction of T_{VE}

Fractions of $\dot{V}O_{2,max}$ and T_{VE} represent the rate of $\dot{V}O_2$ at preferred walking speed in relation to $\dot{V}O_{2,max}$ (% $\dot{V}O_{2,max}$) and the $\dot{V}O_2$ corresponding to the T_{VE} (%T_{VE}), respectively.

Statistical analysis

An unpaired *t*-test was used to determine differences in the descriptive characteristics (i.e. height, body mass and physical activity questionnaire score), in maximal and submaximal parameters of aerobic function ($\dot{V}O_2$, $\dot{V}_E$, HR, C_w and the fractions of $\dot{V}O_{2,max}$ and T_{VE}) and in preferred walking speed between the two groups. Predicted and maximal-submaximal values for each group were compared using a paired *t*-test. When the assumption of normality of distribution was violated, a Mann-Whitney *U*-test for non-parametric values was used to compare the two groups and a Wilcoxon test for non-parametric values was used to compare predicted and maximal-submaximal values for each group.

Correlations between physical activity score and relative $\dot{V}O_{2,max}$ and T_{VE} were performed using the Pearson correlation coefficient (*r*). Multiple regression analysis was employed to analyse the effects of age, height, physical activity level, $\dot{V}O_{2,max}$, T_{VE}, fraction of $\dot{V}O_{2,max}$, fraction of T_{VE} and their interactions on the age-related decline in preferred walking speed. $P<0.05$ was regarded as significant in all tests.

Results

Subject characteristics

The anthropometric data of the two groups are reported in Table 1. The G65 subjects were significantly taller than G80 subjects. There was no significant difference in body mass between two groups (P=0.21). A significant effect of age ($P<0.001$) was observed for the physical activity score, which was lower in G80 than in G65 (Table 1). According to the standard previously established [36], G80 and G65 were classified in the medium and high physical activity categories, respectively. Household and leisure-time activity scores did not differ between the groups, although the sport activity score was significantly lower in G80 (4.53±3.54) than in G65 (13.92±4.17) ($P<0.001$). The physical activity score was correlated inversely with age (r=−0.66; P=0.002) and directly with relative $\dot{V}O_{2,max}$ (ml kg^{-1} min^{-1}) (r=0.68; P=0.001) and relative T_{VE} (ml kg^{-1} min^{-1}) (r=0.69; P=0.001).

Maximal exercise test

For all subjects the test lasted 8–12 min and there was no significant difference in mean exercise duration between G80 (9.6±1.9 min) and G65 (11.2±0.9 min; P=0.064). The mean maximal grade was significantly higher in G65 (18.5 ±3.3%) than in G80 (11.0±3.10%; $P<0.001$). $\dot{V}O_{2,max}$, HR_{max} and T_{VE} were significantly higher in G65 than in G80 ($P<0.05$). There was no significant difference in T_{VE}, expressed as a percentage of $\dot{V}O_{2,max}$, between the two groups (P=0.69) (Table 2; Fig. 1). The values of $\dot{V}O_{2,max}$ and T_{VE}, both absolute and relative to body mass, were significantly higher than those from the predictive equations of Paterson et al. [27] ($P<0.05$) (Table 2). In G80, HR_{max} (127.5±24.4 bpm) was significantly lower than the age-specific maximal heart rate (137.2±2.3 bpm; P=0.007). On the other hand, there was no significant difference between these two parameters in G65 (157.2 ±8.9 vs. 153.1±2.6 bpm; P=0.13).

Table 1 Anthropometric characteristics of octogenarian (G80) and sexagenarian (G65) subjects. Means±SD (*M* male, *F* female)

Variable	G80	G65
Gender	9 F, 1 M	5 F, 5 M
Age (years)	82.8±2.6*	66.9±2.6
Height (m)	1.55±0.9*	1.68±0.7
Body mass (kg)	60±13.9	67.6±12.7
Physical activity score	10.61±4.38*	21.94±5.92

*$P<0.05$ vs. G65

Preferred walking speed and submaximal exercise test

Preferred walking speed was lower in G80 than in G65 ($P<0.001$) (Table 3). There were no significant differences in $\dot{V}O_2$, HR or C_w at the preferred walking speed between the two groups ($P>0.05$), although the difference in C_w almost reached significance (P=0.078). The fraction of $\dot{V}O_{2,max}$ and fraction of T_{VE} at preferred walking speed were significantly higher in G80 compared with G65 ($P<0.001$ for both) (Table 3; Fig. 1).

Multiple regression analysis was performed to determine the significant predictors of preferred walking speed. Variables entered into the analysis included: age, height, physical activity level, $\dot{V}O_{2,max}$ (absolute and relative), T_{VE} (absolute and relative), fraction of $\dot{V}O_{2,max}$ and fraction of T_{VE}. These variables correlated independently

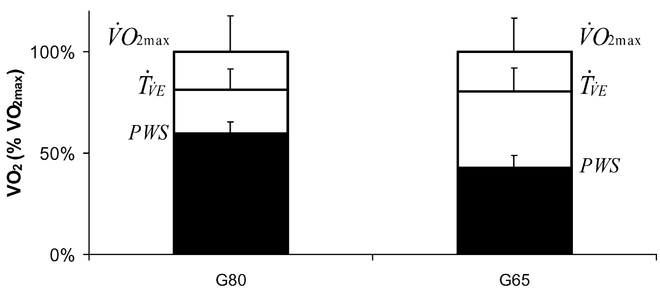

Fig. 1 Oxygen uptake ($\dot{V}O_2$) at ventilatory threshold (T_{VE}) and at preferred walking speed (*PWS*) as a percentage of $\dot{V}O_{2,max}$ in a group of octogenarians (*G80*) and sexagenarians (*G65*)

Table 2 Maximal exercise test. Means±SD ($\dot{V}O_{2,max}$ maximal oxygen uptake, T_{VE} ventilatory threshold)

Variable	G80		G65	
	Measured values	Predicted values[a]	Measured values	Predicted values[a]
$\dot{V}O_{2,max}$(ml·min^{-1})	1386.8±291.4*†	988.7±169.4	2396.5±716.5†	1554.9±327.6
$\dot{V}O_{2,max}$(ml·kg^{-1} min^{-1})	23.12±4.11*†	16.22±1.35	34.94±5.77†	21.67±1.68
T_{VE} (ml O_2·min^{-1})	1128±205.4*†	966.4±88.9	1916±520.5†	1264.4±179.9
T_{VE} (mlO_2·kg^{-1}·min^{-1})	18.76±2.44*†	14.66±0.76	28.07±4.02†	17.58±0.81
T_{VE} (% $\dot{V}O_{2,max}$)	81.84±6.6†	90.59±2.5	80.75±5.2	81.34±2.6

[a]Calculated according to the equations of Paterson et al. [27]
*P<0.05 vs. G65
†P<0.05 vs. respective predicted value

Table 3 Submaximal exercise test. Means±SD (HR_{max} maximal heart rate, C_w energy cost of walking, *fraction of* $\dot{V}O_{2,max}$ $\dot{V}O_2$ at preferred walking speed related to $\dot{V}O_{2,max}$. *fraction of* T_{VE} $\dot{V}O_2$ at preferred walking speed related to $\dot{V}O_2$ at T_{VE})

Variable	G80	G65
Preferred walking speed (m·s^{-1})	1.16±0.09*	1.38±0.09
$\dot{V}O_2$ (ml·min^{-1})	837.8±176.9	1023.1±319.7
$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	13.81±1.35	14.86±2.27
C_w (ml·kg^{-1}·m^{-1})	0.200±0.03	0.179±0.02
HR (bpm)	93.9±14.5	94.6±16.6
Fraction of $\dot{V}O_{2,max}$ (%)	60.75±8.01*	42.92±5.02
Fraction of T_{VE} (%)	74.22±7.89*	53.22±5.71

*P<0.05 vs. G65

Table 4 Correlation coefficients (simple correlation analysis) between preferred walking speed and variables

Variables	Preferred walking speed
Age	−0.73*
Height	0.72*
Physical activity level	0.57*
$\dot{V}O_{2,max}$ (ml·min^{-1})	0.70*
$\dot{V}O_{2,max}$ (ml·kg^{-1}·min^{-1})	0.68*
T_{VE} (ml O_2·min^{-1})	0.73*
T_{VE} (ml O_2·kg^{-1}·min^{-1})	0.73*
Fraction of $\dot{V}O_{2,max}$ (%)	−0.70*
Fraction of T_{VE} (%)	−0.73*

* P<0.05

and significantly with the preferred walking speed (Table 4 and Fig. 2). Multiple regression analysis [R=0.80; standard error of estimate (SEE)=±0.09; P<0.001] showed that 64% of the variance in the preferred walking speed, (expressed in metres/second), was accounted for by the fraction of T_{VE} (48%; beta coefficient=−0.45; P=0.011) and height (16%; beta coefficient=0.43; P=0.014).

Discussion

The main findings of the present study were that octogenarians exhibited a lower preferred walking speed and a greater fraction of T_{VE} at this speed of walking than sexagenarians. Moreover, the fraction of T_{VE} was identified as the primary determinant of the decline in preferred walking speed in our healthy and active elderly subjects.

The preferred walking speed was 16% lower in G80 with respect to G65. Previous reports have shown it to decline by about 7–8% across the four decades between 20 and 60 years [5, 19]. Beyond 60 years, the rate of decline increases to 16% and 12% per decade for males and females, respectively [19]. Although our results corroborated this finding, we found a lower rate of decline (10% per decade) than described by Himann et al. [19]. This is probably related to the fact that our elderly subjects were healthy and active, as attested by the $\dot{V}O_{2,max}$ values in the two groups, which were 160% (G65) and 143% (G80) higher than the values predicted by the equations of Paterson et al. [27]. The participants of the present study did not represent a random sample. With increasing age, volunteers become biased progressively toward the fittest of their group [3]. Though our healthy elderly subjects did not represent the true old population, this selectivity was necessary to study the effect of aging alone on the decline in preferred walking speed, without the interaction of pathological changes. The assessment of preferred walking speed, using the procedure proposed by Martin et al. [24], reflects what the subject normally does and can comfortably achieve. The walking speeds measured in this study were similar to those measured elsewhere [7, 9, 12, 23, 24, 25], indicating that the procedure was a reliable measure of preferred walking speed in these healthy elderly subjects.

$\dot{V}O_{2,max}$ was 34% higher in G65 than in G80. The rate of decline in aerobic power was 0.67 ml O_2·kg^{-1}·min^{-1}·year^{-1} (Fig. 3) and is higher than the 0.4–0.5 ml O_2·kg^{-1}·min^{-1}·year^{-1} found in cross-sectional studies in samples with ages of 25 to 65 or 75 years [10, 21]. It is also higher than the 0.27 ml O_2·kg^{-1}·min^{-1}·year^{-1} found by Paterson et al. [27] in subjects aged 55–85 years. This difference may be explained by the very high aerobic fitness of the G65 subjects and by the lower level of physical activity, particularly because of the lower sport activity score, in our G80 subjects. In fact, a decrease in physical activity, a gain in body mass and aging changes in the cardiovascular system all combine to lower $\dot{V}O_{2,max}$ [16, 21]. Moreover, this decline may accelerate after 70 years or after a reduction in training volume and intensity in master athletes [15, 29, 30]. With aging, our G80 subjects had reduced or stopped their weekly walking sessions. In contrast, the G65 subjects were very fit and active in sport activities with one or two walking sessions per week. The rate of decline found in this study confirms longitudinal

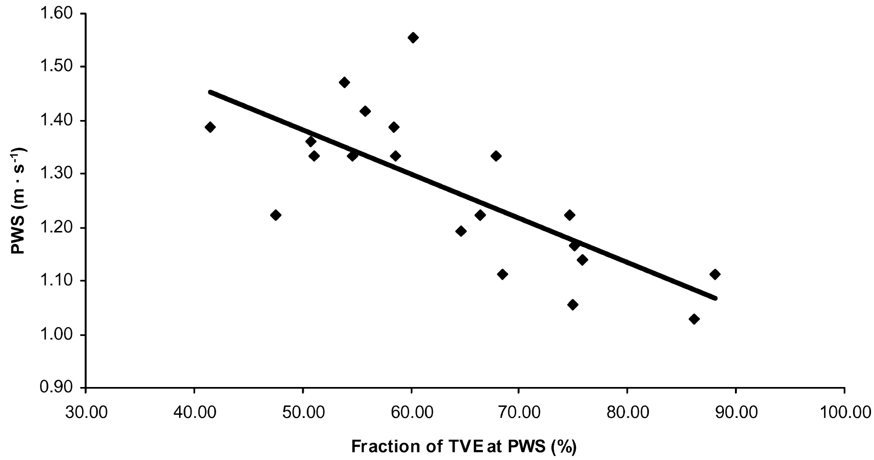

Fig. 2 Correlation between the preferred walking speed and fraction of T_{VE} at PWS ($y=-0.0083x+1.80$; $r=0.73$; $P<0.001$) for the two groups

results showing that the 10-year drop in the $\dot{V}O_{2,max}$ of master athletes who decreased their training intensity was more than 0.7 ml $O_2 \cdot kg^{-1} \cdot min^{-1} \cdot year^{-1}$ [29] and cross-sectional results showing that the rate of decline in maximal aerobic power is greater in endurance-trained men and women than in their sedentary peers [28, 33]. Although there was no significant difference in body mass between our groups, the lower body mass in G80 may have led to the true magnitude of the rate decline between our two groups being underestimated. Indeed, the rate of decline in absolute $\dot{V}O_{2,max}$ was 0.056 l $O_2 \cdot min^{-1} \cdot year^{-1}$ and was still higher than the rate of decline in men (0.034 l $O_2 \cdot min^{-1} \cdot year^{-1}$) and in women (0.019 l $O_2 \cdot min^{-1} \cdot year^{-1}$) found in cross-sectional studies employing larger numbers of older subjects [27, 31, 35]. We realize that the rate of decline in $\dot{V}O_{2,max}$ with age cannot be determined precisely using a cross-sectional study design with different numbers of men and women in each group. However, Jackson et al. [21] showed that the average rate of decline in $\dot{V}O_{2,max}$ was similar with cross-sectional and longitudinal analyses in a single study. Moreover, several studies have shown the same age-related rate of decline in $\dot{V}O_{2,max}$ when expressed relative to body mass in men and women [27, 31, 35]. The greater decline in absolute $\dot{V}O_{2,max}$ in men is partially offset by the greater decline in body mass compared with women [27, 35]. Still, we recognize that genetic and constitutional factors may have influenced our cross-sectional findings.

The rate of age-related decline in T_{VE} was slightly lower than that of $\dot{V}O_{2,max}$ (0.54 ml $O_2 \cdot kg^{-1} \cdot min^{-1} \cdot year^{-1}$) (Fig. 3). Previous studies have shown that the age-related decline in T_{VE} is one-third [2, 13, 31] or one-half [27] the rate of decline in $\dot{V}O_{2,max}$, whereas our rate of decline in T_{VE} was higher, i.e. four-fifths (80%) that of $\dot{V}O_{2,max}$. Although we noted a relatively greater decline in T_{VE} in this study, probably due to the very high level of aerobic fitness in our younger group, the G80 subjects showed a T_{VE}, expressed as a fraction of $\dot{V}O_{2,max}$, similar to that of the G65 subjects (80%). A proportional maintenance of T_{VE} and $\dot{V}O_{2,max}$ with aging may suggest that alteration within skeletal muscles, such as reduced oxidative capacity and muscle volume, contribute to the age-related reduction not only in T_{VE}, but also in $\dot{V}O_{2,max}$. In fact, recently, Hepple et al. [17] have shown that $\dot{V}O_{2,max}$ is reduced independently of muscle convective oxygen delivery in late middle-aged rats, demonstrating that alterations within muscle (i.e. mitochondrial oxidative capacity) contribute significantly to the decline in $\dot{V}O_{2,max}$

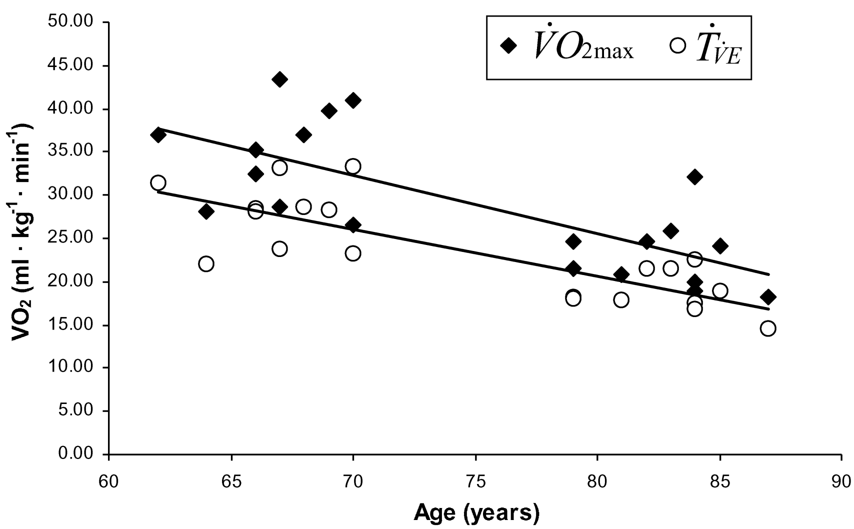

Fig. 3 $\dot{V}O_{2,max}$ and $\dot{V}O_2$ at T_{VE} related to age in the two groups. Regression of $\dot{V}O_{2,max}$ on age is described by the equation: $\dot{V}O_{2,max}$ (ml·kg^{-1}·min^{-1})=−0.67 age+79.62; $r=0.68$; $P<0.001$. Regression of T_{VE} on age is described by the equation: T_{VE} (ml·kg^{-1}·min^{-1})=−0.54 age +64.02; $r=0.73$; $P<0.001$

with aging. Consistent with these findings in animals, the decline in quadriceps oxidative capacity with age in humans resulting from reductions in both muscle volume and oxidative capacity per volume in the elderly, is an important determinant of age-related reduction in $\dot{V}O_{2,max}$ [11].

Previous studies have shown various factors to be associated with the slowing of walking speed in elderly subjects: age, height, weight, body mass index, physical activity level, calf strength, leg muscle strength, $\dot{V}O_{2,max}$ and depressive symptoms [5, 7, 8, 12, 19, 22]. Himann et al. [19] have shown a significant negative correlation between preferred walking speed and age only after 62 years of age. Our finding confirmed this close relationship between age and preferred walking speed in elderly subjects restricted to ages of 64–87 years. Moreover, in this study, preferred walking speed was correlated with height, physical activity level and maximal and submaximal parameters of aerobic fitness. Therefore, our results corroborate the previous findings on the relationship between walking speed and maximal aerobic fitness in elderly subjects. Cunningham et al. [12] reported that $\dot{V}O_{2,max}$, but not age, is related to the speed of self-paced walking in subjects aged 19–66 years. More recently, Buchner et al. [9] has shown with a non-linear model that the gait speed is associated with $\dot{V}O_{2,max}$ and leg muscle strength in elderly subjects aged 68–85 years. To our knowledge, our study is thus the first to investigate the relationship between a decline in preferred walking speed and T_{VE} and energy expenditure at this speed. Our results showed that $\dot{V}O_2$, HR and C_w at preferred walking speed were similar in the two age groups. In contrast, the fraction of $\dot{V}O_{2,max}$ and the fraction of T_{VE} at preferred walking speed were 42% and 39% higher respectively in G80 than in G65. To describe the determinants of preferred walking speed, multiple regression analysis was used. This analysis showed that the fraction of T_{VE} was the primary determinant of the slow-down in preferred walking speed in our healthy and active elderly subjects. T_{VE}, which is a physiological marker of the ability to perform submaximal and prolonged activity, is more representative than $\dot{V}O_{2,max}$ of the elderly population's ability to perform everyday tasks [13, 39]. With age, there is a significant increase in the physiological relative effort (i.e. effort expressed as a percentage of the available submaximal capacity, T_{VE}) required for walking and the execution of daily tasks, which forces older adults to operate at high-effort levels, causes premature fatigue, and in some cases leads to motor accidents [20]. For healthy older subjects, the lower preferred walking speed may be due to working at a higher fraction of T_{VE} than to the absolute energy expenditure imposed by this gait speed. This slower walking speed might be a strategy to preserve a functional submaximal reserve (difference between T_{VE} and energy expenditure at preferred walking speed). Moreover, the decrease in preferred walking speed, as well as the slower execution of daily living activities [20], allows these individuals to seek and attain maximum postural stability and security while performing these activities [25, 32]. In our study, although age was significantly and negatively related to walking in simple regression analysis, it no longer had an effect in the multiple regression analysis. The effect of age was explicable by its association with aerobic submaximal fitness in the elderly.

The correlations noted between preferred walking speed and the other aerobic factors do not necessarily imply causality, but they do suggest possible directions for rehabilitation strategies: a training program designed to increase aerobic fitness in elderly subjects would result in an increase in functional maximal and submaximal reserves. Elderly individuals might find that these greater reserves delay the onset of fatigue and reverse the decline in preferred walking speed.

In summary, this study showed that octogenarians exhibited a lower preferred walking speed and a greater fraction of T_{VE} at this speed of walking. The greater fraction of T_{VE} at preferred walking speed was identified as the primary determinant of the decline in this gait speed in our healthy and active elderly subjects. Future research is needed to confirm these findings with a larger sample of elderly subjects, and an intervention trial with regular aerobic training would be required to test our rehabilitation hypothesis.

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