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Effect of an overground walking training on gait performance in healthy 65- to 80-year-olds

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ABSTRACT

The aim of this study was to examine the effect of an individualized overground walking interval training on gait performance [*i.e.*, speed and energy cost (C_w)] in healthy elderly individuals. Twenty-two older adults were assigned to either a training group (TG; $n = 12$, 73.4 ± 3.9 yr) or a non-training control group (CG; $n = 10$, 70.9 ± 9.6 yr). TG participated in a 7-week individualized walking interval training at intensities progressing from 50 to 100% of ventilatory threshold ($\dot{T}_{VE}$). Aerobic fitness [maximal oxygen uptake ($\dot{V}O_{2max}$) and $\dot{T}_{VE}$], preferred walking speed (PWS), gross and net C_w (GC_w and NC_w, respectively) and relative effort ($\%\dot{V}O_{2max}$) at PWS measured before training (PWS_1) were assessed prior and following the intervention. All outcomes were measured on a treadmill. Significant improvements in GC_w (−8%; $P = 0.007$), NC_w (−12%; $P = 0.003$), relative effort ($\%\dot{V}O_{2max}$: −12%; $P < 0.001$) and PWS (+12%; $P < 0.001$) were observed in TG but not in CG ($P > 0.71$). $\dot{V}O_{2max}$ and $\dot{T}_{VE}$ remained unchanged in both groups ($P > 0.57$). Changes in GC_w at PWS_1 (difference between GC_w at PWS_1 measured pre and post intervention) were inversely correlated with changes in PWS (difference between pre and post PWS; $r = -0.67$; $P = 0.02$). The decreased C_w at PWS_1, with no concomitant improvement in aerobic fitness, represents the main contributing factor for the reduction of the relative effort at this speed. This also allows elderly people to increase their PWS post training. Therefore, the present walking training may be an effective way to improve walking performance and delay mobility impairment in older adults.

1. Introduction

Preferred walking speed (PWS), also known as "most comfortable" or "self-paced" walking speed, is the speed used during normal ambulatory activities. In elderly individuals, PWS represents a common measure of mobility (Buchner et al., 1996), an indicator of general physical health and is associated with independent living (Alexander, 1996). PWS decreases with age (Himann et al., 1988; Murray et al., 1969) and its rate of decline increasing after the age of 65 (Himann et al., 1988). Aerobic fitness [maximal (maximal oxygen uptake; $\dot{V}O_{2max}$) and submaximal aerobic power (ventilatory threshold; $\dot{T}_{VE}$)] is an important determinant of PWS (Buchner et al., 1996; Cunningham et al., 1982; Malatesta et al., 2004).

The physiological relative effort (*i.e.*, effort expressed as a percentage of the individual's maximal or submaximal aerobic power) required for walking or performing daily tasks increases with aging. This forces older adults to operate at high effort levels, causing premature fatigue, and in some cases leading to accidents such as falls (Hortobagyi et al., 2003; Malatesta et al., 2004). This increase in the relative effort at PWS in elderly individuals is due to the decreased maximal and submaximal aerobic power with age (Paterson et al., 2007). In addition, older adults have a greater energy cost of walking (C_w, $mlO_2\ kg^{-1}\ m^{-1}$ or $J\ kg^{-1}\ m^{-1}$) at PWS (*i.e.*, the energy expenditure per unit distance) (Malatesta et al., 2004; Martin et al., 1992; McCann and Adams, 2002; Mian et al., 2006; Waters et al., 1983), and may explain why older adults prefer to walk slower than younger individuals (Malatesta et al., 2004). Thus, both decreased aerobic fitness and increased C_w contribute to mobility impairment (Mian et al., 2007b). This supports the need to develop specific strategies to improve both aerobic fitness and walking performance (*i.e.*, speed and energy cost) and to decrease the relative effort during walking in elderly individuals.

Several studies have shown that older individuals can benefit significantly from aerobic training, showing improvements in both their $\dot{V}O_{2max}$ and $\dot{T}_{VE}$ [reviewed in Paterson et al. (2007)]. However, it has recently been suggested that a marked reduction in aerobic functional reserve in old age may limit the biological capacity to adapt to training, hence limiting the improvements in aerobic

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Nomenclature

a coefficient slope of the equation $y = ax^2 + b$, where y is $\dot{V}O_2$ in $mlO_2\ kg^{-1}\ min^{-1}$ and x is the speed in $m\ s^{-1}$
b coefficient intercepts of the equation $y = ax^2 + b$, where y is $\dot{V}O_2$ in $mlO_2\ kg^{-1}\ min^{-1}$ and x is the speed in $m\ s^{-1}$
CG control group
Compartment 1 standing $\dot{V}O_2$ ($mlO_2\ kg^{-1}\ min^{-1}$)
Compartment 2 metabolic cost associated with maintaining balance calculated by subtracting standing $\dot{V}O_2$ from *b coefficient* ($mlO_2\ kg^{-1}\ min^{-1}$)
Compartment 3 metabolic cost associated with walking movements described by the *a coefficient*
C_w energy cost of walking (energy expenditure per unit distance, $mlO_2\ kg^{-1}\ m^{-1}$)
GC_w gross energy cost of walking (gross oxygen uptake divided by walking speed, $mlO_2\ kg^{-1}\ m^{-1}$)
HR heart rate (beats min^{-1})
HR_{max} maximal heart rate (beats min^{-1})
HR_{SR} Difference between HR at ventilatory threshold and the resting HR (beats min^{-1})
Maximal reserve difference between $\dot{V}O_{2max}$ and energy expenditure at preferred walking speed
NC_w net energy cost of walking (energy cost only associated with walking movements, subtracting the quietly standing value from the gross value, $mlO_2\ kg^{-1}\ m^{-1}$)
PWS preferred walking speed (the "most comfortable" walking speed, $m\ s^{-1}$)
PWS_1 pre intervention PWS (assessed at baseline, $m\ s^{-1}$)
PWS_2 post intervention PWS (assessed at the end of intervention, $m\ s^{-1}$)
Relative effort effort expressed as a percentage of the individual's maximal ($\dot{V}O_{2max}$) or submaximal aerobic power ($\dot{T}_{VE}$)
RER respiratory exchange ratio
Submaximal reserve difference between $\dot{T}_{VE}$ and energy expenditure at preferred walking speed
TG training group
$\dot{T}_{VE}$ ventilatory threshold ($mlO_2\ kg^{-1}\ min^{-1}$)
VAS visual analogue scale
$\dot{V}O_2$ oxygen uptake ($mlO_2\ kg^{-1}\ min^{-1}$)
$\dot{V}O_{2max}$ maximal oxygen uptake ($mlO_2\ kg^{-1}\ min^{-1}$)
$\dot{V}CO_2$ carbon dioxide output ($ml\ min^{-1}$)
$\dot{V}_E$ ventilation ($l\ min^{-1}$)
ΔGC_w changes in GC_w (difference between post GC_w and pre GC_w, $mlO_2\ kg^{-1}\ m^{-1}$)
ΔNC_w changes in NC_w (difference between post NC_w and pre NC_w, $mlO_2\ kg^{-1}\ m^{-1}$)
ΔPWS changes in PWS (difference between post PWS and pre PWS, $m\ s^{-1}$)

capacity in response to aerobic training (Evans et al., 2005). Nevertheless, improving $\dot{V}O_{2max}$ might not be the only way to increase the aerobic functional reserve at PWS and decreasing C_w through submaximal walking endurance training could also be an interesting strategy. Two studies have recently investigated the effect of training on C_w in elderly individuals (Mian et al., 2007b; Thomas et al., 2007). Although, a combination of resistance, aerobic and balance exercises failed to lower C_w in healthy older adults (Mian et al., 2007b), a specific and individualized high-speed interval training at $\dot{T}_{VE}$ on a treadmill associated with body weight unloading, significantly reduced C_w (18–21%) at self-selected overground walking speeds (*i.e.*, slow, comfortable and fast) in healthy elderly (Thomas et al., 2007). Although the latter study is the first one to show a decreased C_w at PWS after training, the complexity of the set up (use of a treadmill with body weight unloading) may render it inappropriate for the general population. Overground walking training performed in natural conditions could provide an alternative type of training, closer to normal ambulatory activities. This more accessible and feasible type of training could generate effective transfer of training adaptations into daily living tasks for elderly people.

Therefore, the purpose of this study was to examine the effect of an individualized overground walking training on gait performance (*i.e.*, speed and energy cost). We hypothesized that individualized training at moderate intensity ($\leqslant \dot{T}_{VE}$) using overground walking would significantly reduce C_w at PWS resulting in a decreased physiological relative effort at PWS allowing an improvement of elderly individuals' PWS, a well recognized predictor of autonomy in the aging population.

2. Methods

2.1. Participants

Thirty independently living elderly individuals were recruited for this study and were extensively screened by a neurologist, who was aware of the study objectives, with a complete medical history and physical examination including resting 12-lead electrocardiogram (ECG) and pulmonary function test. Inclusion criteria were: age over 60, independently living and free of chronic disease as described below. Exclusion criteria were abnormal ECG, cardiovascular or metabolic disease, pulmonary disease, cancer and/or autoimmune disease, joint disease, neurological disease or cognitive impairment, and other pathologies that contraindicated maximal incremental testing (Simar et al., 2005). The participants were ambulatory and free from any limiting orthopedic, neurological, cardiovascular or respiratory problems that might otherwise affect economy and gait mechanics. Twenty-four of the 30 volunteers were eligible for this study and were assigned to either a training group (TG; $n = 12$) or non-training control group (CG; $n = 12$) to obtain two groups matched for age, height and body mass but not for gender since no gender difference in C_w has been reported in older individuals (Waters et al., 1983). Two participants in CG withdrew from the study during the intervention. Thus, data for the current analysis was available for 12 and 10 participants in TG and CG, respectively. Physical characteristics at baseline were not statistically different between groups (Table 1). The protocol was approved by the local ethics committee and all participants provided informed written consent.

2.2. Experimental design

Before the intervention, the participants completed two testing sessions. First, their medical history was collected and a physical

Table 1
Participant characteristics at baseline.

Variable	TG ($n = 12$)	CG ($n = 10$)
Gender	8 F, 4 M	5 F, 5 M
Age (yr)	73.7 ± 3.9	70.9 ± 9.6
Height (m)	1.65 ± 0.08	1.66 ± 0.08
Body mass (kg)	65.5 ± 9.3	73.3 ± 13.2
BMI ($kg\ m^{-2}$)	24.0 ± 2.6	26.0 ± 2.7

Values are means ± SD. n, number of individuals; M, male; F, female; TG, training group; CG, control group; BMI, body mass index.