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Title INFLUENCE OF ENERGY COST AND PHYSICAL FITNESS ON THE PREFERRED WALKING SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

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Abstract

Typically gait speed decreases and gait variability increases in elderly. The aim of this study was to define the influence of energy cost of walking on gait speed and of health-related physical fitness on gait variability. Thirty healthy young and older women were recruited in the study. Energy cost of walking (NetCW) was analyzed with indirect calorimetry while a kinematic analysis was performed with an optoelectronic system to calculate gait variability (GV) during treadmill walking at different speeds. Gait speed was defined as the preferred walking speed (PWS) of the subject and health related physical fitness (HRPF) comprised body fat, strength, flexibility, and cardiorespiratory fitness. In healthy elderly women, the coefficient of variation of step width was found to be a better indicator of GV than stride time, stride length and double support coefficients of variation. GV was not affected by age allowing a high PWS. Furthermore, significant associations, adjusted for age, body mass index and number of falls, were identified neither between NetCW and the PWS, nor between HRPF and GV; only a significant association was found between hand-grip strength and gait stability. Findings highlighted the importance to evaluate hand-grip strength as an indicator of gait efficiency.

Keywords gait variability; preferred walking speed; energy cost; physical fitness; older adults

Taxonomy Gait Ability, Gait Analysis

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UNIVERSITA' CATTOLICA DEL SACRO CUORE
Corso di Laurea in Scienze Motorie

Date: July 25th 2018

From: Christel Galvani, PhD

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To: Dario Farina, Editor in Chief,
Journal of Electromyography and Kinesiology

Object: Submission of a manuscript to Journal of Electromyography and Kinesiology

Dear Editor,

please find enclosed a copy of the revised version (second revision) of the manuscript entitled “INFLUENCE OF ENERGY COST AND PHYSICAL FITNESS ON THE PREFERRED WALKING SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN” written by Daniela Ciprandi, first author, Matteo Zago, Filippo Bertozzi, Chiarella Sforza, Christel Galvani, corresponding author, along with the list of the main modifications inserted in the manuscript and the point-by-point answers to the comments and questions of the referees. All the modifications are highlighted in yellow fonts. The manuscript is 21 pages long and includes 1 table and 1 figure.

We would like to thank the reviewer for his/her further comments and suggestions. We have revised our manuscript accordingly.

The manuscript deals with original matter. It has not been published or submitted for publication elsewhere and it will not be submitted to any other journal before a final decision has been taken as to its acceptability by your journal. Some of the data from this paper were previously presented at the 21st Annual Congress of the ECSS in Vienna, Austria (July 2016).

All authors have contributed to the scientific work: (1) in the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) in drafting the article or revising it critically for important intellectual content. Its publication has been approved by all coauthors. All of the authors listed in the byline have agreed to the byline order and to submission of the manuscript in this form. My coauthors and I do not have any interests that might be interpreted as influencing the research, and APA ethical standards were followed in the conduct of the study.

UNIVERSITA' CATTOLICA DEL SACRO CUORE
Corso di Laurea in Scienze Motorie

The authors declare no conflict of interest.

No funding has been received to carry out this investigation.

I will be serving as the corresponding author for this manuscript. I have assumed responsibility for keeping my coauthors informed of our progress through the editorial review process, the content of the reviews and any revisions made.

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Sincerely yours,

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Christel Galvani, PhD

UNIVERSITA' CATTOLICA DEL SACRO CUORE
Corso di Laurea in Scienze Motorie

Dario Farina, Editor in Chief,
Journal of Electromyography and Kinesiology,

please find enclosed the revised version of the JEK_2018_37_R1

INFLUENCE OF ENERGY COST AND PHYSICAL FITNESS ON THE PREFERRED WALKING SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

Daniela Ciprandi, Matteo Zago, Filippo Bertozzi, Chiarella Sforza, Christel Galvani

We were pleased to know that our manuscript JEK_2018_37_R1 was rated as potentially acceptable for publication in the Journal, subject to adequate revision and response to the new comments raised by the reviewer.

We would like to take this opportunity to express our sincere thanks to the reviewer who identified areas of our manuscript that needed corrections or modification.

We would like also to thank you for allowing us to resubmit a second revised copy of the manuscript.

My best regards
Christel Galvani

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Main Changes introduced in the new version of the manuscript

The modified parts are highlighted in yellow fonts in the submitted version.

Reviewer reports:

Reviewer #1:
In the revised version of the manuscript the authors managed to satisfactorily provide a rationale for their study leading to clear hypotheses.
We thank the reviewer for her/his appreciation of the revised version of the article.

However, as the manuscript stands, there are no conclusions in it. Both the abstract and the end of the discussion lack of conclusions. As it stands, the manuscript appears a "so what" study. The authors should revise both abstract and discussion, by adding a conclusion to their findings.
We have added a conclusion both in the abstract (according to the 200 word limit) and in the manuscript as suggested.

Finally, the authors did not seem to address the last of my previous comments:
"Line 254. "In our study no significant associations, adjusted for age, BMI and number of falls, were identified between NetCW and the PWS, demonstrating that a more efficient gait does not influence gait speed".
I wrote: "I struggle to understand the meaning of correlating the energy cost of walking at different speeds, which was measured on a treadmill, with the self-selected most comfortable overground walking speed. Walking on a treadmill is different from walking overground – moreover, speeds on the treadmill were not self-selected but imposed to each subject, thus not representing their most comfortable speed. Please, address".
The authors replied: "We have deeply analysed the differences between overground PWS and treadmill PWS". In the text they cited the work of Dal et al., 2010, to state that "overground PWS should be used for oxygen consumption".
However, the point that I had asked to address was that in their study the authors measured NetCW during treadmill walking and have correlated it with PWS measured during overground walking. Does it make sense? What is the meaning of such a correlation? The authors should highlight in their discussion the limitation of correlating two measures that have been obtained in different conditions: NetCW has been obtained by dividing the oxygen consumption by the speed of treadmill walking, whereas PWS is the speed of overground walking. The literature reports that the speed with the best walking economy, overground, is the speed that subjects spontaneously choose when asked to walk at their most comfortable speed. In contrast, the speed that the authors have imposed to the subjects on the treadmill during their experiments may not correspond to the "economy speed" and therefore the energy cost per unit of distance, which was obtained by dividing oxygen consumption by walking speed, may have not corresponded the lowest point of the curve energy cost-speed (the most economical cost). As a

consequence, this would affect the correlation between NetCW and PWS (in practice the authors may be correlating the energy cost per unit of distance on a treadmill at a "false" walking economy with the "true" overground walking economy. This should be highlighted as a limitation in the discussion.

We thank the reviewer for his/her additional comments. He/she raises important issues and we have modified the paragraph of the limits of the study according to his/her suggestion.

Abstract

Typically gait speed decreases and gait variability increases in elderly. The aim of this study was to define the influence of energy cost of walking on gait speed and of health-related physical fitness on gait variability. Thirty healthy young and older women were recruited in the study. Energy cost of walking (Net_{CW}) was analyzed with indirect calorimetry while a kinematic analysis was performed with an optoelectronic system to calculate gait variability (GV) during treadmill walking at different speeds. Gait speed was defined as the preferred walking speed (PWS) of the subject and health related physical fitness (HRPF) comprised body fat, strength, flexibility, and cardiorespiratory fitness. In healthy elderly women, the coefficient of variation of step width was found to be a better indicator of GV than stride time, stride length and double support coefficients of variation. GV was not affected by age allowing a high PWS. Furthermore, significant associations, adjusted for age, body mass index and number of falls, were identified neither between Net_{CW} and the PWS, nor between HRPF and GV; only a significant association was found between hand-grip strength and gait stability. Findings highlighted the importance to evaluate hand-grip strength as an indicator of gait efficiency.

Title page

INFLUENCE OF ENERGY COST AND PHYSICAL FITNESS ON THE PREFERRED WALKING SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

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Keywords: gait variability; preferred walking speed; energy cost; physical fitness; older adults

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1. Introduction

Aging is accompanied by detriments in physical function which are predictive of falls, fractures, psychological impairments, loss of independence and mortality (Valentine et al., 2009). Thus, remaining functionally independent and maintaining a high quality of life are two common goals among older adults. Exercise is a key intervention for improving physical function in this population, and walking is the most common physical activity in older adults (Lee and Buchner, 2008). Walking is a complex motor task, often no longer performed automatically by the elderly, a large proportion of falls actually occurring during locomotion or locomotor transition (Maslivec et al., 2018). These falls are often attributed to a decreased quality of gait, due to age-related (Bridenbaugh and Kressig, 2011) peripheral (postural control and muscle strength) (Gimmon et al., 2015; Granacher et al., 2011) and central impairments (atrophy of the motor cortical regions and corpus callosum, degeneration of neurotransmitter systems, delayed muscular commands) (Maslivec et al., 2018; Seidler et al., 2010).

The overground preferred walking speed (PWS), or gait speed, is a reliable and easily evaluated indicator commonly used to assess functional ability and/or to predict disability in ageing studies (Graham et al., 2008). Multiple regressions showed that older age and especially female gender were more likely associated with lower gait speed (Bohannon, 2008). Moreover, the PWS has been negatively associated with adverse health effects, including falls, and mortality (Dumurgier et al., 2009; Kuo et al., 2006). Therefore, an elevated gait speed may be a simple and accessible indicator of the health of the older person (Studenski et al., 2011), also reducing the risk of falls (Almeida et al., 2011). Gait variability (GV) can be considered an indirect assessment of gait stability, in particular the GV associated to spatiotemporal measures (Hamacher et al., 2011). GV tends to increase with age and it has been related to future mobility disability with selfreported and performance-based measures of functional status (Hausdorff et al., 2001). Besides, our research group assessed the relationship between gait stability during treadmill walking and physical activity level, finding that healthy elderly women, with moderate gait variability and high preferred walking speed, were able to meet the recommended levels of physical activity (Ciprandi et al., 2017). According to the literature, it's plausible to hypothesize that a high gait speed and a low GV produce a good gait quality, consequently reducing the risk of falls.

Participation in a regular exercise has been shown to result in improvements in physical fitness, which is defined as a state of well-being with a low risk of premature health problems and energy to participate in a variety of physical activities. Health-related physical fitness (HRPF) consists of those components of physical fitness that have a relationship with good health and encompasses cardiovascular fitness, muscular strength or endurance, flexibility and body composition (ACSM, 2009 and 2017). Energy cost of walking (aerobic demand per unit of distance walked, C_W) is emerging as another significant factor related to functional performance among older adult (Gimmon et al., 2015; Wert et al., 2013). Increased C_W has the potential to yield adverse functional consequences for older adults, as the amount of energy used during walking comprises a greater portion of the total available energy (Schrack et al., 2013). The C_W speed curve in healthy elderly subjects was shown to be shifted upwards, demonstrating greater energy expenditure while walking compared to younger counterparts (Malatesta et al., 2003; Mian et al., 2006). The computation of net C_W (above standing) amplifies the differences between young and older individuals as the standing energy cost per unit of time was higher in younger individuals (Mian et al., 2006).

To permit preventive strategies to become effective, it is therefore imperative to identify individuals with an unstable gait, verifying factors related to a slow gait speed and a high GV. Previous studies demonstrated that the age-associated increase in energy consumption may result in a slowing of gait speed (Schrack et al., 2013), and that decreased stability of gait was more strongly associated with fear of falling than muscle strength (Toebes et al., 2016). No previous studies of walking in elderly adults have considered the influence of C_W at different speeds on the PWS and, furthermore, no previous studies have focused on factors that influence GV, taking all health-related physical fitness parameters into account. Thus the aims of this study were (1) to define the influence of C_W on the PWS and (2) to define the influence of health-related physical fitness on GV in elderly women. We hypothesized that: (1) a lower Cw could allow a higher PWS, (2) a higher physical fitness could allow a lower GV.

2. Methods

2.1 Subjects

15 young women (mean±SD, median: age 22.8±3.3, 22.0 years; height 1.63±0.07, 1.65 m; mass 58.7±4.4, 59.0 kg; BMI 22.1±2.0, 22.1 kg/m^2) and 15 older women (age 68.2±2.9, 68.0 years; height 1.58±0.07, 1.58 m; weight 64.8±9.5, 64.0 kg; BMI 26.0±2.7, 26.2 kg/m^2) were recruited. Both groups can be considered to have a healthy weight (Queensland Government, 2017). Informed consent was obtained from all participants included in the study. All participants were physically healthy, without any medical conditions that preclude the possibility to carry out functional assessments or activities of daily living.

2.2 Study design

An observational study was conducted. An ethical approval has been obtained from the institutional review board. The study was developed in three days. The first day medical screening, a physical activity questionnaire, anthropometric measurements, maximal cardiorespiratory test and the evaluation of the PWS were performed. The number of falls in the previous year was also collected. After one week, fat mass, strength and flexibility were measured. After 7 days C_W and gait parameters were collected.

2.3 Experimental procedures

The waist circumference (WC) was taken at the “natural waist”, which is at the midpoint between the 10th rib (lowest rib margin) and the iliac crest. Hip circumference (HC) was taken around the widest portion of the buttocks, with the tape parallel to the floor (ACSM, 2017). To calculate the waist to hip ratio (WHR) and the waist to height ratio (WHtR), the waist circumference was divided by the hip circumference, and the waist circumference by the standing height, respectively.

During the medical screening, the number of cardiovascular disease risk factors (CVD) were evaluated according to the ACSM classification (ACSM, 2017) The number of falls was used to classify the subjects in fallers and non-fallers, according to Almeida et al. (2011) classification (“fallers” are those having suffered two or more falls in the previous year and “nonfallers” those having suffered either no falls or only one fall in the previous year). The self-administered short format of the International Physical Activity Questionnaire (IPAQ), validated in both adult and older adult population (Craig et al., 2003; Tomioka et al., 2011), was used to obtain an estimate of subject’s physical activity. The PWS was measured with photocells (Polifemo Radio Light, Microgate, Italy) as the average time of three trials taken to walk the middle 10 m of a 14 m path (Beauchet et al., 2012; Dal et al., 2010). The subjects were instructed to walk at their comfortable walking pace.

Skinfold thickness was measured to the nearest mm at four sites on the right side of the body, at the biceps, triceps, subscapular and suprailiac areas. Body density was calculated using Durnin and Wormesley formula (1974), and body fat was calculated using

Siri’s equation (1956). Isometric maximal voluntary contraction (iMVC) was measured by two force plates (Twin plates, Globus, Italy), fixed onto the foot platform of a horizontal leg press (Technogym, Italy) with the knee angle of 90° and the hip angle of 45° (Preatoni et al., 2012), and by handgrip strength for right and left hand (Jamar, Lafayette Instrument Company, USA), following the protocol utilized in a frail population (Alberti et al., 2013). Three trials were allowed, lasting maximum 5 seconds each and with 3 minutes of rest between trials. Maximal strength was defined as the greatest force and was divided by the participants’ weight to correct for total body weight. Flexibility was measured by V Sit & Reach test. Three trials were measured and the best value was taken (Heyward and Gibson, 2014). After a warm up of 12 minutes, maximal oxygen consumption ($V'O_{2peak}$) was evaluated during a modified Balke treadmill test (Balke and Ware, 1959) with breath-by-breath indirect calorimetry (Quark CPET, Cosmed, Italy). The test finished when subjects reached the maximal exhaustion, which was controlled by the achievement of at least two of three conditions based on Midgley et al. (2007) and Huggett et al. (2005) criteria for adults and for older adults, respectively. To calculate $V'O_{2peak}$, data were averaged at 30-s intervals, and the mean value of the last minute of the test was taken into consideration.

C_W was assessed with indirect calorimetry (K4b^2, Cosmed, Italy), a portable, light (<1 kg) breath-by-breath gas analysis system. The protocol comprised 10-min standing on the treadmill in order to obtain standing metabolic rate (SMR). Each subject had then to walk continuously for 6 minutes without any support on a motor driven treadmill (TMX425C, Trackmaster, Cosmed, Italy) at six different speeds (3.0 - 3.5 - 4.0 - 4.5 - 5.0 - 5.5 km/h) with 5 min of rest between speeds. C_W was calculated for every speed considering the averaged oxygen consumption ($V'O_2$) from the 3rd to the 6th minute, controlling that metabolic steady state had been achieved. Net $V'O_2$ (obtained by subtracting SMR from gross $V'O_2$) was converted to joules using Garby and Astrup’s equation (1987): $V'O_2$ (J/min) = $V'O_2$ (mlO_2/min)•(4.94•RER+16.04) and then adjusted for body weight. Net C_W (Net_{CW}) was obtained by dividing net energy expenditure (J/kg/min) by speed (m/min).

The participants were subjected to simultaneous capture of their motion data. Participants gait was recorded at 120 Hz with a 9-cameras three-dimensional optoelectronic motion capture system (BTS Spa, Milano, Italy), calibrated under the manufacturer guidelines before trials. Twenty-three body landmarks were positioned on each participant, and three additional markers were positioned on the treadmill base. For biomechanical acquisitions subjects were captured in a standing position for 5 seconds to provide the reference for orthostatic position; the gait cycles were captured for 30 seconds from the 3rd to the 4th minute of each speed test. Marker coordinates were tracked following a previously created biomechanical model. Customized software within Matlab (The MathWorks Inc., Natick, MA, USA) was developed for data processing. Marker coordinates were filtered with a 15 Hz, low-pass 2nd order Butterworth filter. Each gait cycle was time-normalized to a standard 100 values sequence. Standard spatiotemporal gait parameters (stride length, stride time, step width and double support) were computed from all of the steps. The magnitude of the variability, which is often used to evaluate reliability (stability) of measurements, including gait outcomes and gait variability itself (Hamacher et al., 2011), was calculated using coefficient of variation (CV), which is the ratio of the standard deviation to the mean: [(SD/mean)•100].

2.5 Statistical Analysis

Statistical analysis was carried out with a commercial software package (STATVIEW 5.0). Nonparametric tests were used because data were not likely to be normally distributed. All data are presented as the means ± standard deviation, median. Statistical significance was set at $p < .05$. Differences between young adults (YA) and older adults (OA) were evaluated using Mann-Whitney U Test, with height as a covariate in stride length analysis. Friedman Test was used to analyze the differences between speeds.

A health-related physical fitness index (HRPFI) was calculated using Z-scores (Knaeps et al., 2017) of all five fitness parameters. The Z-score for percentage fat mass was inversed to account for the fact that a lower fat percentage is better than a higher one. The mean of both Z-scores of handgrip and iMVC was computed to attain an average Z-score for strength fitness. An average composite Z-score was created for fat mass, cardiorespiratory fitness, muscular fitness and flexibility where all four parameters were equally weighed. The coefficient of variation index (CVI) was calculated using four gait parameters (step width, stride length, stride time and double support). The fitness and gait parameters used for HRPFI and CVI computation are based on the weighting identified using a principal component (PC) analysis that determines the main correlation pattern among multiple measures; only the first PC was retained (1PC). Backward stepwise regression analysis, adjusted for age, BMI and number of falls, was performed to evaluate the significance of associations between Net_{CW} and PWS or between HRPFI and CVI.

3. Results

3.1 Differences between older adults and young adults

Only one older woman was classified as “faller”. According to medical screening and the number of CVD, both study populations can be considered healthy.

Unsurprisingly, all anthropometric values (WC, HC, WHR and WHtR) of OA were significantly ($p < .05$) greater when compared with YA. According to health conditions analysis, no significant differences were detected between groups for IPAQ and PWS results. As expected, fat mass was significantly ($p < .0001$) greater in OA than in YA, while strength (handgrip, iMVC), flexibility (V Sit & Reach) and cardiorespiratory fitness ($V'O_{2peak}$) were significantly ($p < .05$) lower in OA than in YA (see Table 1).

TABLE 1 NEAR HERE

Taking spatial gait parameters into consideration, step width did not differ between the age groups; only stride length was found significantly ($p < .05$) higher in YA than in OA, except for 4.0 km/h (Fig. 1 A and B). Considering temporal gait parameters, stride time resulted significantly ($p < .01$) longer in YA than in OA (Fig.1 D).

Net_{CW} of walking was at any speed greater in OA than in YA, but significantly ($p < .05$) different only at the slower speeds (3.0-3.5-4.0 km/h) (Fig. 1 E). No statistical differences in terms of CV were found between groups except for stride time (OA: 2.1±0.5, 2.2; YA: 1.7±0.4, 1.7 s; $p < .05$), stride length (OA: 3.0±1.0, 2.7; YA: 2.4±1.1, 2.2 m; $p < .05$) and double support (OA: 9.8±5.2, 10.1; YA: 5.6±3.4, 4.1%; $p < .05$) at 3 km/h and for stride length (OA: 1.9±0.3, 1.9; YA: 1.6±0.4, 1.6 m; $p < .05$) at 5.5 km/h. Across all subjects, step width variability was larger than stride length, stride time and double support variability (Fig. 1 F). Across all subjects, step width variability exceeded stride length variability by 86.4%, stride time variability by 89.6% and double support variability by 5.04%.

3.2 Speed differences

Step width significantly ($p < .0001$) differed between speeds and stride length significantly ($p < .0001$) increased with speed (Fig. 1 A and B). Double support and stride time significantly ($p < .0001$) decreased with increasing speeds (Fig. 1 C and D).

Net_{WC} was significantly ($p < .0001$) influenced by walking speed. All groups exhibited a similar U-shaped relationship between Net_{WC} and walking speed. The speed that corresponded to the lowest Net_{WC} was slightly slower for the YA (4 km/h) compared with the OA (4.5 km/h) (Fig. 1 E). The same U-shaped relationship was found when expressing speeds as a percentage of PWS, and only the lowest point of the Net_{WC} was approaching to the PWS for OA. Step width ($p < .01$) and double support ($p < .05$) CVs significantly increased with speed. Stride time and stride length CVs significantly decreased with speed ($p < .0001$) (Fig. 1 F).

FIGURE 1 NEAR HERE

3.3 Regression Summary

Significant associations, adjusted for age, BMI and number of falls, were identified neither between Net_{WC} and the PWS, nor between HRPFI and CVI.

In OA a significant ($p < .01$), strong (according to Dancey and Reidy's classification, 2004), and negative ($r = -0.67$) correlation was found between HG and CVI, meaning that stronger older women had lower CVI. Accordingly, a significant association between HG and CVI could be demonstrated ($R^2=0.41$; $\beta=-0.037$; $p < .01$): each 1 N/kg less of HG was associated with an increase of 3.6% in CVI.

4. Discussion

In this research, treadmill walking at different speeds in two groups of young and older adults was assessed in terms of C_W and gait stability. The aims were to study: (1) the influence of C_W of different speeds on PWS, and (2) the influence of the health-related physical fitness parameters on GV. The main findings were that: (1) Net_{CW} did not influence PWS, and (2) a significant association was found only between hand-grip strength and CVI. Therefore, the data of this exploratory research did not support our 1st hypothesis that a lower Net_{CW} could allow a higher PWS, and only partially supported our 2nd hypothesis, i.e. that a higher physical fitness could allow a lower GV.

Older women resulted on average slightly overweight, according to all anthropometric parameters (ACSM, 2017), but they had elevated levels of physical activity, in particular of moderate and vigorous intensity (Hurtig-Wennlöf et al., 2010), and a high PWS (Malatesta et al., 2010). The majority (75%) of participants were judged to have fair or good cardiorespiratory fitness; in contrast, almost all the subjects had grip strength, and flexibility values below the average (Heyward and Gibson, 2014; Ratames, 2012).

The Net_{CW} and speed relationship is U-shaped, with an individual's walking speed selected to coincide with the lowest metabolic cost (Bastien et al., 2005). The Net_{CW} increases with age, resulting in an upward shift in the Net_{CW}–speed relationship during aging (Mian et al., 2006). In our study, both groups exhibited a similar U-shaped relationship between Net_{CW} and walking speed, but only in OA the speed with the lowest Net_{CW} corresponded to their PWS, OA maintaining a Net_{CW} greater than in YA at any speed. No previous studies have considered the influence of Net_{CW} of different speeds on the PWS. In our study no significant associations, adjusted for age, BMI and number of falls, were identified between Net_{CW} and the PWS, demonstrating that a more efficient gait does not influence gait speed. In recent years, Schrack et al. (2013) demonstrated that in elderly with a low cardiorespiratory fitness the cost of walking became a conditioning factor to speed, causing a lower usual gait speed, due to a compression of energy reserves and an increased fatigue. Our subjects, on the contrary, had an average cardiorespiratory fitness, thus walking at 5.5 km/h consisted in a moderate effort (49.7% $V'O_{2max}$) (ACSM, 2017). It's likely that the lack of association was due to the fact that our population was active, healthy and still efficient at all the analyzed speeds. Finally, the C_W was estimated using a treadmill in order to ensure a constant speed during six minutes, allowing a steady state oxygen consumption, and a steady rate of speed across age groups. Furthermore, it has been suggested that, since using a PWS evaluated on a treadmill for treadmill walking tests overestimated the C_W, overground PWS should be used for oxygen consumption measurement during treadmill walking tests (Dal et al., 2010).

Assessment of GV via biomechanical measures of foot kinematics provides a viable option for the quantitative evaluation of gait stability. The variabilities of spatial and temporal step kinematics are independent descriptors of locomotion control in healthy young and older adults. The effect of aging on GV has earlier been investigated in several studies but conflicting results have been reported. Our results are in accordance with Kang and Dingwell (2008) who reported no difference in GV between young and older adults. Our data are, on the contrary, inconsistent with those reported by Grabiner et al. (2001), demonstrating that the walking velocity conditions do not influence the variability of the gait variables. These differences can be due to the health condition of the older adults involved in the present study. Owings and Grabiner (2004) suggested that, for healthy young and older adults, step width variability is a more meaningful descriptor of locomotion control. Our results seem to support these findings, demonstrating that step width CV was a better indicator of GV than stride time, stride length and double support CVs. Previous studies demonstrated that stride time variability and stride length variability could be improved by increasing muscle strength (Wang et al., 2015); moreover, stride time variability correlated significantly with strength (grip and knee extension strength), balance and health and mental status (Hausdorff et al., 2001). In the present study, CVI was used as an indicator of age-related deficits in mobility function and was significantly associated only with strength, and in particular only with grip strength: each 1 N/kg less of HG was associated with an increase of 3.6% in CVI. These results need to be considered when recommending health related physical fitness test protocols to submit to older adults during lifespan. Exercise intervention with a combination of strength, endurance, and balance training may improve joint mobility, muscle strength, and endurance and lead to improvements in walking endurance and gait performance among older adults (Wang et al., 2015). Grip strength, a quick and simple evaluation of muscular function, is often used to characterize the strength of elderly individuals, and can be measured feasibly in clinical and field settings. However, until now, it was unknown how handgrip strength performance related to other common measures of physical function in healthy older adults. Our study underlined that a higher muscle strength (handgrip) is related to a reduced gait variability.

The limitations of the study included: 1) the small sample size; 2) a poor population heterogeneity, in terms of health conditions and health-related physical fitness and gait parameters; 3) the absence of men in the population. Furthermore, the speed individually selected as the nearest to the overground PWS among the speeds imposed to the subjects on the treadmill, may not have corresponded to the ‘economy speed’, that is the lowest point of the energy cost-speed curve and this, as a consequence, may have affected the lack of correlation between Net_{CW} and PWS. More research on the influence of C_W on PWS and of health-related physical fitness on GV is needed in the older age groups including men, for understanding which are the parameters important to maintain or enhance with age in order to preserve independence, providing them the opportunity to sustain a better quality of life.

Finally, the mechanisms that underlie reduced gait speed with age are still debated. Our study aimed to verify important relationships between energy cost and usual gait speed, and between health-related physical fitness and mobility function. Findings highlighted the importance to evaluate hand-grip strength as an indicator of gait efficiency.

Identifying indicators of walking inefficiency could lead to targeted interventions aimed at reducing mobility impairment among older adults.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Figure captions

Fig. 1: Mean and standard deviations (Mean±SD) of spatial and temporal gait parameters, and Net Energy Cost of walking vs. walking speed for young (YA) and older adult (OA) women. Pooled mean values (YA and OA) of coefficient of variation (CV) of step width (SW), stride time (ST), stride length (SL), and double support (DS) are presented in Fig. 1 F. P-values for age group (pa) and speed (ps) comparisons are shown. Differences between age-groups and speeds were obtained by Mann-Whitney U Test and Friedman Test, respectively.

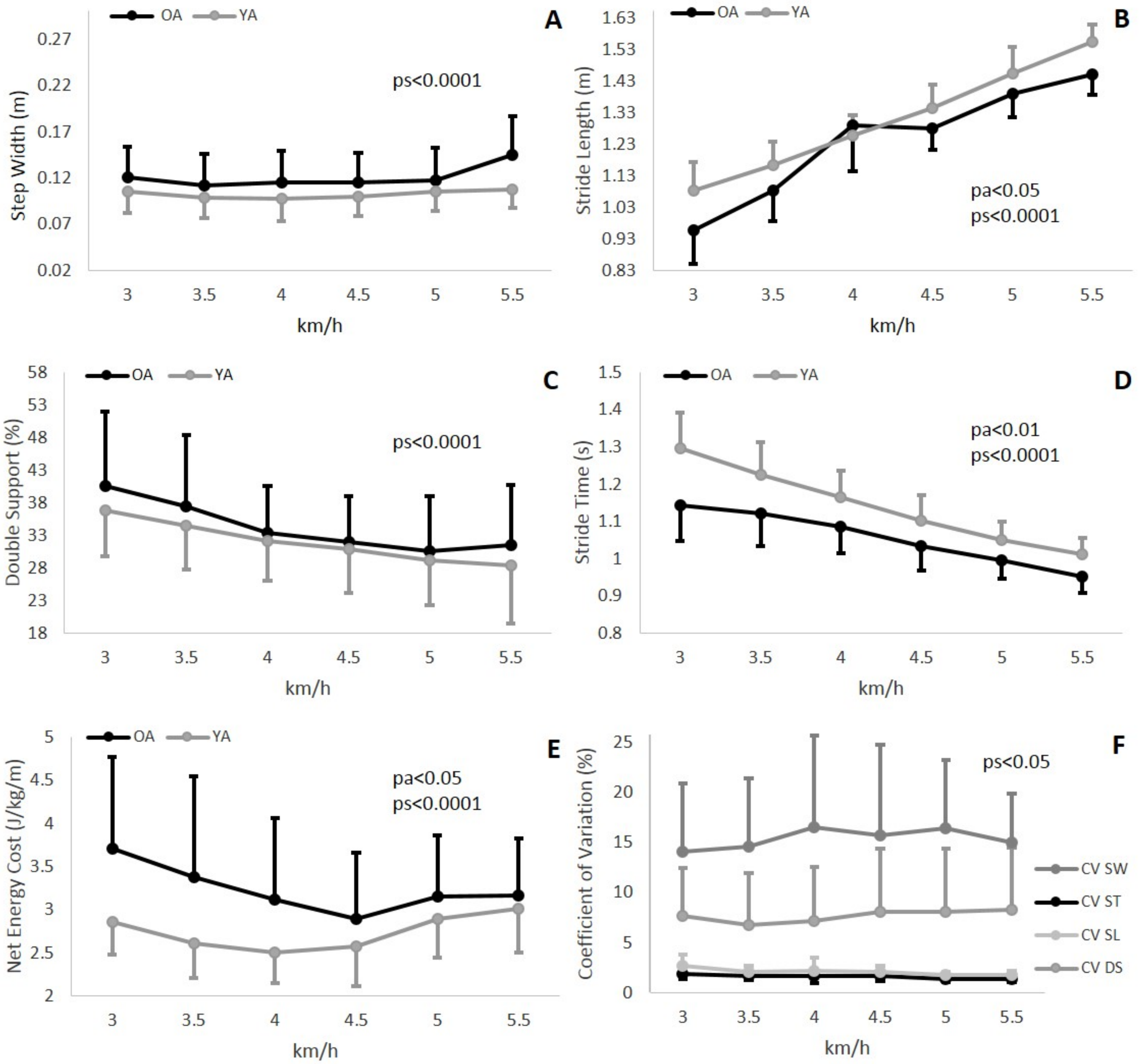
A
OA
YA
ps<0.0001
Step Width (m)
0.27
0.22
0.17
0.12
0.07
0.02
3
3.5
4
4.5
5
5.5
km/h
B
OA
YA
pa<0.05
ps<0.0001
Stride Length (m)
1.63
1.53
1.43
1.33
1.23
1.13
1.03
0.93
0.83
km/h
C
OA
YA
ps<0.0001
Double Support (%)
58
53
48
43
38
33
28
23
18
km/h
D
OA
YA
pa<0.01
ps<0.0001
Stride Time (s)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
km/h
E
OA
YA
pa<0.05
ps<0.0001
Net Energy Cost (J/kg/m)
5
4.5
4
3.5
3
2.5
2
km/h
F
ps<0.05
Coefficient of Variation (%)
25
20
15
10
5
0
CV SW
CV ST
CV SL
CV DS
km/h

Table 1 Anthropometric parameters, Health conditions and Health-Related Physical Fitness

	Older Adults		Young Adults		p-value
	mean±SD	Median	mean±SD	Median	
Anthropometric parameters					
WC (cm)	87.2±9.6	89.5	72.1±4.8	73.2	0.0001
HC (cm)	98.7±9.8	100.0	92.4±4.1	92.9	0.0443
WHR	0.9±0.1	0.9	0.8±0.1	0.8	<0.0001
WHtR	0.6±0.1	0.6	0.5±0.0	0.4	<0.0001
Health conditions					
IPAQ (METs-min/wk)	3642±2276	3546	2559±2256	1866	0.1524
PWS (km/h)	4.9±0.5	4.8	5.2±0.7	5.1	0.0930
Health-Related Physical Fitness					
Fat Mass (%)	35.4±2.2	35.4	25.5±1.8	25.4	<0.0001
Handgrip (N/kg)	2.3±0.8	2.2	3.5±1.0	3.7	0.0026
iMVC (N/kg)	12.7±2.8	12.8	17.1±3.1	17.8	0.0007
V Sit & Reach (cm)	28.1±9.4	26.0	36.6±10.0	39.0	0.0202
$V'O_{2peak}$ (mlO_2/kg/min)	27.1±3.9	25.8	38.9±4.4	39.3	<0.0001

Data are presented as mean±standard deviation (SD) and median. WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; WHtR: waist to height ratio; IPAQ: international physical activity questionnaire; PWS: preferred walking speed; iMVC: isometric maximal voluntary contraction; $V'O_{2peak}$: maximal oxygen consumption. P-values were obtained by Mann-Whitney U Test.

UNIVERSITA' CATTOLICA DEL SACRO CUORE
Corso di Laurea in Scienze Motorie

INFLUENCE OF ENERGY COST AND PHYSICAL FITNESS ON THE PREFERRED WALKING SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

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Title of Paper: INFLUENCE OF ENERGY COST OF WALKING AND HEALTH-RELATED PHYSICAL FITNESS ON GAIT SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

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- ☐ We have a competing interest to declare (please fill in box below):

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Galvani Christel	Galvani Christel

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Title of Paper: INFLUENCE OF ENERGY COST OF WALKING AND HEALTH-RELATED PHYSICAL FITNESS ON GAIT SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

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