

RESEARCH ARTICLE

# Older adults must hurry at pedestrian lights! A cross-sectional analysis of preferred and fast walking speed under single- and dual-task conditions

Patrick Eggenberger<sup>1\*</sup>, Sara Tomovic<sup>2,3</sup>, Thomas Münzer<sup>3</sup>, Eling D. de Bruin<sup>1,4,5</sup>

**1** Institute of Human Movement Sciences and Sport, Department of Health Sciences and Technology, ETH Zurich, Zurich, Switzerland, **2** Institute of Physiotherapy, School of Health Professions, Zurich University of Applied Sciences, Winterthur, Switzerland, **3** Geriatrie Klinik St.Gallen, St.Gallen, Switzerland, **4** Department of Epidemiology, CAPHRI School for Public Health and Primary Care, Maastricht University, Maastricht, Netherlands, **5** Centre for Evidence Based Physiotherapy, Maastricht University, Maastricht, Netherlands

\* [patrick.eggenberger@hest.ethz.ch](mailto:patrick.eggenberger@hest.ethz.ch)



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## Abstract

Slow walking speed is strongly associated with adverse health outcomes, including cognitive impairment, in the older population. Moreover, adequate walking speed is crucial to maintain older pedestrians' mobility and safety in urban areas. This study aimed to identify the proportion of Swiss older adults that didn't reach 1.2 m/s, which reflects the requirements to cross streets within the green–yellow phase of pedestrian lights, when walking fast under cognitive challenge. A convenience sample, including 120 older women (65%) and men, was recruited from the community (88%) and from senior residences and divided into groups of 70–79 years ( $n = 59$ ,  $74.8 \pm 0.4$  y; mean  $\pm$  SD) and  $\geq 80$  years ( $n = 61$ ,  $85.5 \pm 0.5$  y). Steady state walking speed was assessed under single- and dual-task conditions at preferred and fast walking speed. Additionally, functional lower extremity strength (5-chair-rises test), subjective health rating, and retrospective estimates of fall frequency were recorded. Results showed that 35.6% of the younger and 73.8% of the older participants were not able to walk faster than 1.2 m/s under the fast dual-task walking condition. Fast dual-task walking speed was higher compared to the preferred speed single- and dual-task conditions (all  $p < .05$ ,  $r = .31$  to  $.48$ ). Average preferred single-task walking speed was  $1.19 \pm 0.24$  m/s (70–79 y) and  $0.94 \pm 0.27$  m/s ( $\geq 80$  y), respectively, and correlated with performance in the 5-chair-rises test ( $r_s = -.49$ ,  $p < .001$ ), subjective health ( $\tau = .27$ ,  $p < .001$ ), and fall frequency ( $\tau = -.23$ ,  $p = .002$ ). We conclude that the fitness status of many older people is inadequate to safely cross streets at pedestrian lights and maintain mobility in the community's daily life in urban areas. Consequently, training measures to improve the older population's cognitive and physical fitness should be promoted to enhance walking speed and safety of older pedestrians.

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## Introduction

In the older population, reduced usual or preferred walking speed is strongly associated with increased risk for disability, cognitive impairment, falls, and all-cause mortality [1, 2]. A recent meta-analysis demonstrated that the risk of all-cause mortality is elevated by 89% in the older adults exhibiting the lowest preferred walking speeds [1]. Walking speed was therefore proposed as a simple geriatric assessment to identify older adults with increased mortality risk and was suggested to be “the sixth vital sign” [1–6]. The increase in all-cause mortality risk in relation to slow walking speed is mostly associated with increased cardiovascular mortality risk [7, 8]. Moreover, reduced walking speed is predictive of community functioning [9] and is an issue for older adults attempting to maintain their mobility and safety as pedestrians in urban areas [10]. In contrast to what intuitively might be assumed, aging itself is not a strong explanatory factor for the observable slowing of preferred gait speed in the older population. Healthy older adults walk at a speed that exceeds standards for crossing urban streets; furthermore, they are able to adopt a significantly faster gait in response to a crosswalk signal albeit this comes at the cost of increased gait variability [11]. It seems that especially potentially modifiable factors such as impairment of Instrumental Activities of Daily Living, physical inactivity and cardiovascular disease, are related to the observed slowing of walking speed in many older adults [12].

*Preferred walking speed* of a substantial proportion of older adults is slower than 1.2 m/s [13–17]. This speed is required, however, at pedestrian lights in Switzerland and many other countries, including the United States, Canada, the United Kingdom, Ireland, and South Africa, to cross streets safely within the green–yellow phase [11, 13, 14, 18, 19]. For instance, a recent comprehensive investigation from Ireland reported that 31% of older adults in the age group of 65–74 years and 61% of those older than 75 years were walking slower than 1.2 m/s at their preferred speed [13]. Another study, from the United Kingdom, found that up to 84% of men and 93% of women older than 65 years of age did not reach 1.2 m/s with normally paced walking [14]. Recent research indicates that older pedestrians’ mobility and safety is not only negatively affected by physical frailty, which is characterized by slow walking speed, low physical activity, unintentional weight loss, exhaustion, and muscle weakness [20], but also by attention deficits (and visual impairment) [10]. This finding is supported by other investigations linking executive control and attention deficits with increased fall risk [21, 22]. Thus, it appears questionable if the measurement of single-task preferred walking speed adequately reflects the physical and cognitive requirements that are co-existing when crossing a street [23, 24].

Several studies support the notion that *cognitive–motor dual-tasking* and divided attention play an important role in street crossing behavior of older adults. For instance, older adults were more susceptible to dual-task impairments compared to younger adults in a simulated virtual reality street crossing task. In contrast, younger adults did mostly not show any dual-task costs from listening to music or talking on a cell phone while street crossing [24]. Dual-task costs are referred to as percentage of loss, relative to the single-task street crossing or walking condition [24, 25]. Previous research has shown that high dual-task costs for different gait parameters, including stride time, stride velocity and stride length at fast walking speed, are associated with poorer divided attention performance [26]. In addition, a divided attention experiment on a simulated street demonstrated that older adults with poorer perceptual, physical, and cognitive functions were prone to make risky street crossing decisions [27]. Finally, another simulation study identified several predictors of dangerous street-crossing choices which included low walking speed, as well as visual processing speed, visual attention, and attention shifting ability [28]. Therefore, measuring dual-task walking speed, including a cognitive task, may represent a better approximation of real-life conditions for crossing streets at pedestrian lights.

To the best of our knowledge, to date only one study has assessed *preferred dual-task walking speed* as a measure to estimate the proportion of older adults that is at risk when crossing streets at pedestrian lights [13]. The authors demonstrated that the percentage of older adults ( $\geq 75$  years of age) walking slower than 1.2 m/s at preferred speed rose from 61% under single-task to 91% under dual-task walking conditions, respectively [13]. Furthermore, a recent systematic review identified the lack of research examining the effect of cognitive dual-tasks on gait speed in community-dwelling older adults [29]. Particularly, studies are inexistent that include a *fast speed dual-task walking* condition which might reflect time pressure and cognitive challenge when crossing streets at pedestrian lights even more appropriately [26].

Therefore, this study aimed to identify in a convenience sample of Swiss older adults the proportion that doesn't reach 1.2 m/s walking speed, which is required to safely cross streets within the green–yellow phase of pedestrian lights, while walking fast under a cognitively challenging dual-task condition. We hypothesized, that under this *fast speed dual-task walking* condition the proportion of older adults walking slower than 1.2 m/s would be smaller compared to the *preferred speed single- and dual-task walking* conditions.

## Materials and methods

### Study design and participants

This study represents a cross-sectional evaluation of preferred and fast walking speed under single- and dual-task conditions among 120 older adults living in a Swiss city with about 80'000 residents [30]. We used baseline gait data of 90 older adults enrolled for a six-month training intervention as described previously [25, 31]. In addition, 30 participants were recruited for this cross-sectional study to increase sample size in the older age group ( $\geq 80$  y) in order to balance age distribution in the whole sample. We aimed to approximate the proportion of older adults living in senior residences in our sample with the Swiss population average [32]. Data collection was performed at Geriatriische Klinik St.Gallen, Switzerland. The study protocol was approved by the local ethics committee of the canton St.Gallen, Switzerland (study-number: EKSG 14/005, SNCTP 000000039) and the initial training intervention trial was registered at Current Controlled Trials ISRCTN70130279. Our reporting adheres to the STROBE recommendations on what should be included in an accurate and complete report of an observational cross-sectional study [33].

The participants that enrolled to the aforementioned training intervention trial were recruited in August and September 2012 through a newspaper article, a local seniors organization [34], senior residence facilities, primary care physicians, and via the websites of the city's geriatric hospital [35] and the department of sports of the canton St.Gallen [36]; testing sessions succeeded in October 2012. The additional 30 participants were recruited in February and March 2014 among patients receiving ambulatory or inpatient physical therapy at the city's geriatric hospital and were tested in the same period. For eligibility, participants had to be older than 70 years, live independently or at senior residence facilities, and sign informed consent. Participants had to be able to walk at least 20 meters, with or without walking aids, for gait analysis. Older adults with Alzheimer's disease, other type of dementia, or recent head injury were excluded. Judgment by their primary care physician was required in the case of acute or instable chronic diseases (e.g. stroke, diabetes) and rapidly progressing or terminal illnesses before accepting a person for participation.

### Measurements

**Walking speed.** In the 90 participants that were also enrolled for the training intervention trial, walking speed (among other spatio-temporal gait parameters) was assessed at baseline

using the GAITRite electronic walkway system (CIR Systems, Havertown, USA) with the Platinum Version 4.0 software. The validity and reliability of the GAITRite system has been well established [37–39]. Walking was initiated two meters before the 7.3-meter active area of the walkway and ended 2 meters thereafter to allow for steady state gait assessment [40].

In the group of 30 participants that were recruited additionally for this study, walking speed was assessed using photo-electric barriers (Brower Timing Systems, Draper, USA) since other gait parameters were not required. The two photo-electric barriers were set up at a height of 50 cm and measured steady state walking time over 8 meters distance. Therefore, participants started walking 2 meters before the first photo-electric barrier and were asked to walk steadily until the finish line 2 meters after the second photo-electric barrier. The difference in walking distance (7.3 vs. 8 meters) for speed assessment in the two groups of participants described above is not expected to be a confound, since previous research has shown a high level of validity and comparability for walking speed assessment at differing distances between 5 and 10 meters in older adults [40–42].

The testing protocol comprised single- and dual-task walking, in which subjects were instructed to walk under four different conditions: at self-selected preferred walking speed, at a fast walking speed (as fast as possible without running), and each with or without a concurrent cognitive task. Each test condition was repeated three times and the mean value was used for statistical analyses. With participants deemed to be less resilient by the investigator, only two repetitions per walking condition were performed to prevent bias from potential fatigue [43]. Two repetitions per walking condition still represent high measurement reliability for walking speed assessments [39, 44]. Trials were repeated when a participant stopped walking or performing the cognitive task. The cognitive–motor dual-task condition was adjusted to the participant’s cognitive abilities to ensure a similar relative cognitive load among all participants. This approach is supported by a meta-analysis that advised to fit the complexity of the cognitive dual-task to the capacity of the target population [45]. The three levels of cognitive task difficulty that were added to the walking task consisted of either a) counting backwards in steps of seven from a random number between 200 and 250, or b) the same calculation task with steps of three, or c) enumerating objects (e.g. flowers, country names, or first names). The purpose of this procedure was to quantify cognitive–motor interference while walking [46]. In order to define the appropriate level of cognitive task difficulty, the participants were first asked to perform the most difficult task (counting backwards in steps of seven) in a standing position without walking. If they were able to accomplish this calculation task in a continuous manner, it was chosen to be performed during the walking assessments. Otherwise, the next easier task (counting backwards in steps of three) was tested without walking, etc. Meta-analytic data showed no differential effects on walking speed among cognitive tasks involving internal interfering factors, such as the mental tracking and verbal fluency tasks applied in the present study [46]. These tasks may also share complex neural networks [47, 48], which interfere with those of gait control [46]. Participants were instructed not to prioritize either task and were allowed to use assistive walking devices. Relative dual-task costs (DTC) were calculated as percentage of loss relative to the single-task walking performance, according to the formula  $DTC (\%) = 100 \times (\text{dual-task score} - \text{single-task score}) / \text{single-task score}$  [25].

**Secondary outcomes.** To assess the association between walking speed and functional lower extremity strength a *5-chair-rises test* was performed in accordance with the criteria described for the Short Physical Performance Battery [49]. Full criteria for test administration are available at the National Institute on Aging website [50]. In addition, the following data were registered: *date of birth*, *sex*, *educational level* (including four options: secondary school = 9 years, apprenticeship = 13 years, grammar school = 13 years, university/higher education = 17 years), *habitation* (including four options: independent, apartment for older adults, senior

residence, special-care home), *subjective health rating* (including four options: very good, good, medium, poor), *retrospective fall frequency* for the 6-month period prior to the study (including three options: no falls, one fall, more than one fall; a fall was defined as “an event which results in a person coming to rest inadvertently on the ground or floor or other lower level” [51]), and *walking aids* (including three options: no walking aid, cane, walking frame).

## Statistical analyses

Group differences in the socio-demographic measures of age and education years were compared with student's independent *t*-tests. Intra-individual differences between walking conditions were analyzed using student's paired *t*-tests. Inter-individual differences within walking conditions between age groups and sexes were analyzed using student's independent *t*-tests. Pearson's correlation for parametric data or Spearman's correlation and Kendall's  $\tau$  for non-parametric data, were applied to analyze the relationships between walking speed and other parameters. Missing data were excluded from the analysis and are specified in the results section. Statistical calculations were performed with IBM SPSS Statistics software for Macintosh, version 23.0 (IBM Corp., Armonk, NY) with a significance level of  $\alpha = .05$ . Effect size *r* from *t*-tests, was defined as small at  $r = .10$ , medium at  $r = .30$ , and large at  $r = .50$  and above [52].

## Results

Table 1 shows socio-demographic characteristics of the two age groups. The age ranges in the group  $\geq 80$  years were 80–96 years for women and 80–94 years for men, respectively. In each of the following variables one value was missing: *education level* (women 70–79 y), *subjective health* (men 70–79 y), and *walking aids* (women  $\geq 80$  y). The complete dataset on which this publication is based, is provided in the supporting information file [S1 Dataset](#).

## Walking speed

Fig 1 illustrates the percentage of women and men that were walking slower than 1.2 m/s under the four walking conditions. Differences in walking speed between sexes were not statistically significant. The highest percentage of participants, comprising women and men, walking slower than 1.2 m/s was evident in the *preferred speed dual-task (DT)* walking condition (age group 70–79 years: 62.7%, age group  $\geq 80$  years: 88.5%), followed by *preferred speed single-task (ST)* walking (70–79 y: 50.8%,  $\geq 80$  y: 82.0%), *fast speed DT* walking (70–79 y: 35.6%,  $\geq 80$  y: 73.8%), and *fast speed ST* walking (70–79 y: 10.2%,  $\geq 80$  y: 42.6%).

Fig 2 shows the boxplots for the walking speed measurements under the four walking conditions, separated by age group. The younger participants were walking significantly faster under all respective walking conditions (all  $p < .001$ ,  $r$  range from .41 to .43). Walking speed was significantly reduced in the DT walking conditions compared to ST walking (age group 70–79 years, *preferred speed DT* vs. *ST*:  $t(58) = -3.34$ ,  $p = .001$ ,  $r = .40$ ; *fast speed DT* vs. *ST*:  $t(58) = -8.86$ ,  $p < .001$ ,  $r = .76$ ; age group  $\geq 80$  years, *preferred speed DT* vs. *ST*:  $t(60) = -4.26$ ,  $p < .001$ ,  $r = .48$ ; *fast speed DT* vs. *ST*:  $t(60) = -12.35$ ,  $p < .001$ ,  $r = .85$ ). Additionally, walking speed was significantly lower in *preferred ST* walking than in *fast DT* walking (70–79 y:  $t(58) = -3.09$ ,  $p = .003$ ,  $r = .38$ ;  $\geq 80$  y:  $t(60) = -2.50$ ,  $p = .015$ ,  $r = .31$ ). No missing values were present for any walking speed measures.

*Dual-task costs (DTC)* were not different between age groups for preferred speed walking ( $p = .624$ ), whereas for fast speed walking a trend for significantly smaller DTC in the younger group existed ( $t(118) = 1.84$ ,  $p = .069$ ,  $r = .17$ ). Fast speed DTC were significantly higher than preferred speed DTC in both age groups (70–79 y:  $t(58) = 7.68$ ,  $p < .001$ ,  $r = .71$ ;  $\geq 80$  y:  $t(60) =$

**Table 1. Socio-demographic characteristics of the two age groups.**

	70–79 years		≥80 years	
	Women	Men	Women	Men
<b>N, n (%)</b>	34 (57.6%)	25 (42.4%)	44 (72.1%)	17 (27.9%)
<b>Age (years), mean ± SD</b>	74.3 ± 0.5	75.5 ± 0.5	85.0 ± 3.8 <sup>†</sup>	86.8 ± 4.0
<b>Habitation, n (%)</b>				
<i>independent</i>	32 (94.1%)	25 (100%)	33 (75.0%)	12 (70.6%)
<i>apartment for older adults</i>	1 (2.9%)	0	2 (4.5%)	1 (5.9%)
<i>senior residence</i>	1 (2.9%)	0	9 (20.5%)	4 (23.5%)
<i>special-care home</i>	0	0	0	0
<b>Education (years), mean ± SD</b>	13.0 ± 0.4	13.6 ± 0.4	12.5 ± 2.0*	13.9 ± 2.7
<b>Subjective health, n (%)</b>				
<i>very good</i>	4 (11.8%)	4 (16.0%)	3 (6.8%)	1 (5.9%)
<i>good</i>	18 (52.9%)	11 (44.0%)	19 (43.2%)	10 (58.8%)
<i>medium</i>	12 (35.3%)	7 (28.0%)	22 (50.0%)	5 (29.4%)
<i>poor</i>	0	2 (8.0%)	0	1 (5.9%)
<b>Falls last 6 months, n (%)</b>				
<i>0</i>	19 (55.9%)	19 (76.0%)	28 (63.6%)	11 (64.7%)
<i>1</i>	11 (32.4%)	5 (20.0%)	13 (29.5%)	4 (23.5%)
<i>&gt;1</i>	4 (11.8%)	1 (4.0%)	3 (6.8%)	2 (11.8%)
<b>Walking aids, n (%)</b>				
<i>none</i>	27 (79.4%)	23 (92.0%)	27 (61.4%)	9 (52.9%)
<i>cane</i>	5 (14.7%)	0	9 (20.5%)	5 (29.4%)
<i>walking frame</i>	2 (5.9%)	2 (8%)	7 (15.9%)	3 (17.6%)

SD, standard deviation.

<sup>†</sup> = trend for statistical difference between sexes within age group ( $p = .097$ ).

\* = significant statistical difference between sexes within age group ( $p = .023$ ).

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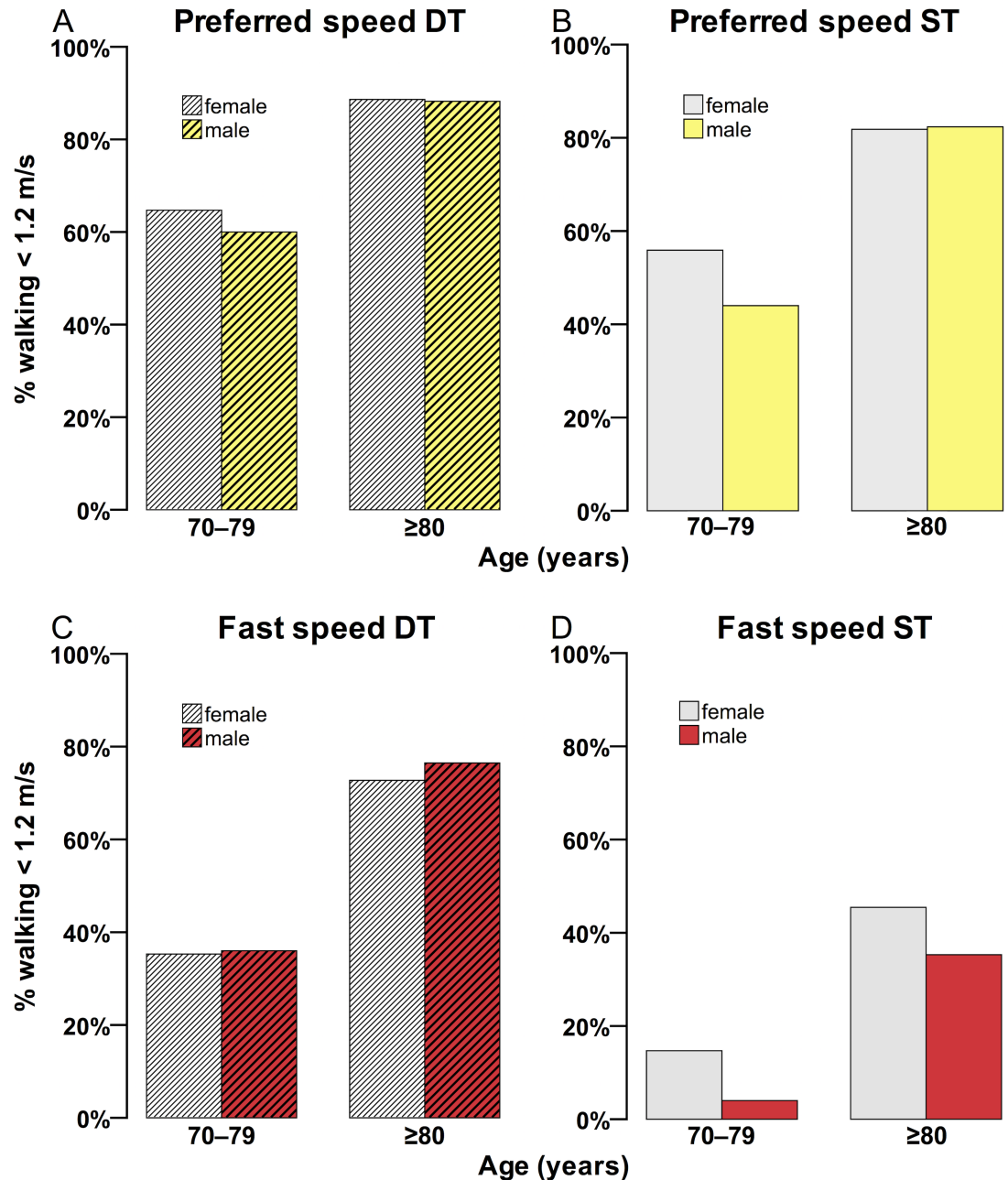
4.38,  $p < .001$ ,  $r = .49$ ). No differences in DTC between sexes were found. Performance data for all four walking conditions, as well as DTC, are summarized in [Table 2](#).

### Correlation with the 5-chair-rises test

A significant association was found between better performance (= shorter time duration) in the 5-chair-rises test and higher preferred and fast ST walking speeds, respectively ( $r_s = -.49$ , 95% BCa CI [-.628, -.350],  $p < .001$ ;  $r_s = -.51$ , 95% BCa CI [-.636, -.355],  $p < .001$ , [Fig 3](#)). No difference in 5-chair-rises test performance was evident between sexes within the age groups. The younger age group was significantly faster at completing the 5-chair-rises test ( $t(113) = -2.54$ ,  $p = .012$ ,  $r = .23$ ). Missing values in the 5-chair-rises test were present for one male participant in age group 70–79 years, and for two female and two male participants in age group >80 years. Performance data for the 5-chair-rises test are presented in [Table 2](#).

### Correlation with subjective health and fall frequency

Better *subjective health ratings* were significantly related to higher preferred and fast ST walking speeds, respectively, ( $\tau = .27$ , 95% BCa CI [.134, .404],  $p < .001$ ;  $\tau = .29$ , 95% BCa CI [.143, .425],  $p < .001$ ). The same result was found for the relation with the 5-chair-rises test ( $\tau = -.22$ , 95% BCa CI [.072, .352],  $p = .003$ ). Lower *retrospective fall frequency* was significantly associated with higher preferred and fast ST walking speeds, and shorter 5-chair-rises test time,



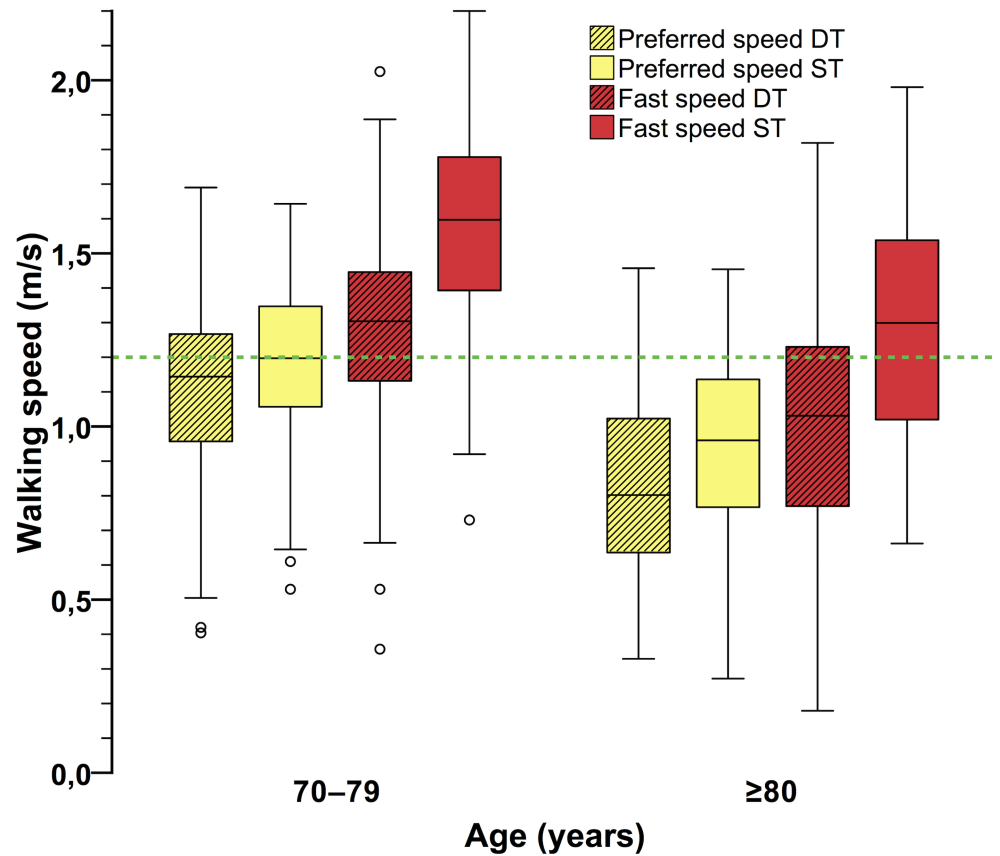
**Fig 1. Percentage of women and men walking slower than 1.2 m/s.** The graphs represent each of the four walking conditions (A–D). DT, dual-task; ST, single-task.

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respectively ( $\tau = -.23$ , 95% BCa CI  $[-.360, -.096]$ ,  $p = .002$ ;  $\tau = -.20$ , 95% BCa CI  $[-.334, -.053]$ ,  $p = .009$ ;  $\tau = .27$ , 95% BCa CI  $[.123, .414]$ ,  $p < .001$ ). Data for subjective health ratings and retrospective fall frequency are presented in [Table 1](#).

## Discussion

This study aimed to identify in a convenience sample of Swiss older adults the proportion that doesn't reach 1.2 m/s walking speed, which is required to safely cross streets within the green-



**Fig 2. Walking speed under the four walking conditions.** Mean walking speed was higher in the younger age group in all four respective walking conditions (all  $p < .001$ ). Mean values of adjacent boxplots in the respective age group are significantly different (all  $p < .05$ ). The dashed green line represents the required 1.2 m/s walking speed to cross streets safely within the green–yellow phase of pedestrian lights. DT, dual-task; ST, single-task.

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yellow phase of pedestrian lights, while walking fast under a cognitively challenging dual-task condition. Our main finding is that 35.6% of Swiss older adults of our convenience sample in

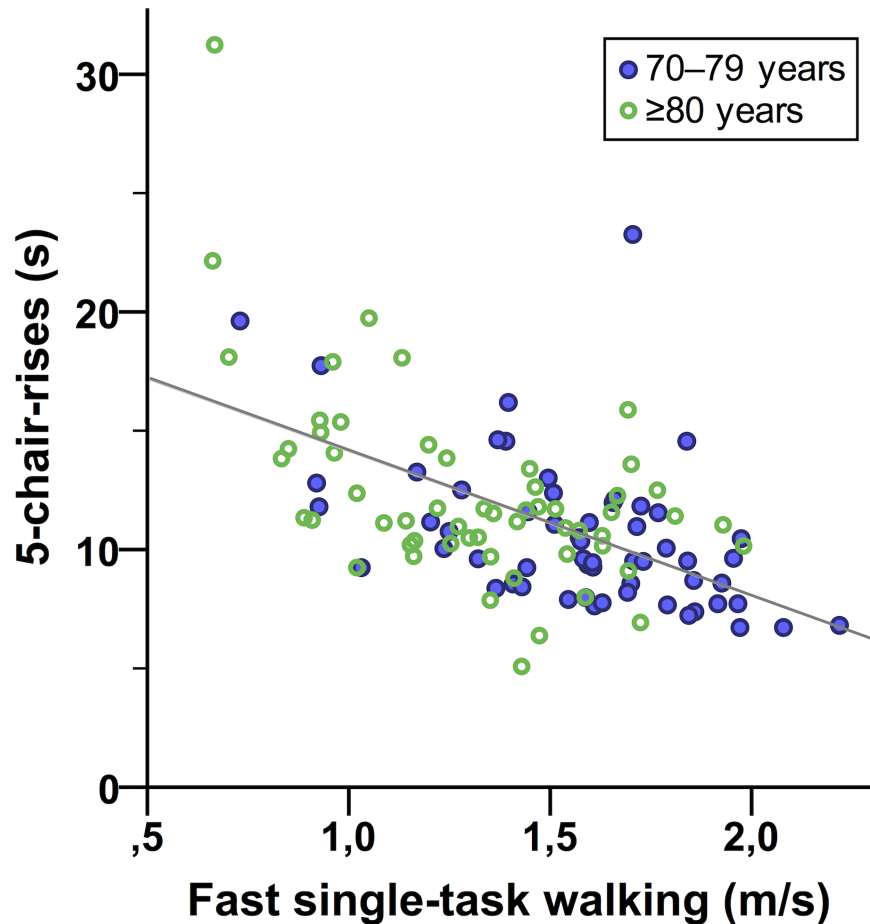
**Table 2. Walking speed, dual-task costs, and 5-chair-rises-test performance.**

	70–79 years		≥80 years	
	Women	Men	Women	Men
<b>Walking speed (m/s), mean ± SE</b>				
<i>Preferred DT</i>	1.08 ± 0.05	1.13 ± 0.05	0.83 ± 0.04	0.86 ± 0.06
<i>Preferred ST</i>	1.17 ± 0.04	1.21 ± 0.05	0.94 ± 0.04	0.96 ± 0.06
<i>Fast DT</i>	1.25 ± 0.05	1.33 ± 0.06	0.99 ± 0.05	1.03 ± 0.06
<i>Fast ST</i>	1.52 ± 0.05	1.63 ± 0.06	1.28 ± 0.05	1.31 ± 0.08
<b>Dual-task costs (%), mean ± SE</b>				
<i>Preferred</i>	-7.3 ± 3.2%	-6.3 ± 2.4%	-8.0 ± 4.0%	-10.4 ± 3.6%
<i>Fast</i>	-17.0 ± 2.5%	-18.2 ± 2.2%	-22.8 ± 2.3%	-20.6 ± 3.0%
<b>5-chair-rises test (s), mean ± SE</b>	11.2 ± 0.5	10.4 ± 0.7	12.9 ± 0.7	11.9 ± 0.9

SE, standard error; DT, dual-task; ST, single-task.

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**Fig 3. Association between fast single-task walking speed and performance in the 5-chair-rises test.** The gray line represents the regression line ( $y = 20.53 - 6.09 \times x$ ,  $R^2$  linear = 0.310).

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the age group of 70–79 years and 73.8% in the age group older than 80 years are not able to walk faster than 1.2 m/s under fast speed dual-task walking. Therefore, it seems feasible to conclude that a similar proportion of older adults is not capable of crossing streets safely within the green–yellow phase of pedestrian lights. These results, first, suggest that the fitness status of many older adults seems not to be appropriate to safely encounter the requirements for pedestrians in urban areas and, second, reinforce the need for regular cognitive and physical training in the older population [53] to keep up with the demands of daily life in the community.

Notably, to date no other study that stated a discrepancy between older adults walking ability and the requirements to cross streets at pedestrian lights, has interpreted their findings in the view of older adult’s lack of fitness. In contrast, these researchers recommended that policy makers should think about reducing the walking speed requirements at pedestrian lights [13–17, 19]. However, we would argue that this recommendation is tackling the problem of impaired walking and street crossing ability in older adults only indirectly. Generally, there are strong indications that cognitive and physical factors are related to the observed slowing of walking speed in older adults [12, 53], and recent research demonstrated that aging-related sensorial, cognitive and physical changes, have a major negative impact on older pedestrian’s mobility [10]. Furthermore, walking speed and cognitive measures (e.g. processing speed and spatial planning) are predictive of unsafe street crossing behavior in old adults [54]. Therefore,

the most direct way of enhancing older pedestrians' safety would include training of their cognitive and physical capacities [10, 54]. Particularly, walking speed is modifiable through strength training [55] and other physical exercise modalities [56] and is trainable until old age [55, 57, 58]. Cognitive components are improvable, for instance, through aerobic training [57, 58] or recent combined cognitive–physical training approaches [31, 59]. Consequently, older adults should invest time in modifying cognitive and physical capacities to improve their street crossing behavior, which represents one of the main components of pedestrian activity that older adults should be able to perform in order to maintain independence in daily functioning [10].

### Proportion of older adults walking slower than 1.2 m/s

A wide range of proportions of older adults walking slower than 1.2 m/s have been described previously [13–17, 19], ranging from 31% [13] to over 99% [17]. These proportions varied depending on the heterogeneity of the included samples; e.g. participants' age and health status, walking test conditions (preferred or fast speed, single- or dual-task), measurement methods (steady-state speed or speed including an acceleration phase), and sample size. Regarding these factors, the study by Donoghue and colleagues, examining an Irish nationally representative sample of 4909 participants, seems best suited for comparisons with our study. They similarly applied steady state walking speed measurements and were the only researchers to date that included a preferred speed dual-task walking condition [13]. Nonetheless, this is the first study applying a *fast speed dual-task walking* condition to approximate the real-life situation of crossing streets at pedestrian lights under cognitive challenges and time pressure. We found that under this test condition the proportion of older adults walking slower than 1.2 m/s is smaller compared to our preferred speed single- and dual-task walking results, thus confirming our hypothesis. In addition, our novel approach resulted in a more conservative estimation of the proportion of older adults that are at risk when crossing streets at pedestrian lights compared to the preferred speed dual-tasks walking approach applied by Donoghue and colleagues [13].

Comparing the *preferred speed dual-task walking* conditions, fewer of our Swiss 70–79 years old group were slower than 1.2 m/s (62.7%) than in the aforementioned Irish 65–74 years old group (76%) [13]. In the older age groups, this difference between the two studies was not present with almost identical values (88.5% Swiss vs. 91% Irish <1.2 m/s) [13]. We hypothesize that the discrepancy in the dual-task condition might have occurred due to disparate cognitive tasks that were added. In our study, a serial subtracting task was applied and adapted to each participant's abilities. On the other hand, Donoghue et al. asked their participants to recite alternate letters of the alphabet (e.g. A–C–E etc.) [13]. Apparently, in the younger participants, the letters task slowed walking speed more than the subtracting task. This effect might not have come into play in the older participants due to a similarly high percentage of around 90% in both studies. Nevertheless, Al-Yahya and colleagues asserted a lack of evidence regarding differential effects of specific cognitive tasks on walking speed [46]. Based on meta-analytical data, it was concluded that in general, tasks involving internal interference (e.g. mental tracking tasks, such as those described above) would disturb walking performance more than tasks involving external interference (e.g. reaction time tasks) [45, 46].

The younger participants in our study (70–79 y) tended to exhibit lower *fast walking speed dual-task costs* compared to the older participants ( $\geq 80$  y). This finding might reflect a cognitive advantage, since dual-task effects on walking speed, induced by mental tracking tasks, are strongly related with cognitive status as was shown by meta-analytical evidence [46]. In addition, our result is in line with the notion that younger adults (<40 y) demonstrated

consistently less interference on walking speed from concurrent cognitive tasks than healthy older adults [46]. Similarly, Zito and colleagues reported that older adults looked more at the ground while crossing a virtual street and to a lesser extent at the other side of the street compared to younger adults [60]. Together, these cognitive–motor dual-tasking effects could be explained with the *resource-based attentional model* which proposes that the total capacity of attentional resources is limited and declines at older age, causing problems in dual-task situations where attentional resources are shared between competing tasks [61, 62].

In the *preferred speed single-task walking* condition, about 20% more older adults in our sample walked slower than 1.2 m/s in both age groups (70–79 y and  $\geq 80$  y) when compared to the Donoghue et al. study. This discrepancy might be explained by the fact that participants in the latter study were divided into groups that were five years younger (65–74 y and  $\geq 75$  y) [13]. *Fast speed single-task walking* was assessed by one previous study. Amosun and colleagues tested 47 South African participants aged 65–93 years and reported that 34% walked slower than 1.2 m/s which is between the percentages of our two age groups showing 10.2% and 42.6%, respectively [19].

## Implications for cognitive and physical training

Recently, Leisman and colleagues argued that cognitive and motor processes are functionally connected, providing ample clinical and neural evidence supporting their dynamic bidirectional influences [63]. For instance, early impairments of cognitive processes, including attention, executive function, and working memory, were shown to be associated with slowed single- and dual-task walking speed and instability [64, 65]. The interrelation of cognition and gait in combination with the cognitive–motor dual-task characteristics of crossing streets at pedestrian lights asks for combined cognitive and physical training measures to improve older people's mobility and safety on public streets [60, 66].

Several studies attained positive effects from physical training on walking speed. For instance, Plummer and colleagues reported significant effects of physical exercise on single- and dual-task walking speed in their meta-analysis. The interventions included varied types of exercise with or without dual-task components. The authors concluded that improvements in dual-task walking were primarily on account of an increase in walking speed under dual-task conditions and not due to reduced dual-task costs [67]. Another recent meta-analysis by Van Abbema and colleagues demonstrated that progressive strength training (at 70–80% of the one repetition maximum) was most effective to improve preferred walking speed, followed by exercise with a rhythmic component, and combined strength, balance, and endurance training [55]. This concurs with our finding that higher walking speed correlated significantly with better functional lower extremity strength as measured with the 5-chair-rises test.

Moreover, in a recent combined cognitive–physical multicomponent training intervention with 71 older adults we have shown a 12% increase in preferred walking speed ( $1.16 \pm 0.24$  m/s to  $1.30 \pm 0.25$  m/s from pre- to post-test, respectively; mean  $\pm$  SD) and a concurrent improvement of 13% in preferred dual-task walking speed ( $1.05 \pm 0.29$  m/s to  $1.19 \pm 0.31$  m/s) [25]. Thereby, it seems noteworthy that an increase in preferred walking speed of 0.1 m/s was established as substantial and meaningful [2, 68, 69]. Interestingly, when translating the data of the latter study into the context of crossing streets at pedestrian lights, 42.6% of the participants (mean age  $78.9 \pm 5.5$  years) were not able to walk faster than 1.2 m/s under dual-task conditions at baseline, whereas after 6 months of training this percentage decreased to 25.5% (calculation based on original data from [25]). Additionally, the substantial improvements in walking speed were accompanied by broad improvements in various cognitive domains (including executive functions and attention) [31]. Such training-induced cognitive improvements appear to be

mediated by functional brain adaptations in the prefrontal cortex during challenging walking [59]. These adaptations might free up attentional resources that could be potentially useful when crossing streets in addition to improvements in walking speed.

## Walking speed and health-related parameters

Further support for the benefits of an adequate walking speed level and appropriate lower extremity strength is provided by their association with health-related parameters. Our results indicate a significant association between the *subjective health rating* and both, walking speed and functional lower extremity strength (5-chair-rises test), respectively. This finding is in line with other studies reporting a strong relationship between reduced walking speed and adverse health outcomes in older adults [1, 2, 70]. Thereby, preferred walking speed below 0.8 m/s (in a 4-meter walk) was established as a sensible and often used cut-point to identify persons at risk of adverse outcomes [2]. Moreover, our correlation analyses also show significant relations of *retrospective fall frequency* with both, walking speed and functional lower extremity strength. Similarly, a meta-analysis demonstrated that single- and dual-task walking speed tests were equally applicable to predict falls in older people [71]. However, findings appear to be controversial in this context, since a recent systematic review concluded that future fall risk is stronger related to dual-task than single-task gait testing [72].

## Strengths and limitations

A methodological strength of this study is the integration of four different walking conditions, comprising single- and dual-task walking at preferred and fast speed, to approximate real-life street crossing behavior at pedestrian lights. However, some limitations should be considered. First, the applied measurements of gait speed do only reflect an approximation of the conditions at real pedestrian lights, since the measurements were performed indoors in a protected environment, which implies a lack of ecological validity [73]. A second limitation of this study is that it includes a convenience sample of participants that either intended to participate in a prospective training intervention or that were additionally recruited for cross-sectional walking speed assessments. Therefore, it is possibly not representative for the general population of (Swiss) older adults and the data does not reflect normative aging. However, because average preferred single- and dual-task walking speeds in our heterogenic sample were comparable to values reported in two recent meta-analyses [29, 74], we assume that our measurements are reasonably representative. Moreover, the distribution of participants living independently vs. those living in senior residences was approximately in the range of the distribution in the Swiss older population (70–79 y: 1.7% of our sample living in senior residences vs. 1.7–4.8% of Swiss population, respectively;  $\geq 80$  y: 21.3% vs. 8.5–30.3%) [32]. Another, third, limitation of the presented data is that actual crosswalk speed requirements do not always follow the 1.2 m/s guideline, but appear to vary widely [15, 19, 75]. A recent systematic review, for instance, reported mean walking speed requirements of 0.44, 0.73–0.78, and 1.32 m/s, in the large cities of Melbourne, Singapore, and Los Angeles, respectively [75]. However, considering the limited number of crossroads that were analyzed in these studies, it still seems adequate to compare older adult's walking speed with the 1.2 m/s standard recommended by national traffic authorities, including the United States, Canada, the United Kingdom, Ireland, South Africa, and Switzerland [11, 13–15, 18, 19].

## Conclusions

This study demonstrates that about every third (35.6%) older person at the age of 70–79 years and almost three-quarters (73.8%) of persons  $\geq 80$  years cannot walk faster than 1.2 m/s,

which is required to cross streets safely within the green–yellow phase of pedestrian lights, under cognitively challenging conditions (fast speed dual-task walking). We propose that fast speed dual-task walking is more reflective of the time pressure and cognitive challenge at real pedestrian lights than the previously applied assessments of single- or dual-task walking at preferred speed. This novel approach led to a more conservative estimation of the proportion of older adults that are unable to walk as fast as 1.2 m/s compared to a previous investigation assessing dual-task walking at preferred speed [13]. Nonetheless, this proportion is still alarmingly high, given the fact that slowed walking speed is related to various adverse health outcomes [1, 2, 64, 65].

We therefore strongly recommend acknowledging the results of this and other similar studies as evidence that the fitness status of many older people is inadequate for maintaining their mobility-related independence in daily life and their safety as pedestrians in urban areas. In the long run, it clearly appears more fruitful to promote direct measures that improve the older population's cognitive and physical fitness instead of tackling the problem indirectly by adapting pedestrian light's settings as proposed by preceding studies [13–17, 19]. Slow walking speed, as the main cause of the problem, is modifiable particularly through strength and other training modalities [55, 56], while the cognitive, attentional components are improvable through aerobic [57, 58] and other exercise training modes [76, 77], or recent promising combined cognitive–physical training approaches [31, 59]. Future research should, therefore, investigate combinations of cognitive and physical training strategies targeting the dual-task requirements of safe street crossing behavior related to gait speed and assess their effectiveness in ecologically valid settings.

## Supporting information

**S1 Dataset. Complete dataset on which the present study is based.**  
(XLSX)

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## Author Contributions

**Conceptualization:** Patrick Eggenberger, Sara Tomovic, Thomas Münzer, Eling D. de Bruin.

**Formal analysis:** Patrick Eggenberger, Sara Tomovic.

**Funding acquisition:** Eling D. de Bruin.

**Investigation:** Patrick Eggenberger, Sara Tomovic.

**Methodology:** Patrick Eggenberger, Sara Tomovic, Thomas Münzer, Eling D. de Bruin.

**Resources:** Patrick Eggenberger, Sara Tomovic, Thomas Münzer, Eling D. de Bruin.

**Supervision:** Thomas Münzer, Eling D. de Bruin.

**Visualization:** Patrick Eggenberger.

**Writing – original draft:** Patrick Eggenberger.

**Writing – review & editing:** Patrick Eggenberger, Sara Tomovic, Thomas Münzer, Eling D. de Bruin.

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