Normal walking speed: A descriptive meta-analysis

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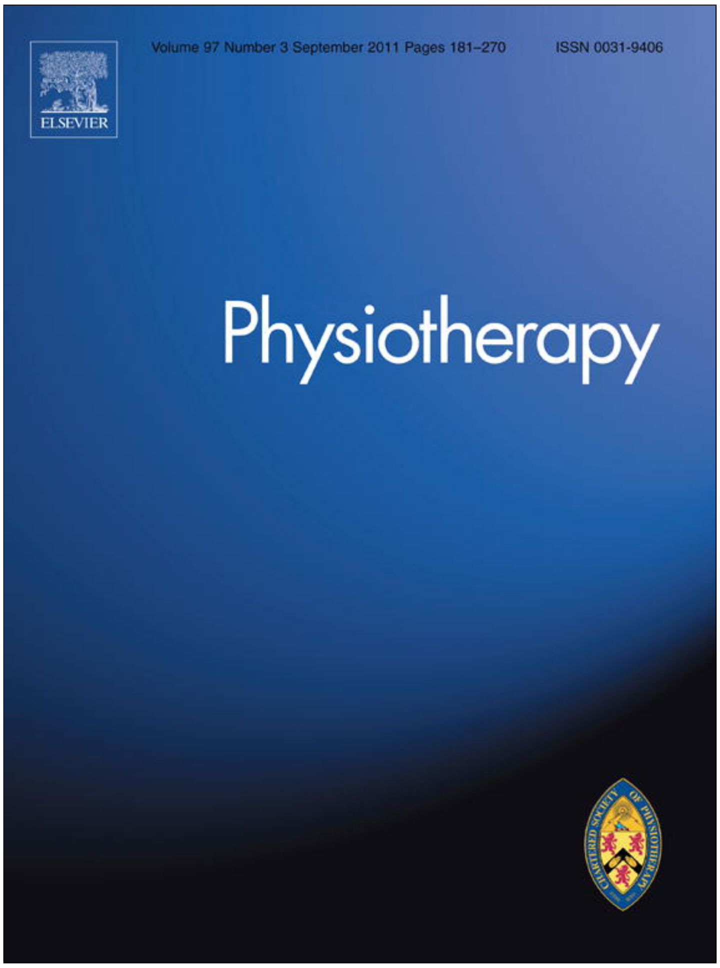
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Systematic review

Normal walking speed: a descriptive meta-analysis

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Abstract

Background Walking speed has implications for community functioning and is predictive of important outcomes. Determining whether an individual's walking speed is limited requires normal values for comparison.
Objectives To use meta-analysis to describe normal gait speed for healthy individuals within age and gender strata.
Data sources PubMed, the Cumulative Index of Nursing and Allied Health (CINAHL), Scopus, Science Citation Index and articles identified by hand searches.
Study selection criteria Inclusion required that the gait speed of apparently healthy adults was documented as they walked at a normal pace over a course of 3 to 30 m. Summary data were excluded unless obtained from at least 10 participants within a gender and decade stratum.
Study appraisal and synthesis methods The two authors independently reviewed articles and extracted data. Accuracy was confirmed by the other author. Data were grouped within gender and decade strata. A meta-analysis macro was used to consolidate data by strata and to determine homogeneity.
Results Forty-one articles contributed data to the analysis. Combined, they provided data from 23 111 subjects. The gait speed was homogeneous within strata and ranged from a mean of 143.4 cm/second for men aged 40 to 49 years to a mean of 94.3 cm/second for women aged 80 to 99 years.
Limitations The data presented herein may not be useful as a standard of normal if gait is measured over short distances from the command 'go' or if a turn is involved.
Conclusions and implications The consolidation of data from multiple studies reported in this meta-analysis provides normative data that can serve as a standard against which individuals can be compared. Doing so will aid the interpretation of their performance.

Keywords: Gait; Measurement; Meta-analysis; Normative values

Introduction

Walking is second only to private cars as the most common means by which individuals get from place to place in the USA and Europe [1]. The speed at which individuals walk is relevant to their functioning in the community [2,3]. Moreover, gait speed is an important predictor of outcomes such as: length of stay and discharge disposition for patients admitted for acute rehabilitation after stroke [4], mortality of older adults [5], incident ischaemic stroke among postmenopausal women [6], and incident dementia among older adults [7]. It should not be surprising, therefore, that gait speed is commonly measured by physical therapists and other clinicians [8,9].

Judgements about how an individual's task performance compares with that of a relevant population requires the availability of normative reference values (norms) for that population [10]. Several studies have presented data purported to be normative for comfortable walking speed [12–17]. Other studies, not normative by intent, present walking speed data for apparently healthy individuals. These studies, regardless of purpose, involve samples that vary greatly in number and composition. They also incorporate instructions, courses and timing procedures that vary considerably [18].

If the data from these seemingly diverse studies could be legitimately consolidated, a better sense of normal might

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be obtained than is provided by individual studies. Meta-analysis is a means by which relevant data from multiple sources can be consolidated if homogeneous. Such analysis has been used previously to estimate norms for other physical performance tests, such as the single-limb stance test [19], five repetition sit-to-stand test [20], and 6-minute walk test [21]. The purpose of this meta-analysis was to use the data from multiple relevant but diverse studies to estimate norms for normal gait speed that could be used in clinical practice.

Methods

Identification of potentially relevant literature began with the electronic search of four databases: PubMed, the Cumulative Index of Nursing and Allied Health (CINAHL), Scopus and Science Citation Index. The terms and Boolean mode used were (gait speed OR walking speed) AND (normal OR comfortable OR usual OR preferred OR self-selected). Databases were searched up to the end of 2008. Searches were limited to human subjects, adults aged ≥19 years and published in the English language. The two authors examined the search outputs for articles independently with a focus on articles that purported to report normative or reference values or values for population-based samples. The abstracts of articles deemed to be potentially relevant by either author were examined to determine if perusal of the full-text was warranted. Each author inspected the full-text of articles that he deemed likely to contain relevant information on gait speed. Thereafter, hand searches of articles in reference lists and personal files were performed. These searches permitted the inclusion of articles published after the electronic search end-date.

For data in an article to be included, the source article had to describe: (1) normal speed (or equivalent) as opposed to fast or maximum speed gait; (2) overground gait as opposed to treadmill gait; (3) gait speed measured over a distance of at least 3 m (10 feet) but no more than 30.5 m (100 feet); and (4) gait speed measured with an allowance for acceleration and deceleration (i.e. not from the command 'go') unless the distance was more than 25 m. This last criterion was included to exclude reaction time and to help ensure that steady-state speed was approached before timing began. Previous research has shown that steady-state speed can be reached by the end of a first step [22]. Data were excluded if they were: (1) gathered from patients with pathology (e.g. stroke); (2) obtained from a decade and age stratum with less than 10 male or female subjects; (3) collected from walking trials involving a turn [23]; or (4) acquired by the observation of pedestrians. Potentially relevant literature was abstracted for the following information: (1) source; (2) participants' characteristics (sample type, country, number, age and gender); (3) method of measuring speed; and (4) mean and standard deviation of walking speed. Where important information regarding methods or walking speed was not presented in an article, the authors were contacted by e-mail to obtain the necessary details. Of the 39 authors contacted, 26 responded with the necessary information. Data were entered into a Statistical Package for the Social Sciences database (SPSS Inc., Chicago, IL, USA). The inverse variance of gait speed was computed from the standard deviation of gait speed. A macro provided by Wilson [24] used this inverse variance along with the mean gait speed and sample size (n) for each gender and age stratum (e.g. male, 20 to 29 years) from all relevant studies to determine effect size (weighted grand mean) and homogeneity. Homogeneity, the degree to which the effect sizes from contributing studies estimate the same population mean, was described using the Q statistic [25].

Results

The yield of potentially relevant articles for the four databases was: PubMed, 621; CINAHL, 509; Scopus, 1622; and Science Citation Index, 674. Based on the focus of this study, adherence to inclusion and exclusion criteria, and ability to obtain clarification from authors, 41 articles were ultimately judged to be relevant sources of data for normal gait speed (Table 1) [12–17,26–61]. Most of the investigations employed convenience samples. However, 15 articles presented data gathered, at least in part, from population-based samples. Individual studies contributed from 10 to 8883 subjects. The total number of subjects for all studies was 23 111. The distances over which speed was measured ranged from 3.7 to 30 m. A stopwatch was used in most studies ($n = 19$), but instrumented walkways, photocells and other methods were also used.

The results of the meta-analysis are presented by strata in Table 2. Depending on the stratum, grand mean speed ranged from 94.3 cm/second (women aged 80 to 99 years) to 143.4 cm/second (men aged 40 to 49 years). The grand mean gait speed was relatively consistent for the decades 20 to 29 years to 60 to 69 years for men (133.9 to 143.3 cm/second) and women (124.1 to 139.0 cm/second). Thereafter, the grand means fell outside the lower level of the confidence intervals of all previous decades. By the time subjects were aged 80 years or more, their mean gait speed declined to less than 100 cm/second. The Q statistics for all strata had probability levels exceeding 0.05. Consequently, within strata, studies were homogeneous and consolidation of their data was justified [25].

Discussion

Given the relevance of gait speed to community ambulation [2,3] and its value as a predictor of important outcomes [4–9], it should not be surprising that gait speed has been recommended as a 'vital sign' [62,63]. As such, an individual's gait speed can be interpreted relative to a criterion reference or a normative reference [10,11], the focus of this meta-analysis. By consolidating data from numerous diverse studies, this meta-analysis provides strata-specific estimates

Table 1
Summary of studies included in meta-analysis.

Study	Study sample	Test specifics				Stratified speed data (cm/second)
	Type (location)	Distance (m)	Timing	Gender (*n*)	Age group (years)	Mean (SD)
Al-Obaidi 2003 [17]	Convenience (Kuwait)	3.8	Gait mat	Male (15)	20 to 29	121.7 (19.9)
				Female (15)	20 to 29	108.2 (14.6)
Aniansson 1980 [26]	Population-based (Sweden)	30	Stopwatch	Male (160)	70 to 79	120.0 (20.0)
				Female (194)	70 to 79	110.0 (20.0)
Aoyagi 2001 [27]	Population-based (Japan)[a]	6	Stopwatch	Female (82)	60 to 69	108.0 (32.0)
				Female (50)	70 to 79	99.0 (29.0)
				Female (19)	70 to 79	89.0 (31.0)
				Female (12)	80 to 99	86.0 (28.0)
	Population-based (Japan and USA)[b]	6	Stopwatch	Female (113)	60 to 69	118.0 (38.0)
				Female (273)	70 to 79	112.0 (34.0)
				Female (218)	70 to 79	101.0 (38.0)
				Female (76)	80 to 99	87.0 (36.0)
	Population-based (USA)[c]	6	Stopwatch	Female (3535)	60 to 69	97.0 (30.0)
				Female (2557)	70 to 79	90.0 (26.0)
				Female (1258)	70 to 79	83.0 (36.0)
				Female (690)	80 to 99	74.0 (27.0)
Arnadottir 2000 [28]	Convenience (USA)	10	Stopwatch	Female (14)	70 to 79	126.0 (28.0)
				Female (17)	80 to 99	117.0 (24.0)
Atkinson 2007 [29]	Population-based (USA)[d]	20	Stopwatch	Male (1120)	70 to 79	120.0 (21.0)
				Female (1229)	70 to 79	111.0 (21.0)
Ble 2005 [61]	Population-based (Italy)[e]	4	Photocell	Male (27)	20 to 29	131.1 (19.7)
				Male (30)	30 to 39	137.5 (18.3)
				Male (27)	40 to 49	127.0 (16.8)
				Male (28)	50 to 59	126.5 (16.4)
				Male (157)	60 to 69	119.4 (23.1)
				Male (213)	70 to 79	106.8 (23.9)
				Male (65)	80 to 99	87.6 (25.7)
				Male (15)	80 to 99	60.8 (30.3)
				Female (24)	20 to 29	126.6 (21.5)
				Female (32)	30 to 39	125.6 (15.5)
				Female (27)	40 to 49	128.3 (14.6)
				Female (37)	50 to 59	123.9 (18.2)
				Female (180)	60 to 69	105.7 (18.8)
				Female (253)	70 to 79	94.7 (25.6)
				Female (111)	80 to 99	71.2 (25.0)
				Female (22)	80 to 99	55.7 (24.5)
Bohannon 1997 [12]	Convenience (USA)	7	Stopwatch	Male (15)	20 to 29	139.3 (15.3)
				Male (13)	30 to 39	145.8 (9.4)
				Male (22)	40 to 49	146.2 (16.4)
				Male (22)	50 to 59	139.3 (22.9)
				Male (18)	60 to 69	135.9 (20.5)
				Male (22)	70 to 79	133.0 (19.6)
				Female (22)	20 to 29	140.7 (17.5)
				Female (23)	30 to 39	141.5 (12.7)
				Female (21)	40 to 49	139.1 (15.8)
				Female (21)	50 to 59	139.5 (15.1)
				Female (18)	60 to 69	129.6 (21.3)
				Female (20)	70 to 79	127.2 (21.1)
Bohannon 2008 [31]	Population-based (USA)[f]	6.1	Stopwatch	Male (311)	50 to 59	112.2 (21.0)
				Male (292)	60 to 69	103.3 (21.0)
				Male (237)	70 to 79	95.7 (22.9)
				Male (134)	80 to 99	83.2 (22.2)
				Female (281)	50 to 59	110.9 (22.2)
				Female (318)	60 to 69	100.6 (22.9)
				Female (210)	70 to 79	93.0 (22.9)
				Female (140)	80 to 99	78.3 (21.9)
Bohannon 1996 [30]	Convenience (USA)	7.6	Stopwatch	Male (20)	50 to 59	149.1 (19.0)
				Male (22)	60 to 69	147.9 (11.3)
				Male (22)	70 to 79	141.8 (21.3)
				Female (20)	50 to 59	140.4 (21.0)

Table 1 (*Continued*)

Study	Study sample	Test specifics				Stratified speed data (cm/second)
	Type (location)	Distance (m)	Timing	Gender (*n*)	Age group (years)	Mean (SD)
				Female (27)	60 to 69	143.2 (16.8)
				Female (21)	70 to 79	134.3 (19.6)
Brach 2007 [32]	Population-based (USA)[g]	4	Gait mat	Male (108)	70 to 79	112.0 (20.0)
				Male (84)	80 to 99	106.0 (21.0)
				Female (183)	70 to 79	104.0 (19.0)
				Female (120)	80 to 99	94.0 (20.0)
Busse 2006 [34]	Convenience (UK)	10	Camera	Male (11)	30 to 39	153.8 (16.0)
				Female (15)	20 to 29	149.9 (18.9)
				Female (14)	30 to 39	138.1 (23.5)
				Female (13)	40 to 49	133.6 (27.6)
				Female (11)	50 to 59	123.2 (10.5)
Button 2005 [35]	Convenience (UK)	15	Camera	Male (17)	20 to 29	147.4 (13.6)
				Male (14)	30 to 39	143.2 (13.6)
				Female (22)	20 to 29	144.8 (25.1)
Callisaya 2008 [36]	Population-based (Australia)[h]	4.2	Gait mat	Male (15)	60 to 69	126.3 (21.0)
				Male (28)	60 to 69	120.6 (15.0)
				Male (27)	70 to 79	113.7 (12.4)
				Male (26)	70 to 79	108.6 (22.0)
				Male (24)	80 to 99	103.9 (14.9)
				Female (22)	60 to 69	116.5 (17.0)
				Female (21)	60 to 69	116.6 (15.5)
				Female (15)	70 to 79	121.9 (19.2)
				Female (27)	70 to 79	104.4 (16.4)
				Female (18)	80 to 99	88.6 (19.4)
Cyarto 2004 [37]	Convenience (Canada)	7	Photo cell	Female (14)	70 to 79	122.0 (18.0)
Delval 2006 [38]	Convenience (France)	10	Camera	Male (11)	20 to 29	135.3 (9.3)
DePasquale 2009 [43]	Convenience (USA)	3	Stopwatch	Male (13)	80 to 99	117.9 (32.2)
				Female (10)	70 to 79	117.5 (18.0)
				Female (23)	80 to 99	110.8 (20.9)
Fitzpatrick 2007 [33]	Population-based/convenience (USA)[i]	4.6	Stopwatch	Male (1083)	70 to 79	98.9 (20.1)
				Male (564)	80 to 99	93.4 (27.3)
				Female (939)	70 to 79	94.3 (23.0)
				Female (467)	80 to 99	87.0 (23.0)
Freiberger 2007 [40]	Population-based (Germany)	8	Stopwatch	Male (141)	70 to 79	139.6 (27.6)
				Male (35)	80 to 99	122.1 (29.7)
				Female (106)	70 to 79	129.9 (25.2)
				Female (35)	80 to 99	113.8 (24.0)
Goble 2003 [41]	Convenience (USA)	4	Radar gun	Male (20)	20 to 29	138.0 (16.0)
Haghani 2000 [42]	Convenience (Canada)	8	Stopwatch	Male (10)	20 to 29	144.0 (25.0)
Hansen 2004 [44]	Convenience (USA)	3.7	Camera	Female (12)	20 to 29	137.0 (22.0)
Hill 1999 [45]	Convenience (Australia)	6	Stopwatch	Female (60)	70 to 79	116.3 (66.8)
				Female (27)	70 to 79	109.2 (77.8)
Hollman 2007 [46]	Convenience (USA)	8.3	Gait mat	Female (10)	20 to 29	138.7 (12.6)
Kamide 2009 [59]	Convenience (Japan)	7.0	Stopwatch	Female (20)	60 to 69	143.0 (16.0)
				Female (56)	70 to 79	135.0 (22.0)
				Female (23)	80 to 99	116.0 (16.0)
Laufer 2003 [60]	Convenience (Israel)	3.7	Gait mat	Male (14)	20 to 29	146.5 (18.5)
				Female (15)	20 to 29	144.5 (16.6)
				Female (11)	70 to 79	96.2 (27.2)
Leiper 1991 [47]	Convenience (USA)	3.8	Gait mat	Female (20)	60 to 69	113.0 (13.0)
				Female (35)	70 to 79	97.0 (21.0)
				Female (26)	80 to 99	86.0 (22.0)
Lindsey 2005 [48]	Convenience (USA)	8	Stopwatch	Female (10)	50 to 59	155.0 (25.0)
				Female (67)	60 to 69	145.0 (22.0)
				Female (34)	70 to 79	136.0 (28.0)
Lord 1996 [49]	Population-based (Australia)[j]	7.2	Sensors	Female (21)	20 to 29	138.0 (16.0)
				Female (20)	30 to 39	132.0 (17.0)
				Female (19)	40 to 49	129.0 (12.0)
				Female (18)	50 to 59	

Table 1 (*Continued*)

Study	Study sample	Test specifics				Stratified speed data (cm/second)
	Type (location)	Distance (m)	Timing	Gender (*n*)	Age group (years)	Mean (SD)
	124.0 (19.0)					
				Female (37)	60 to 69	113.0 (16.0)
				Female (22)	70 to 79	107.0 (17.0)
				Female (26)	70 to 79	101.0 (19.0)
				Female (11)	80 to 99	96.0 (19.0)
Lusardi 2003 [13]	Convenience (USA)	3.7	Gait mat	Female (10)	70 to 79	125.0 (18.0)
				Female (17)	80 to 99	87.0 (16.0)
Mills 2001 [50]	Convenience (Australia)	5	Photocell	Male (10)	20 to 29	141.0 (12.6)
Mündermann 2004 [50]	Convenience (USA)	9.1	Camera	Male (18)	60 to 69	107.7 (16.0)
				Female (10)	40 to 49	122.0 (11.0)
				Female (14)	50 to 59	135.0 (24.0)
				Female (18)	60 to 69	119.0 (10.0)
Nagasaki 1996 [52]	Population-based (Japan)	5.0	Stopwatch	Male (208)	60 to 69	128.6 (23.8)
				Male (135)	70 to 79	118.0 (24.3)
				Male (84)	70 to 79	110.5 (26.5)
				Male (48)	80 to 99	92.3 (21.8)
				Female (260)	60 to 69	118.3 (24.0)
				Female (213)	70 to 79	103.8 (27.0)
				Female (108)	70 to 79	97.0 (23.2)
				Female (75)	80 to 99	80.3 (24.2)
Öberg 1993 [14]	Convenience (Sweden)	5.5	Photocell	Male (15)	20 to 29	123.0 (11.0)
				Male (15)	30 to 39	132.0 (15.0)
				Male (15)	40 to 49	133.0 (10.0)
				Male (15)	50 to 59	125.0 (18.0)
				Male (15)	60 to 69	128.0 (12.0)
				Male (15)	70 to 79	118.0 (15.0)
				Female (15)	20 to 29	124.0 (17.0)
				Female (15)	30 to 39	128.0 (19.0)
				Female (15)	40 to 49	125.0 (14.0)
				Female (15)	50 to 59	110.0 (10.0)
				Female (15)	60 to 69	116.0 (17.0)
				Female (15)	70 to 79	111.0 (12.0)
Obuchi 1994 [53]	Population (Japan)	5	Stopwatch	Male (107)	60 to 69	126.2 (23.7)
				Female (146)	60 to 69	116.5 (19.7)
Purser 2003 [54]	Convenience (USA)	10	Stopwatch	Male (10)	60 to 69	121.3 (11.8)
				Male (28)	70 to 79	119.8 (14.7)
				Female (38)	60 to 69	112.8 (15.0)
				Female (48)	70 to 79	108.9 (18.3)
Rogers 2005 [55]	Convenience (USA)	10	Camera	Female (10)	20 to 29	135.0 (15.9)
Steffen 2002 [15]	Convenience (USA)	6	Stopwatch	Male (15)	60 to 69	159.0 (24.0)
				Male (14)	70 to 79	138.0 (23.0)
				Female (22)	60 to 69	144.0 (25.0)
				Female (22)	70 to 79	133.0 (22.0)
				Female (15)	80 to 99	115.0 (21.0)
Tiedemann 2005 [56]	Population-based (Australia)	6	Stopwatch	Male 124)	70 to 79	115.6 (24.9)
				Male (98)	80 to 99	109.6 (23.9)
				Male (11)	80 to 99	86.0 (18.9)
				Female (225)	70 to 79	110.8 (19.9)
				Female (199)	80 to 99	98.2 (22.3)
				Female (11)	80 to 99	79.6 (25.2)
Van Iersel 2007 [57]	Convenience (Holland)	6	Gait mat	Male (17)	70 to 79	140.7 (13.1)
				Female (41)	70 to 79	150.0 (18.7)
Willén 2004 [58]	Population-based (Sweden)	30	Stopwatch	Male (16)	40 to 49	147.0 (22.0)
				Male (20)	50 to 59	143.0 (16.0)
				Male (18)	60 to 69	139.0 (13.0)
				Male (15)	70 to 79	132.0 (16.0)
				Female (18)	40 to 49	140.0 (14.0)
				Female (14)	50 to 59	143.0 (19.0)
				Female (27)	60 to 69	128.0 (24.0)
				Female (14)	70 to 79	116.0 (23.0)

Table 1 (*Continued*)

Study	Study sample	Test specifics				Stratified speed data (cm/second)
	Type (location)	Distance (m)	Timing	Gender (*n*)	Age group (years)	Mean (SD)
Wolfson 1996 [39]	Population-based (USA)	8	Photo cell	Male (39)	70 to 79	123.2 (16.3)
				Male (24)	80 to 99	113.0 (25.1)
				Female (26)	70 to 79	113.2 (19.1)
				Female (20)	80 to 99	99.1 (18.4)

SD, standard deviation.
[a] Mitsugi Bone and Joint Study.
[b] Hawaii Osteoporosis Study.
[c] Study of Osteoporotic Fractures.
[d] Health Male: ABC.
[e] InCHIANTI.
[f] NHANES.
[g] Cardiovascular Health Study.
[h] TASCOG.
[i] Ginkgo Evaluation of Memory Study.
[j] Radwich Falls and Fractures Study.

Table 2
Results of meta-analysis.

Strata gender (age in years)	Source articles (*n*)	Subjects (*n*)	Gait speed (cm/second)	Grand mean (95% CI) range	Homogeneity *Q* (*P*)
Men (20 to 29)	10	155	135.8 (127.0 to 144.7)	121.7 to 147.4	3.255 (0.953)
Men (30 to 39)	5	83	143.3 (131.6 to 155.0)	132.0 to 153.8	1.169 (0.883)
Men (40 to 49)	4	96	143.4 (135.3 to 151.4)	127.0 to 147.0	2.609 (0.625)
Men (50 to 59)	6	436	143.3 (137.9 to 148.8)	112.2 to 149.1	4.721 (0.580)
Men (60 to 69)	12	941	133.9 (126.6 to 141.2)	103.3 to 159.0	15.217 (0.294)
Men (70 to 79)	18	3671	126.2 (121.0 to 132.2)	95.7 to 141.8	12.848 (0.914)
Men (80 to 99)	10	1091	96.8 (83.4 to 110.1)	60.8 to 122.1	4.159 (0.940)
Women (20 to 29)	11	180	134. 1 (123.9 to 144.3)	108.2 to 149.9	5.307 (0.870)
Women (30 to 39)	5	104	133.7 (119.3 to 148.2)	125.6 to 141.5	0.785 (0.940)
Women (40 to 49)	7	142	139.0 (133.9 to 141.1)	122.0 to 142.0	5.666 (0.579)
Women (50 to 59)	10	456	131.3 (122.2 to 140.5)	110.0 to 155.5	12.291 (0.266)
Women (60 to 69)	17	5013	124.1 (118.3 to 130.0)	97.0 to 145.0	11.515 (0.932)
Women (70 to 79)	29	8591	113.2 (107.2 to 119.2)	83.0 to 150.0	16.775 (0.998)
Women (80 to 99)	17	2152	94.3 (85.2 to 103.4)	55.7 to 117.0	11.428 (0.954)

CI, confidence interval.

of normal gait speed that are more precise than those possible with individual studies. Despite the diversity of subject pools and procedures employed in studies included in this meta-analysis, the consolidated studies were homogeneous. While this was not a foregone conclusion, many of the factors that might have influenced gait speed [64] were controlled via inclusion and exclusion criteria.

This study does have several limitations. First, it is not comprehensive. Although four databases were used to find relevant literature, the final search was up to the end of 2008. Between that time and the present, relevant articles other than the two identified through hand searches may have been published. Of the relevant articles identified, some did not provide data in a manner that enabled inclusion. If the authors of a study could not be reached, failed to respond or refused to provide the necessary information, the data could not be incorporated. This resulted in the loss of several thousand subjects. Second, the quality of the studies included was not rated. While quality 'is of obvious relevance to meta-analysis' [65], quality rating scales are typically designed for use with clinical trials. This meta-analysis merely used descriptive data. Third, no sensitivity analysis was performed. As data within strata were homogeneous, such analysis was not deemed to be necessary or informative. Fourth, factors other than age and gender (e.g. stature) that are known to affect gait speed [66] were not addressed. They were too infrequently reported to consider.

Conclusions

This meta-analysis consolidates measurements of normal gait speed from over 23 000 subjects tested in 41 different studies. Normative reference values are provided for gender- and age-specific strata. The norms provided can be used to determine how an individual's speed compares with the average for healthy individuals of the same gender and age.

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Conflict of interest: None declared.

References

[1] Mitchell C. Pedestrian mobility and safety. A key to independence for older people. Top Geriatr Rehabil 2006;22:45–52.

[2] Robinett CS, Vondran MA. Functional ambulation velocity and distance requirements in rural and urban communities. Phys Ther 1988;68:1371–2.

[3] Langlois JA, Keyl PM, Guralnik JM, Foley DJ, Marottoli RA, Wallace RB. Characteristics of older pedestrians who have difficulty crossing the street. Am J Publ Health 1997;87:393–7.

[4] Rabadi MH, Blau A. Admission ambulation velocity predicts length of stay and discharge disposition following stroke in an acute rehabilitation hospital. Neurorehabil Neural Repair 2005;19:20–6.

[5] Ostir GV, Kuo Y-F, Berges IM, Markides KS, Ottenbacher KJ. Measures of lower body function and risk of mortality over 7 years of follow-up. Am J Epidemiol 2007;166:599–605.

[6] McGinn AP, Kaplan RC, Verghese J, Rosenbaum DM, Psaty BM, Baird AE, *et al.* Walking speed and risk of incident ischemic stroke among postmenopausal women. Stroke 2008;39:1233–9.

[7] Waite LM, Grayson DA, Piguet O, Creasey H, Bennett HP, Broe GA. Gait slowing as a predictor of incident dementia: 6-year longitudinal data from the Sydney Older Persons Study. J Neurol Sci 2005;229–230:89–93.

[8] Andrews AW, Folger SE, Norbet SE, Swift LC. Tests and measures used by specialist physical therapists when examining patients with stroke. J Neurol Phys Ther 2008;32:122–8.

[9] Howard LS, Doherty P, Boyes C. A survey of outcome measurement of balance, walking and gait amongst physiotherapists working in neurology in the UK. Physiotherapy 2008;94:125–32.

[10] Rothstein JM, Echternach JL. Primer on measurement: an introductory guide to measurement issues. Alexandria, VA: American Physical Therapy Association; 1993. pp. 46–54.

[11] Mitrushina M, Boone KB, Razani, D'Elia LF. Handbook of normative data for neuropsychological assessment. 2nd edn. New York: Oxford University Press; 2005.

[12] Bohannon RW. Comfortable and maximum walking speed of adults aged 20 to 79 years: reference values and determinants. Age Ageing 1997;26:15–9.

[13] Lusardi MM, Pellecchia GL, Schulman M. Functional performance in community living older adults. J Geriatr Phys Ther 2003;26:14–22.

[14] Öberg T, Karsznia A, Öberg K. Basic gait parameters: reference data for normal subjects, 10 to 79 years of age. J Rehabil Res Dev 1993;30:210–23.

[15] Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: six minute walk test, Berg balance scale, timed up & go test, and gait speeds. Phys Ther 2002;82:128–37.

[16] Hinman JE, Cunningham DA, Rechnitzer PA, Paterson DH. Age-related changes in gait speed of walking. Med Sci Sports Exerc 1988;20:161–6.

[17] Al-Obaidi S, Wall JC, Al-Yaqoub A, Al-Ghanim M. Basic gait parameters: a comparison of reference data for normal subjects 20–29 years of age from Kuwait and Scandinavia. J Rehab Res Devel 2003;40:361–6.

[18] Graham JE, Ostir GV, Fisher SR, Ottenbacher KJ. Assessing walking speed in clinical research: a systematic review. J Eval Clin Pract 2008;14:552–62.

[19] Bohannon RW. Reference values for single limb stance: a descriptive metaanalysis. Top Geriatr Rehabil 2006;22:70–7.

[20] Bohannon RW. Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders. Percept Motor Skills 2006;103:215–22.

[21] Bohannon RW. Six-minute walk test: a meta-analysis of data from apparently healthy elders. Top Geriatr Rehabil 2007;23:155–60.

[22] Breniere Y, Do MC. When and how does steady state gait movement induced from upright posture begin? J Biomech 1986;19:1035–40.

[23] Van Herk IEH, Arendzen JH, Rispens P. Ten-metre walk, with or without a turn? Clin Rehabil 1998;12:30–5.

[24] Wilson DB. Meta-analysis stuff. Available at: http://mason.gmu.edu/~dwilsonb/home.html (last accessed 01.07.2009).

[25] Lipsey MW, Wilson DB. Practical meta-analysis. Thousand Oaks, CA: Sage Publications; 2001.

[26] Aniansson A, Rungren Å, Sperling L. Evaluation of functional capacity in activities of daily living in 70-year-old men and women. Scand J Rehab Med 1980;12:145–54.

[27] Aoyagi K, Ross PD, Nevitt MC, Davis JW, Wasnich RD, Hayashi T, *et al.* Comparison of performance-based measures among native Japanese, Japanese-Americans in Hawaii and Caucasian women in the United States, ages 65 years and over: a cross-sectional study. BMC Geriatr 2001;1:3.

[28] Arnadottir SA, Mercer VS. Effects of footwear on measurements of balance and gait in women between the ages of 65 and 93 years. Phys Ther 2000;80:17–27.

[29] Atkinson HH, Rosano C, Simonsick EM, Williamson JD, Davis C, Ambrosius WT, *et al.* Cognitive function, gait speed decline, and comorbidities: the Health, Aging and Body Composition Study. J Gerontol Med Sci 2007;62A:844–50.

[30] Bohannon RW, Andrews AW, Thomas MW. Walking speed: reference values and correlates for older adults. J Orthop Sports Phys Ther 1996;24:86–90.

[31] Bohannon RW. Population representative gait speed and its determinants. J Geriatr Phys Ther 2008;31:49–52.

[32] Brach JS, Studenski SA, Perera S, VanSwearingen JM, Newman AB. Gait variability and the risk of incident mobility disability in community-dwelling older adults. J Gerontol Med Sci 2007;62A:983–8.

[33] Fitzpatrick AL, Buchanan CK, Nahin RL, Dekosky ST, Atkinson HH, Carlson MC, *et al.* Association of gait speed and other measures of physical function with cognition in a healthy cohort of elderly persons. J Gerontol A Biol Sci Med Sci 2007;62:1244–51.

[34] Busse ME, Wiles CM, van Deursen RWM. Community walking activity in neurological disorders with leg weakness. J Neurol Neurosurg Psychiatry 2006;77:359–62.

[35] Button K, van Deursen R, Price P. Measurement of functional recovery in individuals with acute anterior cruciate ligament rupture. Br J Sports Med 2005;39:866–71.

[36] Callisaya ML, Blizzard L, Schmidt MD, McGinley JL, Srikanth VK. Sex modifies the relationship between age and gait: a population-based study of older adults. J Gerontol Med Sci 2008;63A:165–70.

[37] Cyarto EV, Myers AM, Tudor-Locke C. Pedometer accuracy in nursing home and community-dwelling older adults. Med Sci Sports Exerc 2004;36:205–9.

[38] Delval A, Krystkowiak P, Blatt J-L, Labyt E, Dujaardin K, Destée A, *et al.* Role of hypokinesia and bradykinesia in gait disturbances in Huntington's disease. J Neurol 2006;253:73–80.

[39] Wolfson L, Whipple R, Derby C, Judge J, King M, Amerman P, *et al.* Balance and strength training in older adults: intervention gains and Tai Chi maintenance. J Am Geriatr Soc 1996;44:498–506.

[40] Freiberger E, Menz HB, Abu-Omar K, Rütten A. Preventing falls in physically active community-dwelling older people: a comparison of two intervention techniques. Gerontology 2007;53: 298–305.

[41] Goble DJ, Marino GW, Potvin JR. The influence of horizontal velocity on interlimb symmetry in normal walking. Hum Mov Sci 2003;22:271–83.

[42] Haghani H, Marks R. Relationship between maximal isometric knee extensor and flexor strength measures, age and walking speed of healthy men and women aged 18 to 74. Physiother Can 2000;52: 33–8.

[43] DePasquale L, Toscano L. The Spring Scale Test: a reliable and valid tool for explaining fall history. J Geriatr Phys Ther 2009;32:159–67.
[44] Hansen AH, Childress DS, Miff SC, Gard SA, Mesplay KP. The human ankle during walking: implications for design of biomimetic ankle prostheses. J Biomech 2004;37:1467–74.
[45] Hill K, Schwarz J, Flicker L, Carroll S. Falls among healthy, community-dwelling, older women: a prospective study of frequency, circumstances, consequences and predictive accuracy. Aust N Z J Public Health 1999;23:41–4.
[46] Hollman JH, Kovash FM, Kubik JJ, Linbo RA. Age-related differences in spatiotemporal markers of gait stability during dual task walking. Gait Posture 2007;26:113–9.
[47] Leiper CI, Craik RL. Relationships between physical activity and temporal-distance characteristics of walking in elderly women. Phys Ther 1991;71:791–803.
[48] Lindsey C, Brownbill RA, Bohannon RW, Illich JZ. Association of physical performance measures with bone mineral density in post-menopausal women. Arch Phys Med Rehabil 2005;86:1102–7.
[49] Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait patterns and falls in community-dwelling women. Age Ageing 1996;25:292–9.
[50] Mills PM, Barrett RS. Swing phase mechanics of healthy young and elderly men. Hum Mov Sci 2001;20:427–46.
[51] Mündermann A, Dyrby CO, Hurwitz DE, Sharma L, Andriacchi TP. Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity. Arthritis Rheum 2004;50:1172–8.
[52] Nagasaki H, Itoh H, Hashizume K, Furuna T, Maruyama H, Kinugasa T. Walking patterns and finger rhythm of older adults. Percept Motor Skills 1996;82:435–47.
[53] Obuchi S, Shibata H, Yasumura S, Suzuki T. Relationship between walking ability and risk of falls in community dwelling elderly in Japan. J Phys Ther Sci 1994;6:39–44.
[54] Purser JL, Pieper CF, Poole C, Morey M. Trajectories of leg strength and gait speed among sedentary older adults: longitudinal pattern and dose response. J Gerontol Med Sci 2003;58A:1125–34.
[55] Rogers HL, Cromwell RL, Newton RA. Association of balance measures and perception of fall risk on gait speed: a multiple regression analysis. Exper Aging Res 2005;31:191–203.
[56] Tiedemann A, Sherrington C, Lord SR. Physiological and psychological predictors of walking speed in older community-dwelling people. Gerontology 2005;51:390–5.
[57] Van Iersel MB, Olde Rikkert MG, Borm GF. A method to standardize gait and balance variables for gait velocity. Gait Posture 2007;26:226–30.
[58] Willén C, Sunnerhagen KS, Ekman C, Grimby G. How is walking speed related to muscle strength? A study of healthy persons and persons with late effects of polio. Arch Phys Med Rehabil 2004;85: 1923–8.
[59] Kamide N, Shiba Y, Koide K, Haga H, Shibata H. The timed up and go test is related to quantitative ultrasound parameters of bone strength in Japanese community-dwelling older women. J Phys Ther Sci 2009;21:373–8.
[60] Laufer Y. Age- and gender-related changes in temporal-spatial characteristics of forwards and backwards gaits. Physiother Res Int 2003;8:131–42.
[61] Ble A, Volpato S, Zuliana G, Guralnik JM, Bandinelli S, Lauretani F, *et al.* Executive function correlates with walking speed in older persons: the InCHIANTI study. J Am Geriatr Soc 2005;53:410–5.
[62] Studenski S, Perera S, Wallace D, Chandler JM, Duncan PW, Rooney E, *et al.* Physical performance measures in a clinical setting. J Am Geriatr Soc 2003;51:314–22.
[63] Fritz S, Lusardi M. White paper: 'Walking speed: the sixth vital sign'. J Geriatr Phys Ther 2009;32:2–5.
[64] Graham JE, Ostir GV, Kuo Y-F, Fisher SR, Ottenbacher KJ. Relationship between test methodology and mean velocity in timed walk tests: a review. Arch Phys Med Rehabil 2008;89:865–72.
[65] Jüni P, Witschi A, Bloch R, Egger M. The hazards of scoring the quality of clinical trials for meta-analysis. JAMA 1999;282:1054–60.
[66] Bendall MJ, Bassey EJ, Pearson MB. Factors affecting walking speed of elderly people. Age Ageing 1989;18:327–32.