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The Importance of Racially and Ethnically Inclusive Gait Speed Reference Values in Individuals 90 Years and Older: LifeAfter90

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ABSTRACT

Background and Purpose: Clinicians use reference values to contextualize physical performance scores, but data are sparse in individuals 90 years and older and racial/ethnic diversity is limited in existing studies. Gait speed provides valuable information about an individual's health status. Slow gait speed is associated with falls, cognitive decline, and mortality. Here, we report gait speed reference values in a racially/ethnically diverse oldest-old cohort.

Methods: *LifeAfter90* is a multiethnic cohort study of individuals 90 years and older. Participants are long-term members of an integrated healthcare delivery system without a dementia diagnosis at enrollment. We assessed gait speed using the 4-m walk test and calculated means, standard deviations, and percentiles by age, sex, assistive device use, and device type. We used linear regression to compare means by sex, age, device use and type, living situation and arrangement, and race/ethnicity.

Results and Discussion: The mean age of the 502 participants was 92.9 (range 90.1–102.8) years. Of these, 62.6% were women, 34.7% were college educated, 90.8% lived in a private residence, 20.9% self-reported as Asian, 22.5% as Black, 11.8% as Hispanic, 35.7% as White, and 9.2% as multiple, "other," or declined to state. The overall mean gait speed was 0.54 m/s (women = 0.51 m/s, men = 0.58 m/s). Mean gait speeds were 0.58 m/s, 0.53 m/s, and 0.48 m/s in the 90 to 91, 92 to 93, and 94+ age categories, respectively. In those without a device, mean gait speed was 0.63 m/s compared to 0.40 m/s in those with a device (cane = 0.44 m/s, walker = 0.37 m/s). Mean gait speed was significantly slower in women compared to men, age category 94+ compared to 90 to 91, participants with a device compared to those without, participants with a walker compared to a cane, and Black participants compared to Asian and White participants. However, differences by race/ethnicity were attenuated when chronic health conditions were considered.

Conclusions: Reference values developed from this multiethnic 90+ cohort will help clinicians interpret gait speed measures and tailor recommendations toward a 90+ population that is growing in number and in racial/ethnic diversity.

Key Words: geriatric, normative, older adults, physical performance, racial/ethnic diversity, walking speed

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The authors declare no conflicts of interest.

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CLINICAL IMPLICATIONS

- Gait speed reference values in individuals aged 90+ years (Table 2) are important for accurate evaluation of gait. Reference values from racially/ethnically inclusive cohorts are necessary due to increasing diversity in the older adult population.
- Mean gait speed was 0.54 m/s (0.58 m/s in men and 0.51 m/s in women) in our 90+ cohort, which is slower than mean values currently used and derived from individuals younger than 90.
- Values for gait speed for age categories of 90 to 91, 92 to 93, and 94+ years decreased by age.

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INTRODUCTION

The population of individuals ages 90 years and older, often referred to as the "oldest old," is the fastest-growing segment of the US population.[1] In 2010, there were 1.9 million people in this age category. This number is projected to more than quadruple by 2050, when there will be over 8 million individuals 90 years and older.[1] In addition to growing older, the population of older adults in the United States is also growing more diverse. In 2009, 20% of older adults belonged to racial/ethnic groups other than non-Hispanic White. That number is projected to increase to 34% by 2040, a 70% increase.[2] Thus, inclusion of individuals 90 years and older and prioritization of racial/ethnic diversity have become increasingly important in aging research.

Physical performance reference values characterize what is usual for a population and provide context for clinically observed measures of physical status. Gait speed is commonly used as a measure of physical performance in older adults. Previous research has demonstrated that slow gait speed is associated with many adverse events, including falls, hospitalization, postoperative outcomes, depression, cognitive decline, disability, frailty, and mortality.[3-8] In the context of older adult physical assessment, gait speed is sometimes called "the sixth vital sign" due to the valuable information it can provide about an individual's health status.[9] Although gait speed reference values exist for older adults, few studies have been published specific to those 90 years and older, and racial/ethnic diversity has been limited in the data that do exist. Due to this lack of physical performance data specific to the oldest old, clinicians often extrapolate reference values from younger age groups to categorize the gait speeds of patients in their 90s and above. This extrapolation could result in the incorrect classification of observed gait speed measurements in patients who are 90+ years. We aimed to fill these gaps by establishing reference values for gait speed in a racially/ethnically diverse oldest-old cohort.

METHODS

Study Design and Participants

The *LifeAfter90* study is a longitudinal study aiming to investigate life course determinants of cognitive outcomes in a multiethnic cohort of adults 90 years and older. Participants are long-term members of the Kaiser Permanente Northern California, an integrated health care delivery system, who resided in the San Francisco Bay and Sacramento areas of California at the time of recruitment and spoke English or Spanish. Participants were excluded from enrollment if they had a diagnosis of dementia, hospice care, or dialysis in their medical record at the time of recruitment or if they could not provide informed consent. Participants were not specifically excluded due to any other health condition, but some self-selection out of the study due to chronic disease may have occurred. Enrollment began in July 2018 and is ongoing, with evaluations completed every 6 months. Our study included participants of the *LifeAfter90* study who were evaluated in person and completed the 4-m walk test (4MWT) before June 11, 2021. Assessments took place mostly in participants' residences, which included private homes, assisted living centers, and nursing facilities.

All participants provided informed consent upon enrollment in the *LifeAfter90* study. The *LifeAfter90* Study is a collaboration between the Kaiser Permanente Division of Research and the University of California, Davis. The institutional review board from both institutions reviewed and approved the study. Research was completed in accordance with the Helsinki Declaration.

Data Collection

Gait speed measurement

The 4MWT was used to assess gait speed. The 4MWT is a commonly used gait speed measurement that has demonstrated excellent test-retest reliability and has been validated in a variety of populations.[10-12] Although the information about gait provided by the 4MWT is limited compared with more sophisticated measurements, the 4MWT has the advantage of being simple to perform, with no specialized equipment required, and can be performed in participants' homes as well as in a clinical setting. Examiners timed participants using a stopwatch while walking 4 m at their usual pace. The timed 4-m section was marked using tape. The participants began walking from a static stand in front of the starting tape. Timing began when a participant's first foot crossed the tape. The participant continued walking past the finishing tape with an approximate 0.5- to 1-m deceleration phase outside of the timed area. Timing ended when the participant's second foot crossed the finishing tape. The same testing protocol was used regardless of the evaluation setting. We converted the 4MWT time to gait speed in meters per second (m/s) using 4 m/time (s).

Additional covariates

Information on demographics and background characteristics was obtained from participants during semi-annual evaluations. Relevant variables documented included age, sex, race/ethnicity, educational attainment, living situation (in a home or supported living environment), and living arrangement (alone or with another person). Age was calculated as the time from the participant's date of birth to the visit date. Sex, race/ethnicity, educational attainment, and living situation were all self-reported by participants. Sex was coded as male or female. Participant's responses to race and ethnicity were combined and coded in the following categories: Asian, Black, Hispanic/Latino, and White. Those who reported multiple, "other," or who declined to state race/ethnicity were combined into one additional category labeled "multiple/other/declined." Educational attainment was collected as the highest level of education completed and coded in 3 categories: high school degree or lower, associate degree or some college, and college degree or higher. The living situation was coded into 3 categories: private residence,

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assisted living, and nursing home. Living arrangement was coded as living alone versus living with a spouse or caregiver. The use of an assistive device (yes/no) was determined by the interviewer and set to yes if the participant used an assistive device to complete the 4MWT. The type of device was recorded as cane or walker. The Modified Mini-Mental State Examination (3MS)[13] score (0-100) was recorded as part of the clinical evaluation included in the semi-annual visit. Information on medical history was self-reported by participants during semi-annual visits. A health index was developed in which participants were given 1 point for each health condition included in the index. The points were summed for a total score of 0 to 8. Health conditions that were potential confounders of the association between slow gait speed and race/ethnicity comprised the index. These conditions included stroke, transient ischemic attack, diabetes, hypertension, hypercholesterolemia, arthritis, congestive heart failure, and Parkinson's disease.

Data Analyses

We developed gait speed reference values for age categories 90 to 91, 92 to 93, and 94+ years by calculating means, standard deviations, and percentiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th) for each age group and categorized by assistive device use in the entire sample and stratified by sex. Because more individuals 90 years and older are on the younger end of the range, both in our study and in the population, we chose these age categories for a more even distribution of participants between the groups and to best represent the oldest-old population. We also developed gait speed reference values by assistive device type (cane or walker) in all participants who used a device, stratified by sex.

Next, we wanted to compare mean gait speeds by sex, age, device use, and living situation. To accomplish this, we used separate linear regression models to compare mean gait speeds: (1) in men vs women, adjusted for age and device use; (2) in 3 age categories (90-91, 92-93, and 94 years or more), adjusted for sex and device use; (3) in device vs no device groups, adjusted for age and sex; (4) in cane vs walker users, adjusted for age and sex; (5) in participants living in a private household vs a nursing home or assisted living, adjusted for age, sex, and assistive device use; and (6) in those living alone vs with a spouse or caregiver, adjusted for age, sex, and assistive device use. Age was included as a continuous variable in the regression models mentioned previously.

We also wanted to compare mean gait speeds by racial/ethnic category (Asian, Black, Hispanic/Latino, White, and multiple/other/declined). We used linear regression models with racial/ethnic categories as the main independent variable and adjusted for age, sex, and assistive device use. Next, we wanted to determine whether cognition and multimorbidity accounted for differences in mean gait speed by race/ethnicity, so we added 3MS and a health index score to the model for participants who had data for these variables. To assess the differences between the study group and participants who were excluded due to lack of an in-person visit or 4MWT score, we compared age, sex, and living situation between the groups using chi-square tests and *t* tests. We used SAS 9.4 (SAS Institute Inc., Cary, NC) statistical software to perform all analyses.

RESULTS

Participant Characteristics

Of the 819 participants in the *LifeAfter90* Study, 108 participants were excluded because they did not complete the clinical evaluation component of baseline assessments, which included physical performance evaluation. An additional 140 participants were excluded because their baseline assessments were done by phone during the Covid-19 pandemic, and they did not complete an in-person visit before June 11, 2021. Of the 571 participants who were evaluated in person, 69 were excluded because they did not complete the 4MWT (64 participants), required physical assistance from another person to complete the test (3 participants), or used a handrail to complete the test (2 participants), rendering their score invalid. Five hundred and two participants had a valid 4MWT score and were included in our analyses, as shown in Figure 1. The characteristics of these participants are presented in Table 1 for the entire group and stratified by age category and sex. The mean age of the entire sample was 92.9 years, with a range of 90.1 to 102.8 years. Of these participants, 62.6% were women, 34.7% reported having a college education or higher, 20.9% self-reported as Asian, 22.5% as Black, 11.8% as Hispanic, 35.7% as White, and 9.2% as multiple/other/declined. Over 90% of participants reported living in a private residence, with 41.8% living alone.

Gait Speed Measurements

The overall mean gait speed of study participants was 0.54 m/s, with a range of 0.36 to 1.46 m/s. In Table 2, we present gait speed reference values, including means, standard deviations, and percentiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th) stratified by sex (men and women) in 3 age groups (90-91, 92-93, and 94+ years), by assistive device category (yes/no), and by assistive device type (cane and walker). Men 90 to 91 years of age who did not use a device had the fastest mean gait speed of all the categories (0.68 m/s), while women 94 years and older who used a device had the slowest mean gait speed (0.37 m/s).

In Figure 2, we present scatter boxplots of the distribution of gait speed in men vs women, in age categories 90 to 91 years vs 92 to 93 and 94+ years, and in participants who ambulated with no device vs device users. We also present differences in adjusted mean gait speeds by sex, age, device use, device type, living situation, and living arrangement in **Supplemental Table 1,** http://links.lww.com/JGPT/A187. Stratifying by sex, the mean gait speed was 0.51 m/s in women vs 0.58 m/s in men. Adjusting for age and device use,

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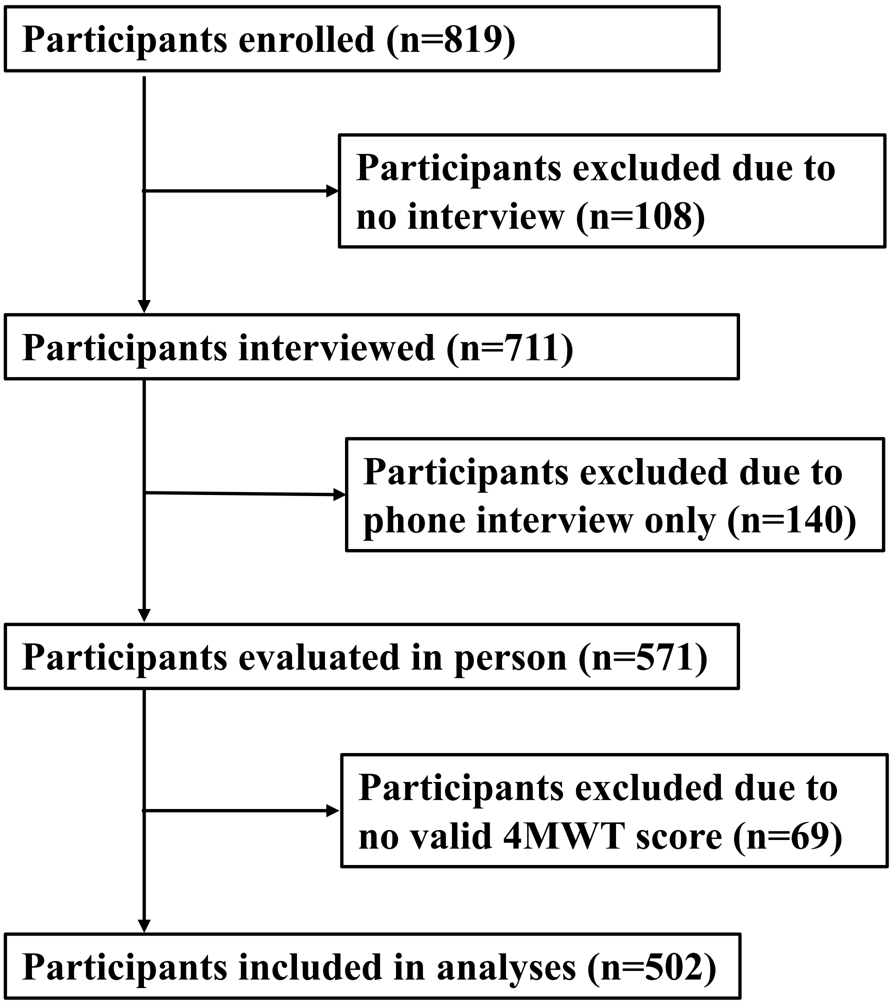

Figure 1. Flowchart of participant selection process. Participants were excluded if 4MWT was not completed.

mean gait speed was significantly faster in men than in women (0.04 m/s; 95% CI, 0.01-0.07). Stratifying by age, the mean gait speed was 0.58, 0.53, and 0.48 m/s in the 90 to 91 category, 92 to 93 category, and 94+ category, respectively. Adjusting for sex and device use, mean gait speed was faster in those in the 90 to 91 category compared with those in the 94+ category (0.05 m/s; 95% CI, 0.01-0.09). Stratifying by device use, the mean gait speed was 0.63 m/s in participants who did not use an assistive device vs 0.40 m/s in those who used a device. Adjusting for sex and age, participants who used a device walked more slowly than those who did not (−0.23 m/s; 95% CI −0.26 to −0.19). Among those who used a device, the mean gait speed was 0.44 in those who used a cane and 0.37 in those who used a walker. Adjusting for sex and age, participants who used a cane walked faster than those who used a walker (0.06 m/s; 95% CI, 0.01-0.10). We did not find any significant differences in mean gait speed by living situation or living arrangement after adjusting for age, sex, and assistive device use.

We then examined differences in mean gait speeds by age, stratified by use of assistive device, and further divided by sex (Figure 3). In women who did not use a device, the mean gait speed in the 90 to 91 age group was 0.06 m/s faster compared with the 92 to 93 age group (95% CI, 0.001-0.12) and 0.07 m/s faster compared with the 94+ age group (95% CI 0.004-0.14). No significant differences by age were found in women who used a device or in men with or without a device.

The mean gait speed also varied by race/ethnicity. The mean gait speed was 0.59 m/s in Asian participants, 0.47 m/s in Black participants, 0.49 m/s in Hispanic/Latino participants, 0.56 m/s in White participants, and 0.54 m/s in participants in the Multiple/Other/Declined category. To explore potential confounders that might account for the association between gait speed and race/ethnicity, we examined a subset of 413 participants who had complete data for race, age, sex, 3MS score, and health index score. In Table 3, we compare differences in mean gait speed by race/ethnicity using linear regression. In Model 1, we adjusted for sex, age,

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Table 1. Background Characteristics of Study Participants by Age (Years) in Women, Men, and the Entire Sample[a]

Women				
	90-91 (N = 138)	**92-93 (N = 87)**	**94 + (N = 89)**	**Total (N = 314)**
Mean age (SD)	90.9 (0.6)	92.8 (0.5)	96.1 (1.8)	92.9 (2.4)
Race/ethnicity, n (%)				
Asian	029 (21)	016 (18)	009 (10)	054 (17)
Black	032 (23)	017 (20)	026 (29)	075 (24)
Hispanic/Latino	021 (15)	012 (14)	010 (11)	043 (14)
White	042 (30)	033 (38)	035 (39)	110 (35)
Multiple/other/declined to state	014 (10)	009 (10)	009 (10)	032 (10)
Educational level, n (%)				
≤High school	007 (5)	011 (13)	012 (14)	030 (10)
Associate degree or some college	089 (65)	053 (62)	050 (56)	192 (62)
≥College degree	041 (30)	022 (26)	027 (30)	090 (29)
Living situation, n (%)				
Private residence	086 (88)	056 (89)	044 (86)	186 (88)
Assisted living	012 (12)	006 (10)	005 (10)	023 (11)
Nursing home	000 (0)	001 (2)	002 (4)	003 (1)
Living arrangement, n (%)				
Lives alone	16 (25)	7 (22)	12 (32)	35 (26)
Lives with another person	49 (75)	25 (78)	25 (68)	99 (74)
Assistive device use				
Yes	21 (22)	18 (42)	23 (46)	62 (33)
No	74 (78)	25 (58)	27 (54)	126 (67)
Assistive device type				
Cane	019 (36)	010 (29)	016 (30)	045 (32)
Walker	034 (64)	025 (71)	037 (70)	096 (68)
Mean 3MS Score (SD)	89.6 (8.7)	85.9 (10.8)	85.3 (10.4)	87.2 (10.0)
Mean Health Index Score (SD)	2.2 (1.3)	2.3 (1.1)	2.2 (1.2)	2.2 (1.2)
Men				
	90-91 (N = 95)	**92-93 (N = 43)**	**94 + (N = 50)**	**Total (N = 188)**
Mean age (SD)	90.9 (0.6)	93.0 (0.6)	96.1 (1.7)	92.8 (2.4)
Race/ethnicity, n (%)				
Asian	32 (34)	08 (19)	11 (22)	051 (27)
Black	15 (16)	12 (28)	11 (22)	038 (20)
Hispanic/Latino	06 (6)	05 (12)	05 (10)	016 (9)
White	34 (36)	13 (30)	22 (44)	069 (37)
Multiple/other/declined to state	08 (8)	05 (12)	01 (2)	014 (7)
Educational level, n (%)				
≤High school	09 (10)	03 (7)	08 (16)	020 (11)
Associate degree or some college	42 (44)	22 (51)	20 (41)	084 (45)
≥College degree	44 (46)	18 (42)	21 (43)	083 (44)
Living situation, n (%)				
Private residence	64 (99)	32 (100)	32 (87)	128 (96)
Assisted living	01 (2)	00 (0)	04 (11)	005 (4)

(*continues*)

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Table 1. Background Characteristics of Study Participants by Age (Years) in Women, Men, and the Entire Sample[a] (*Continued*)

Men				
	90-91 (N = 95)	**92-93 (N = 43)**	**94 + (N = 50)**	**Total (N = 188)**
Nursing home	00 (0)	00 (0)	01 (3)	001 (1)
Living arrangement, n (%)				
Lives alone	49 (75)	25 (78)	25 (68)	99 (74)
Lives with another person	16 (25)	7 (22)	12 (32)	35 (26)
Assistive device use				
Yes	21 (22)	18 (42)	23 (46)	62 (33)
No	74 (78)	25 (58)	27 (54)	126 (67)
Assistive device type				
Cane	09 (43)	08 (44)	08 (35)	025 (40)
Walker	12 (57)	10 (56)	15 (65)	037 (60)
Mean 3MS Score (SD)	88.5 (8.3)	86.6 (8.9)	84.2 (10.6)	87.0 (9.2)
Mean Health Index Score (SD)	2.1 (1.1)	2.3 (1.2)	2.1 (1.4)	2.1 (1.2)
All				
	90-91 (N = 233)	**92-93 (N = 130)**	**94 + (N = 139)**	**Total (N = 502)**
Mean age (SD)	90.9 (0.6)	92.9 (0.5)	96.1 (1.7)	92.9 (2.4)
Race/ethnicity, n (%)				
Asian	061 (26)	024 (19)	020 (14)	105 (21)
Black	047 (20)	029 (22)	037 (27)	113 (23)
Hispanic/Latino	027 (12)	017 (13)	015 (11)	059 (12)
White	076 (33)	046 (35)	057 (41)	179 (36)
Multiple/other/declined to state	022 (9)	014 (11)	010 (7)	046 (9)
Educational level, n (%)				
≤High school	016 (7)	014 (11)	020 (15)	050 (10)
Associate degree or some college	131 (57)	075 (58)	070 (51)	276 (55)
≥College degree	085 (37)	040 (31)	048 (35)	173 (35)
Living situation, n (%)				
Private residence	150 (92)	088 (93)	076 (86)	314 (91)
Assisted living	013 (8)	006 (6)	009 (10)	028 (8)
Nursing home	000 (0)	001 (1)	003 (3)	004 (1)
Living arrangement, n (%)				
Lives alone	62 (38)	47 (49)	36 (41)	145 (42)
Lives with another person	101 (62)	49 (51)	52 (59)	202 (58)
Assistive device use				
Yes	74 (32)	53 (41)	76 (55)	203 (40)
No	159 (68)	77 (59)	63 (45)	299 (60)
Assistive device type				
Cane	028 (38)	018 (34)	024 (32)	070 (35)
Walker	046 (62)	035 (66)	052 (68)	133 (66)
Mean 3MS Score (SD)	89.1 (8.5)	86.1 (10.2)	84.9 (10.4)	87.2 (9.7)
Mean Health Index Score (SD)	2.1 (1.2)	2.3 (1.1)	2.2 (1.3)	2.2 (1.2)

[a]Number of missing values for educational level = 3, living situation = 156, living arrangement = 155, 3MS score = 73, and health index score = 85.
Abbreviations: 3MS = Modified Mini-Mental State Examination

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Table 2. Reference Values for Usual Gait Speed (m/s) According to Age (Years), Use of Assistive Device (Yes or No), and Device Type (Cane or Walker) in Women (N = 314) and Men (N = 188)

Women									
Age (years)	**N**	**Mean (SD)**	**P5**	**P10**	**P25**	**P50**	**P75**	**P90**	**P95**
All Women									
90-91	138	0.55 (0.21)	0.21	0.28	0.40	0.55	0.70	0.86	0.89
92-93	87	0.51 (0.20)	0.19	0.29	0.35	0.50	0.63	0.77	0.88
94+	89	0.45 (0.19)	0.20	0.22	0.32	0.43	0.61	0.71	0.78
All ages	314	0.51 (0.20)	0.20	0.26	0.35	0.51	0.64	0.80	0.88
No Assistive Device									
90-91	85	0.65 (0.18)	0.41	0.44	0.53	0.62	0.80	0.88	0.96
92-93	52	0.59 (0.18)	0.30	0.34	0.48	0.57	0.70	0.88	0.94
94+	36	0.58 (0.17)	0.34	0.37	0.43	0.57	0.71	0.80	0.82
All ages	173	0.62 (0.18)	0.34	0.41	0.50	0.60	0.74	0.88	0.94
Assistive Device									
90-91	53	0.39 (0.16)	0.17	0.20	0.28	0.36	0.50	0.63	0.70
92-93	35	0.38 (0.15)	0.14	0.17	0.29	0.38	0.48	0.62	0.66
94+	53	0.37 (0.15)	0.16	0.20	0.26	0.34	0.46	0.62	0.65
All ages	141	0.38 (0.15)	0.16	0.20	0.27	0.36	0.48	0.62	0.66
Cane (all ages)	45	0.43 (0.16)	0.19	0.25	0.31	0.42	0.54	0.69	0.70
Walker (all ages)	96	0.36 (0.15)	0.15	0.19	0.26	0.34	0.46	0.57	0.64
Men									
Age (years)	**N**	**Mean (SD)**	**P5**	**P10**	**P25**	**P50**	**P75**	**P90**	**P95**
All Men									
90-91	95	0.62 (0.22)	0.28	0.36	0.46	0.59	0.75	0.86	0.96
92-93	43	0.56 (0.21)	0.26	0.30	0.39	0.53	0.70	0.82	0.87
94+	50	0.51 (0.19)	0.26	0.28	0.35	0.50	0.61	0.74	0.93
All ages	188	0.58 (0.22)	0.28	0.32	0.42	0.56	0.70	0.84	0.93
No Assistive Device									
90-91	74	0.68 (0.20)	0.38	0.44	0.53	0.68	0.79	0.89	1.09
92-93	25	0.61 (0.16)	0.36	0.42	0.48	0.62	0.74	0.82	0.87
94+	27	0.61 (0.17)	0.39	0.44	0.50	0.57	0.70	0.93	0.96
All ages	126	0.65 (0.19)	0.38	0.44	0.51	0.65	0.75	0.89	0.96
Assistive Device									
90-91	21	0.39 (0.12)	0.20	0.28	0.34	0.40	0.48	0.54	0.57
92-93	18	0.50 (0.26)	0.25	0.26	0.30	0.45	0.61	0.82	1.28
94+	23	0.39 (0.13)	0.23	0.26	0.29	0.35	0.50	0.56	0.61
All ages	62	0.42 (0.18)	0.23	0.26	0.30	0.39	0.51	0.61	0.62
Cane (all ages)	25	0.44 (0.15)	0.26	0.28	0.33	0.43	0.56	0.62	0.62
Walker (all ages)	37	0.41 (0.20)	0.15	0.23	0.28	0.39	0.50	0.55	0.75

Abbreviations: m/s, meters per second.

and assistive device use and found significant differences by race/ethnicity. Asian participants walked faster than Black participants (0.11 m/s; 95% CI, 0.05-0.16) and Hispanic participants (0.07 m/s; 95% CI, 0.01-0.13). Black participants walked more slowly than White participants (−0.12 m/s; 95% CI, −0.16 to −0.06), and Hispanic participants walked more slowly than White participants (−0.07 m/s; 95% CI, −0.13 to −0.01). In Model 2, we added 3MS score and health index to Model 1 to account for confounding that may occur due to variation in cognitive

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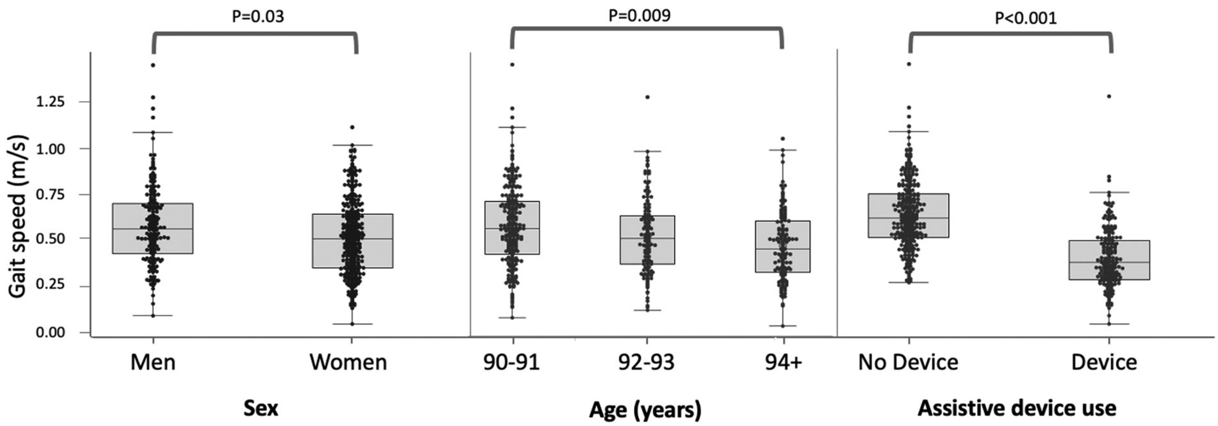

Figure 2. Boxplots of gait speed in men vs women, in age categories 90-91 years vs 92-93 and 94+ years, and in participants who ambulated with no device vs device users (n = 502). Abbreviations: m/s, meters per second. This figure is available in color online (www.jgeript.com).

status or multimorbidity between the groups. We found that the differences in mean gait speed between racial/ethnic groups were diminished. The differences in adjusted mean gait speeds between Asian and Hispanic participants (0.05 m/s; 95% CI, –0.01 to 0.11) and Hispanic and White participants (–0.04 m/s; 95% CI, –0.01 to 0.02) were no longer significant. The differences between Asian and Black participants (0.09 m/s; 95% CI, 0.04 to 0.14) and between Black and White participants (–0.08 m/s; 95% CI, –0.13 to –0.04) were attenuated.

Excluded Participants

Of the 317 participants who were excluded from the study, 69 were evaluated in person but did not have a valid 4MWT score. Of these, 36 participants (52%) did not have a valid score because they were unable or unsafe to walk unassisted, and 25 participants (36%) did not have a score because the visit was modified due to time constraints. Other reasons for non-completion of the 4MWT included the interviewer feeling unsafe, a lack of space in the interview environment, a caregiver or family member refusing on behalf of the participant, and the participant being fatigued.

The 317 excluded participants had a mean age of 92.3 years, while the mean age of the study group was 92.9 years. This difference of 0.6 years was statistically significant (*t* test *p* value < .001), but the effect size was small (Cohen's D effect size = 0.27). Of the excluded participants, 62.8% were women, compared with 62.6% in the study group. This difference was not statistically significant. The living situation was also similar between the two

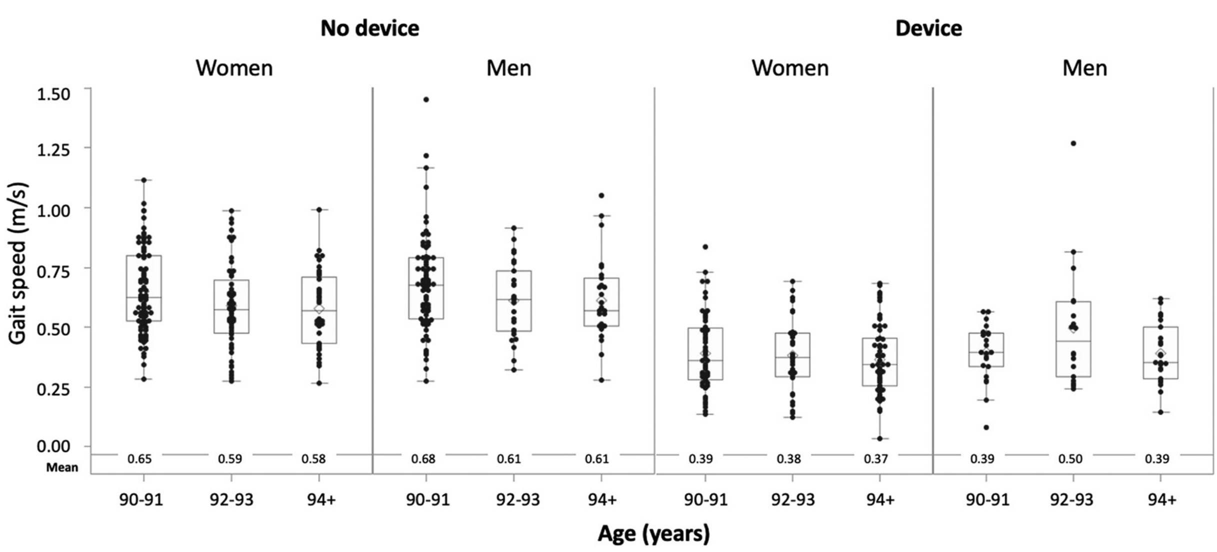

Figure 3. Boxplot of gait speed (m/s) stratified by age, sex, and assistive device category (n = 502). Abbreviations: m/s, meters per second. This figure is available in color online (www.jgeript.com).

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Table 3. Differences in Adjusted Mean Gait Speeds Between Racial/ethnic Groups Are Attenuated When Adjusting for Chronic Health Conditions[a]

Race/Ethnicity:	Adjusted Mean Difference (95% Confidence Interval) Model 1[b]	Adjusted Mean Difference (95% Confidence Interval) Model 2[c]
Asian vs Black	**0.11 (0.05 to 0.16)**	**0.09 (0.04 to 0.14)**
Asian vs Hispanic/Latino	**0.07 (0.01 to 0.13)**	0.05 (–0.01 to 0.11)
Asian vs White	0.00 (–0.05 to 0.04)	0.01 (–0.04 to 0.05)
Asian vs Multiple/other/declined	0.05 (–0.02 to 0.12)	0.05 (–0.02 to 0.11)
Black vs Hispanic/Latino	–0.04 (–0.10 to 0.03)	–0.04 (–0.10 to 0.02)
Black vs White	**–0.12 (–0.16 to –0.06)**	**–0.08 (–0.13 to –0.04)**
Black vs Multiple/other/declined	–0.05 (–0.12 to 0.02)	–0.04 (–0.01 to 0.02)
Hispanic/Latino vs White	**–0.07 (–0.13 to –0.01)**	–0.04 (–0.01 to 0.02)
Hispanic/Latino vs Multiple/other/declined	–0.02 (–0.09 to 0.06)	–0.01 (–0.08 to 0.07)
Multiple/other/declined vs White	–0.06 (–0.12 to 0.01)	–0.04 (–0.10 to 0.02)

[a]Bolded text indicates a *p*-value < .05.
[b]Sex, age, and assistive device use included in the linear regression model.
[c]Sex, age, assistive device use, 3MS score, and health index included in the linear regression model.

groups, with 88.7% of excluded participants and 90.5% of the study group living in a private household. This difference was not statistically significant.

DISCUSSION

In this study, we report reference values for gait speed for age categories of 90 to 91, 92 to 93, and 94+ years using data from a multiracial/ethnic oldest-old cohort. The overall mean gait speed in our study was 0.54 m/s. Stratified by sex, the mean gait speed was 0.51 m/s in women and 0.58 m/s in men. Stratified by age, the mean gait speeds were 0.58, 0.53, and 0.48 m/s in the 90 to 91, 92 to 93, and 94+ categories, respectively. Stratified by assistive device use, the mean gait speed was 0.63 m/s in those who did not use a device and 0.40 m/s in those who did. Among those who used a device, the mean gait speed was 0.44 m/s in those who used a cane and 0.37 m/s in those who used a walker. The mean gait speed was faster in men than in women, slower with increasing age, slower in those who used a device compared with those who did not, and slower in those who used a walker compared with those who used a cane. Gait speeds were slower in Black participants compared with Asian and White participants; however, these differences were attenuated when cognition and chronic health conditions were taken into account.

Many studies have suggested gait speed reference values for older adults, yet most of these have had few or no participants 90 years or older.[14-23] Only one previous study has focused specifically on gait speed reference values in the oldest old. In 797 individuals from The 90+ Study, with a mean age of 93.5 years, the average gait speed was 0.58 m/s, just slightly faster than the mean gait speed of 0.54 m/s found in our study. The gait speeds in our study may have been marginally slower than those in the previous study due to slight variations in testing. Although both studies used the 4MWT to assess gait speed, our timing stopped after the participant's second foot crossed the finishing tape, while the previous study ended the timing when the participant's first foot crossed the finishing tape.[23] In addition, our testing began from a static start, while the previous study began from a dynamic start, with a 0.6-m acceleration phase. Slightly slower gait speeds have been reported in tests beginning from a static start, such as ours, compared with those beginning from a dynamic start. In a study of 150 community-dwelling older adults with a mean age of 80.5 years, the mean gait speed was 1.23 m/s in participants who were tested using a dynamic start and end, whereas the mean gait speed was 1.17 m/s in participants who were tested using a static start and dynamic end. Although the difference in mean gait speeds between the groups was small (0.06 m/s), it was statistically significant.[24] When taking these small differences in testing into consideration, the mean gait speeds in our study appear even more similar to those in the previous study, which focused on individuals 90 years and older.

Another recent study of gait speed reference values included a small 90+ age category. The study had a total of 4656 community-dwelling individuals from the Rotterdam Study, with a mean age of 67.7 years, and an average gait speed of 1.20 m/s. The 90+ category included 15 women, with a mean gait speed of 0.76 m/s, and 12 men, with a mean gait speed of 0.91 m/s. The mean gait speeds of the 90+ group in the Rotterdam Study were faster than those in our study. However, due to small sample sizes, the gait speed data in the 90+ age group from the Rotterdam Study may not be as representative of the usual performance of the 90+ population as data from larger 90+ cohorts. The authors reported that the mean gait speeds of participants in their 90+ age category were slower than those of participants in the 80 to 89 age categories and that gait speed means were statistically significantly different between age categories.[22]

Gait speed reference values for older adults under 90 years of age have been reported in several studies.[17-21,25,26] In a recent multicenter study of 196 community-dwelling

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participants in Brazil, mean gait speeds of 0.95 m/s in men and 0.96 m/s in women were reported in the oldest age category of 70 to 80 years.[21] In another study, gait speed was assessed in 1320 participants of the National Institutes of Health Toolbox norming study. The oldest age category was 80 to 85 years, and the mean gait speeds were 0.95 m/s in women and 0.97 m/s in men.[20] In a study in Thailand with 1030 participants and an oldest age category of 80+, the authors reported mean gait speeds of 0.88 m/s in women and 0.97 m/s in men.[17] In addition, in a 2011 meta-analysis with a combined 20,111 individuals, average gait speeds of 0.94 m/s in women and 0.96 m/s in men were reported in the 80 to 99 age category.[19] All of these previous studies reported faster mean gait speeds than we reported in the current study of individuals 90 years and older, likely due to the younger mean ages of these studies compared with our study. However, the pattern of slower gait speeds with increasing age categories in these studies was consistent with our findings. In the current study, the average gait speeds of individuals 90 years and older are substantially slower than those reported in individuals 80 to 89 years in previous literature. These results reinforce the assertion that gait speed reference values specific to those 90 years and older are essential to the accurate classification of gait speed measurements in this population.

Most of the above studies report significant differences in gait speed by sex in older adults, with men walking faster than women, and suggest separate reference values for men and women.[18,22,23,25,26] Some studies have examined whether men walk faster than women due to height differences between the sexes. In one study, sex differences in gait speed were eliminated by adjusting for height.[22] In another study, women walked significantly faster than men after adjusting for height.[27] We did not have height recorded for enough participants to assess whether the differences we observed by sex could be explained by height. To increase clinical usefulness, we present reference values separately in men and women, acknowledging that the variability may be ascribed to variability in height between the sexes.

We examined gait speed by race/ethnicity and found that Asian participants had the fastest average gait speed, followed by White, multiple/other/declined, Hispanic/Latino, and Black participants. Black and Hispanic participants had significantly slower gait speeds compared with Asian and White participants. Because cognitive status and multimorbidity (the co-occurrence of two or more chronic diseases) have strong associations with slow gait speed in older adults[28,29] and are higher in non-White groups,[30–32] we adjusted for 3MS score and for chronic conditions that were potential confounders of the association between slow gait speed and race/ethnicity. When adjusting for 3MS score and health index score, the differences we observed by race/ethnicity were attenuated. The presence of additional confounders, such as vision problems, falls, hip fractures, chronic obstructive pulmonary disease, and peripheral vascular disease, may account for residual differences we observed by race/ethnicity. In the future, we plan to obtain information on other potential confounders to better understand the observed variation in gait speed between racial and ethnic groups. We expect that this variation is due to disparities in the prevalence and severity of chronic conditions between groups and is not intrinsic to race and ethnicity.

Previous studies have reported similar results when examining the association of gait speed and race in younger groups. In 7977 older adults (≥ 65 years) from the Health and Retirement Study,[26] gait speed was reported to be significantly slower in Black participants compared with White participants. As in our study, when potential confounders, including medical conditions and health behaviors, were added to the model, these group differences were substantially attenuated. Because gait speed differences by race/ethnicity are likely to be caused by external factors and not biologically intrinsic to race, we do not present reference values stratified by race. However, the observed differences in gait speed by race/ethnicity highlight the importance of including representative racial and ethnic groups in geriatric research, especially when characterizing the usual performance of a diverse group.

Gait speed is often used as an indicator of a person's ability to ambulate within the community. Several studies have examined speed requirements for walking outside the home,[33,34] including a meta-analysis in which the average speed required to cross the street in the United States at the time of a walk signal was reported to vary between 0.49 and 1.32 m/s. For large, urban areas within the United States, the mean time was 1.32 m/s.[33,34] With a mean gait speed of 0.54 m/s in our 90+ cohort, many of our participants do not meet even the minimum thresholds for community ambulation, and very few meet the threshold necessary to cross the street in an urban environment. To preserve the community mobility of the 90+ population, policies that affect traffic light timing should be modified to account for the slower gait speeds of this rapidly growing group.

Gait speed is also often used as a clinical indicator of well-being and has been associated with falls, disability, cognition, and mortality.[7,35-37] However, gait speed cut points commonly used to predict adverse outcomes may not have the specificity to be useful in the oldest old, where most people walk very slowly. For example, because only a few participants walk at a velocity of 1 m/s or faster in our 90+ cohort, the 1 m/s cut point frequently used to define slow gait speed is not useful in identifying those at risk within this group. We are currently examining gait speed cut points that can be used to identify those at risk for adverse events or health conditions within the 90+ population.

Our study had several major strengths. The greatest strengths were our large sample of individuals 90 years and older and the racial/ethnic diversity of our cohort. Few studies have reported sufficient physical performance data to develop gait speed reference values specifically for a 90+ age category. With our large cohort of individuals 90 years and older, we were able to develop reference

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values for three oldest-old age categories. The racial and ethnic inclusivity of our study was representative of the increasing diversity of the older adult population and allowed for a more generalizable characterization of the usual performance of this group. An additional strength of our study was the assessment of gait speed using the 4MWT. The 4MWT has been shown to have excellent test-retest reliability in a variety of populations and has been widely used in previous studies of gait speed in older adults.[10-12] Another strength was our ability to evaluate participants in their homes. This allowed us to include participants in our study who would not have been able to travel to a research center.

Our study also had several limitations. First, 315 participants were excluded from the study due to a lack of a 4MWT score. These participants were slightly younger than our study participants, but similar in gender and living situation. Because younger age is associated with faster gait speed, the exclusion of these participants could have caused a slight underestimation of gait speed in our results. However, although statistically significant, the difference in mean ages was small (92.3 years vs 92.9 years). Thus, it is unlikely that the exclusion of these participants made a substantial difference in our results. In addition, we did not have data available on chronic conditions for all participants. We were able to observe attenuation of differences by race/ethnicity by completing a subgroup analysis examining gait speed in relation to race/ethnicity and taking chronic conditions into account, but we may have observed further elimination of differences by race/ethnicity if we had data on potential confounders for the entire group. Another limitation was that the sample size of some groups was small when stratifying by age, sex, and assistive device category. However, our smallest groups were still larger than the oldest-old groups in most previous studies. In addition, although the 4MWT has been reported to be reliable[10-12] and has been frequently used to develop gait speed reference values, it is limited in the information it provides about gait compared with more sophisticated devices, like electronic walkways. However, since many individuals who are 90 years and older have difficulty leaving home to travel to appointments, using a test that was easy to perform in the homes of participants was important to our study because it allowed us to include more participants and increased the generalizability of our results.

CONCLUSIONS

In this study, we report gait speed reference values using data from a racially/ethnically diverse oldest-old cohort. This data will help clinicians better interpret physical performance measures and tailor recommendations toward the unique needs of oldest-old individuals. Racially/ethnically inclusive physical performance data specific to the oldest old are essential to meeting the future health needs of our society, which is growing older and more diverse each year.

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