Journals of Gerontology: Medical Sciences
cite as: *J Gerontol A Biol Sci Med Sci*, 2023, Vol. 78, No. 1, 104–110
https://doi.org/10.1093/gerona/glac055
Advance Access publication February 28, 2022

Research Report

Development and Validation of a Cutoff for the Chair Stand Test as a Screening for Mobility Impairment in the Context of the Integrated Care for Older People Program

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Received: November 22, 2021; Editorial Decision Date: February 22, 2022

Decision Editor: Lewis A. Lipsitz, MD, FGSA

Abstract

Background: The 5-repetition chair stand test (CST) is increasingly being used to assess locomotion capacity in older adults. However, there is a lack of age-stratified cutoffs for adults aged ≥70 validated against a higher risk of functional loss.
Methods: We used 2 population-based studies (Study on global AGEing and adult health in Mexico [SAGE Mexico] and Toledo Study for Healthy Aging [TSHA]) and receiver operating characteristic (ROC) analyses to develop and cross-validate age-stratified chair stand cutoffs with activities of daily living (ADL) disability as the outcome. Then, we used data from an randomized controlled trial (RCT) (Multidomain Alzheimer Preventive Trial [MAPT]) and a frailty day-hospital for external validation with cross-sectional and longitudinal measures of ADL disability. The merged sample of SAGE Mexico and TSHA was n = 1 595; sample sizes for external validation were: MAPT n = 1 573 and Frailty day-hospital n = 2 434. The Cox models for incident disability in MAPT had a mean follow-up of 58.6 months.
Results: Cutoffs obtained were 14 second (ages 70–79) and 16 second (ages 80+). Those cutoffs identified older adults at higher odds of incident ADL disability odds ratio (OR) = 1.72 (95% confidence interval [CI] 1.06; 2.78) for ages 70–79 and odds ratio (OR) = 2.27 (95% CI 1.07; 4.80) in those aged 80+. Being a slow chair stander according to the cut points was associated with ADL disability in cross-sectional and longitudinal measures.
Conclusions: Fourteen- and 16-second cut points for the CST are suitable to identify people at higher risk of functional decline among older adults in Mexico and Toledo, Spain. Adjusting the cut point from 14 to 16 second generally improved the psychometric properties of the test. The validation of these cutoffs can facilitate the screening for limited mobility and the implementation of the Integrated Care for Older People program.

Keywords: Chair stand test, Cutoffs, Integrated care, Intrinsic capacity, Locomotion assessment, Mobility clinimetrics

The 5-repetition chair stand test (CST) is a proxy of leg power, strength, and anteroposterior balance used in the context of functional assessment in older adults (1–3). Childhood socio-economic circumstances, chronological age, and knee extension strength have been recognized as factors explaining the CST result in older adults (4,5). Impaired locomotion plays a role in multimorbidity, depression, probable sarcopenia and disability, and has been assessed using the CST (1,5–8).

The CST is part of the intrinsic capacity assessment in the World Health Organization's Integrated Care for Older People (ICOPE) strategy (9). If an older person performs 5 chair-stands in more than 14 second, the ICOPE handbook recommends that he/she should be further assessed for limited mobility with the complete Short Physical Performance Battery (SPPB) test (1). However, to the best of our knowledge, the 14 second cut point has not been validated to detect older adults at higher risk of functional decline. The CST, as part of SPPB, uses the cutoffs 11.2, 13.7, and 16.7 second for defining chair stand performance categories (1). Other studies have set 5-repetition chair stand cut points ranging from 9.7 to 14 second (listed in Supplementary Table A), with 1 meta-analysis reporting age-stratified mean values for the 5-repetition CST (11.4 second for 60–69 years; 12.6 second for 70–79 years; 14.8 second for 80–89 years) (10). Nevertheless, we did not find any cutoff validated against a functional decline in ages 80+. So far, the CST validation literature is lacking of: representative samples, longitudinal outcomes, and a focus on very old adults. There are no cutoffs validated for old and very old adults (aged 80+) in different clinical settings to stratify their risk of functional decline.

In the context of the ICOPE program, applying best-performing cut points for the CST would serve to flag those adults who need a closer follow-up along their care pathways (9,11). Therefore, our objective was to obtain cutoff points for the CST using population-based studies, with further cross-validation and external validation in populations from different settings.

Method

Data from 2 population-based studies were used for obtaining and cross-validating the age-stratified chair stand cutoffs (70–79 and ≥80 years) retrospectively. We used 2 different data sets (randomized controlled trial [RCT] and real-world users of the health system) for external validation in a second stage.

Study samples and characteristics are summarized in Table 1.

Chair Stand Cutoff Points: Development and Cross-validation

Population

We used the WHO Study on global AGEing and adult health in Mexico (SAGE Mexico) and the Toledo Study for Healthy Aging (TSHA) cohort. Briefly, SAGE Mexico is a prospective cohort designed to be representative of adults aged 50 and over at the national level. All participants provided their informed consent, and the scientific board of the National Institute of Public Health approved the SAGE Mexico study. Further information on study design can be found elsewhere (12).

The TSHA is a prospective cohort designed to represent adults aged 65 and older living in the Spanish province of Toledo and comprising 24% of the census population of this population group (13). The Clinical Research Ethics Committee approved the TSHA of the Toledo Hospital. Data for both studies was collected by previously trained and standardized staff.

SAGE Mexico and TSHA measured the chair stand and ADL using the same standardized procedures. Adults aged 70 years or over were included in the present study, given that the incidence of ADL disability in younger participants was very low.

We randomly selected 50% of the combined data set (SAGE Mexico plus TSHA) stratified by age group to perform the cross-validation. Half of the population was used for obtaining the cut points, and the other half was used to cross-validate them. Based on previous observations about the difference in chair stand time by age group and the need for validating a cutoff tailored for very old adults, we performed our analysis separately for participants aged 70–79 and those aged 80 and over (1,14). Additionally, we compared the performance of sex-stratified cut points versus only age-stratified and sex-and age-stratified cut points (Table 2).

Chair stand measurement

Chair stand test: both studies measured the time in seconds taken by the participant to perform 5 chair rises at maximum speed with their arms folded across their chest. Standardized staff previously verified that at least 1 stand could be performed safely. Time was measured by previously standardized interviewers using a stopwatch to the nearest 0.1 second, from the starting sitting position to the last standing position at the end of the fifth stand (1).

Outcome measurement

The endpoint for elaborating the chair stand cutoff points and their cross-validation was the incidence of disability for the basic activities of daily living (ADLs, Katz scale—ambulating, feeding, dressing, personal hygiene, continence, and toileting) (15). Participants with the event at baseline (Katz <6) were excluded from this analysis, and incidence was defined as reporting disability for one or more ADLs during the follow-up.

Covariates

Age, sex, level of education (harmonized in 7 categories going from less than the primary school to postgraduate education), gait speed at usual pace (3- and 4-meter walk in TSHA and SAGE, respectively, harmonized in m/s), and study source (TSHA or SAGE).

Chair Stand Cutoff Points: External Validation

We used data from a randomized controlled trial (RCT—the Multidomain Alzheimer Preventive Trial (MAPT)) and a clinical database of users of the frailty day-hospital of the Toulouse University Hospital.

Populations

MAPT methodology has been described elsewhere (16). In brief, MAPT was a 3-year RCT examining the effects of a multidomain intervention on cognitive function among community-dwelling adults aged 70 years and older. An additional 2-year observational period was carried on after the intervention. The trial protocol (ClinicalTrials.gov identifier: NCT00672685) was approved by the French Ethical Committee located in Toulouse (CPP SOOM II). All participants signed their consent forms before any study assessment. Inclusion criteria were meeting at least one of (a) spontaneous memory complaints, (b) limitation in 1 instrumental activity of daily living, or (c) slow gait speed (≤0.8 m/s). Exclusion criteria comprised: Mini-Mental State Examination (MMSE) score <24, diagnosis of dementia, limitation in any basic ADLs, and taking polyunsaturated fatty acid (PUFA) supplements at baseline.

We also used cross-sectional routinely collected data from the frailty ambulatory clinic of the Toulouse University Hospital (2011–2019). This service receives patients referred from their family

Table 1. Qualitative Features and Relevant Variables of the Studies Used

Study features	SAGE Mex + TSHA	MAPT	Toulouse Frailty Clinic
Used for	Development and cross-validation	External validation	External validation
Dates of data collection	SAGE: 2014–2017 TSHA: 2011–2013	2008–2013	2011–2019
Mean follow-up	SAGE: 3 years TSHA: 3 years	4.5 years	Cross-sectional
Type of population	Community-dwelling older adults*. Sampling stratified by sex, age, and rural/urban location; representative at the national level for Mexico and at the local level for Toledo	Community-dwelling volunteers in an RCT in 13 memory clinics in France	Users of the health system in Toulouse
Methods	ROC analysis (Youden's index) and logistic regression with incident ADL as an outcome for cross-validation	Incident ADL disability: Cox regression Number of ADLs impaired: Mixed-effects linear regression	Logistic regression for association with ADL disability

Key variables	SAGE Mex + TSHA		MAPT		Toulouse Frailty Clinic	
n (%)	70–79	80+	70–79	80+	70–79	80+
n	1 229 (77.1)	366 (22.9)	1 295 (82.3)	278 (17.7)	786 (32.3)	1 648 (67.7)
Age (y), mean (*SD*)	73.9 (2.9)	82.9 (3.1)	73.7 (2.8)	82.6 (2.5)	75.9 (2.9)	85.9 (3.8)
Women	650 (52.9)	188 (51.4)	849 (65.6)	170 (61.2)	497 (63.2)	1 053 (63.9)
Chair stand time (s), mean (*SD*)	13.6 (3.9)	14.9 (4.5)	11.4 (3.4)	12.8 (3.8)	13.6 (4.7)	15.2 (5.2)
Incident ADL*	198 (16.1)	99 (27.1)	109 (13.5)	29 (25.4)	286† (36.5)†	765† (46.7)†

Notes: ADL = activities of daily living; MAPT = Multidomain Alzheimer Preventive Trial; RCT = randomized controlled trial; ROC = receiver operating characteristic.

*Except for 1.9% of the total population of TSHA who was institutionalized.

†Prevalence (only cross-sectional data are available for the Toulouse frailty clinic).

doctors. After a comprehensive geriatric assessment, an integrative care plan is designed and transmitted to the caregivers by the Gerontopole's team. Patients are informed by a notice that their data might be used for research. In all cases we used data from people aged 70 and older.

Variables of Interest

The CST was also used in MAPT and frailty day-hospital (1). Incident ADL disability was measured using the Katz scale as for SAGE and TSHA (15). ADL data were available at baseline for MAPT and the frailty clinic and at 48 and 60 months for MAPT. Covariates used in our cross-validation models were: sex, age, MAPT randomization group, level of education, MMSE score (17), and 15-item geriatric depression scale (GDS-15) (18).

Statistical Analysis

Chair Stand Cut Point Elaboration and Cross-validation

Data from SAGE and TSHA were merged. We randomly selected 50% of the age-stratified merged populations (70–79 and ≥80 years old in SAGE + TSHA) using the "sample" routine in STATA. In this first half of the randomly selected sample we ran 1 000 bootstrap repetitions of the cutoff point estimation using Youden's index overall and for age-, sex- and, sex-and age stratified cut points.

The psychometric parameters (ie, sensitivity, specificity, accuracy) of those cut points found were tabulated and compared to those of the cut point suggested by the WHO (14 seconds). Comparison for age-, sex- and sex-and age stratified cut points are shown in Table 2. Additionally, we obtained cut points according to different levels of either sensitivity or specificity, as an alternative to Youden's index (Online resource Supplementary Table B). We also compared the area under the ROC curve (AUC) for gait speed with that of CST as a reference (Supplementary Figure S1).

The second half of the randomly selected population was used to cross-validate the cut points' capacity of identifying older adults with a higher probability of incident disability in a bootstrapped logistic regression adjusted for age, sex, education, gait speed, and study source to control for the "intrinsic" characteristics of the study within the merged sample.

External Validation

MAPT: (a) Cox models (time-to-first event) for incident ADL disability were adjusted by age, sex, education level, MAPT group, baseline MMSE (17), and baseline GDS (18). The proportionality assumption was confirmed by the Schoenfeld residuals test. (b) Linear mixed-effect models were used to assess the association between slow chair standers and functional decline for ADLs.

Frailty day-hospital data set: we ran binary logistic regression models for ADL disability. We estimated the odds of ADL disability for slow chair standers (disability for ≥1 ADL vs full functionality). All analyses were performed using Stata (StataCorp, College Station, TX), with $\alpha = 0.05$.

Role of the Funding Source

The funder had no role in study design, data collection, data analysis, data interpretation, or report writing. The corresponding author had

Table 2. Age-, Sex- and Age-and-sex Stratified Cut Points Found Using the Youden's Index and Their Psychometric Properties Compared to the Current Cut Point

		No Age Stratification		70–79	80+	
		param 95% CI New cut point found	% change	param 95% CI Cut point found is the same as current 14 s	param 95% CI New cut point found	% change
		14 s		**14 s**	**16 s**	
No Sex Stratification	Sensitivity	0.56 (0.50; 0.62)	—	0.53 (0.46; 0.60)	0.44 (0.35; 0.55)	−28
	Specificity	0.61 (0.58; 0.64)	—	0.63 (0.60; 0.66)	0.74 (0.69; 0.79)	42*
	ROC area	0.58 (0.55; 0.62)	—	0.58 (0.54; 0.63)	0.61 (0.56; 0.68)	7*
	Accuracy	0.60 (0.57; 0.63)	—	0.62 (0.58; 0.65)	0.66 (0.61; 0.71)	21
	PPV	0.25 (0.21; 0.28)	—	0.22 (0.18; 0.26)	0.39 (0.30; 0.49)	20*
	NPV	0.86 (0.83; 0.88)	—	0.88 (0.85; 0.90)	0.78 (0.73; 0.83)	0
		14.6 s		**14 s**	**14.6 s**	
Women	Sensitivity	0.57 (0.49; 0.65)	−8	0.58 (0.48; 0.67)	0.71 (0.57; 0.83)	0
	Specificity	0.62 (0.58; 0.66)	11*	0.58 (0.54; 0.63)	0.55 (0.47; 0.64)	22*
	ROC area	0.59 (0.55; 0.64)	1	0.58 (0.53; 0.63)	0.63 (0.56; 0.71)	9
	Accuracy	0.61 (0.56; 0.65)	7	0.58 (0.53; 0.63)	0.60 (0.49; 0.70)	14*
	PPV	0.27 (0.22; 0.32)	6	0.23 (0.18; 0.28)	0.36 (0.27; 0.47)	15*
	NPV	0.85 (0.82; 0.88)	0	0.86 (0.82; 0.90)	0.85 (0.76; 0.91)	3
		15.8 s		**14 s**	**17.1 s**	
Men	Sensitivity	0.35 (0.27; 0.44)	−28	0.48 (0.36; 0.59)	0.36 (0.23; 0.51)	−31
	Specificity	0.83 (0.79; 0.85)	24*	0.69 (0.65; 0.73)	0.84 (0.76; 0.90)	41*
	ROC area	0.59 (0.55; 0.63)	2	0.58 (0.52; 0.64)	0.60 (0.52; 0.67)	7
	Accuracy	0.74 (0.71; 0.77)	17*	0.66 (0.61; 0.70)	0.70 (0.64; 0.76)	23*
	PPV	0.30 (0.23; 0.37)	26*	0.20 (0.14; 0.26)	0.46 (0.30; 0.63)	39*
	NPV	0.86 (0.83; 0.89)	0	0.89 (0.86; 0.92)	0.77 (0.69; 0.84)	1

Notes: CI = confidence interval; NPV = negative predictive value; param = psychometric parameter; PPV = positive predictive value; ROC area = area under the receiver–operator–characteristics curvevis à vis ADL incidence. The psychometric properties for the current cut point of 14 s are provided in Supplementary Table C.

*Psychometric features of the new cut point were >10% higher compared with the current cut point.

full access to all the data in the study and had the final responsibility for submitting it for publication.

Results

Chair Sand Cutoff Points: Elaboration and Cross-validation

The cutoffs derived were 14 second for the overall study sample. Also 14 second for those aged 70–79 and 16 second for those aged 80 and over. Sex-and-age-stratified cut points are shown in Table 2. We will refer to older adults with a chair stand result at or above the cutoff points as "slow chair standers"; those with chair stand result below the cutoff were "fast chair standers." Both cutoff points provided AUC values higher than 0.5 (Table 2). The age-stratified cut point (16 second for the 80+ age group) performed with higher specificity, accuracy, and positive predictive value compared to the 14 second cut point (Table 2). The highest increases in accuracy were found with age-stratified cut points, even when compared to sex- and age-stratified cut points. Cross-validation found that slow chair standers in both age groups had 2-fold higher odds of incident ADL disability than their counterparts OR = 1.72 (95% confidence interval [CI] 1.06; 2.78) for 70–79 year and OR = 2.27 (95% CI 1.07; 4.80) for 80+ (Table 3).

Chair Stand Cut Point External Validation

Data from MAPT showed that slow chair standers are at higher risk of incident ADL disability than their faster counterparts in Cox models adjusted for covariates with a mean follow-up of 58.6 months (for 70–79: Hazard ratio (HR) = 1.65 (95% CI 1.07; 2.57) and for 80+: HR = 1.85 (95% CI 0.75; 4.61). (Table 3).

Slow chair standers had a significantly steeper functional decline for ADLs over time than fast chair standers for both age groups and the difference was clinically relevant for those aged 80+. Between-group differences over 5 years were 0.038 (95% CI −0.07; −0.01), and 0.325 (95% CI −0.50; −0.15) points for 70–79 and 80+ age groups, respectively (Table 3 and Supplementary Figure S2).

Data from the Frailty day-hospital showed that slow chair standers had 2.3 times and 2.1 higher odds and of being disabled in ADLs than their fast counterparts for 70–79 and 80+ age groups, respectively (Table 3).

Discussion

The cutoff points found for the CST were 14 second for the 70–79 age group and 16 second for those aged 80+ for incident ADL disability. According to these cut points, slow chair standing was linked

Table 3. Cross-validation and External Validation of the Cut Points

Model	70–79				80+			
	n	param	95% CI	*p*	*n*	param	95% CI	*p*
	Cross-validation							
A	612	1.72	(1.06; 2.78)	.027	183	2.27	(1.07; 4.80)	.032
	External validation							
B	794	1.65	(1.07; 2.57)	.025	112	1.85	(0.75; 4.61)	.072
C	794	−0.04	(−0.07; −0.01)	.018	112	−0.32	(−0.50; −0.15)	<.001
D	721	2.33	(1.68; 3.21)	<.001	1523	2.08	(1.67; 2.59)	<.001

ADL = activities of daily living; CI = confidence interval; GDS = geriatric depression scale; MAPT = Multidomain Alzheimer Preventive Trial; MMSE = Mini-Mental State Examination; param = estimated parameter. Model A. Odds ratio from a logistic model for incident disability for basic ADLs over 3-year FU, adjusted for age, sex, education, gait speed, and study (SAGE + TSHA). Model B. Hazards ratio from a Cox model for incident disability for basic ADLs over a 5-year FU, adjusted for age, sex, education, MAPT group, and baseline MMSE, GDS (MAPT). Model C. Mean difference in number of functionally-preserved basic ADLs between fast chair standers and slow chair standers after 5-year FU from a mixed-effects model adjusted for age and sex (MAPT; Supplementary Figure S2). Model D. Odds ratio from a cross-sectional logistic model for basic ADLs disability, adjusted for age, sex, education, and baseline MMSE (Toulouse Frailty clinic).

to ADL disability in a cross-sectional and longitudinal fashion among older adults from different clinical settings. Our findings provide the first development and validation of age-stratified cutoffs for the CST in older adults using population-based studies.

The validated cutoff point of 14 second for the age group 70–79 is consistent with what is currently proposed in the screening (Step 1) of the ICOPE handbook. It is also congruent with cutoffs found by 5 out of 10 previous studies from different countries (see online resource Supplementary Table A). Lower cutoff points (10 second) have been found in younger/healthier populations with lower incident disability rates (19,20).

We did not find any reference focusing on the age group 80+, highlighting the importance of the present work. The cutoff point we found for this age group is congruent with Bohannon's meta-analysis reporting a mean time of 14.8 second for those aged 80–89 (10) and with the population in the validation study of the SPPB (1).

The 14 second cutoff proposed in the WHO ICOPE handbook (9) was validated in our study for the adults aged 70–79. Indeed, our results suggest that the cutoff of 16 second for adults aged 80 and over would be more appropriate. Adjusting the cut point from 14 to 16 second in adults aged 80+ would bring important improvements in specificity, accuracy, and positive predictive value. Thus, fewer adults would be falsely catalogued as having impaired mobility and a potential reduction in the health systems' burden. Innovative approaches for measuring the CST in older adults such as sensors or mobile apps are advantageous for research or clinical contexts (21,22).

Our study has several strengths: the cutoffs were derived from population-based studies from different countries and then tested in data sets representing volunteers for an RCT and users of the health system. Limitations are that we cannot be sure that these cut points will apply in other latitudes. Regarding the relatively low values for the AUC 0.58 (CI 95% 0.54; 0.63) and 0.61 (CI 95% 0.56; 0.68) for the 70–79 and 80+, respectively (Table 2), it is essential to note that previous studies have published AUC values <0.70 for chair stand discrimination of incident disability (20). The relatively low AUC values found throughout studies suggests that the CST cutoff should be used along other parameters such as the rest of the domains of intrinsic capacity to better discriminate those older adults at higher risk of ADL disability (23,24) (Supplementary Figure S1).

Noteworthy, cutoff points obtained using Youden's index are not the only possible ones, as different thresholds might be chosen in different settings according to the main objective of the test (online resource Supplementary Note and Table B). Also, similar studies focused on younger adults should assess functional outcomes different from ADL disability.

In conclusion, 14 second and 16 second cut points for the CST were validated to identify individuals at higher risk of functional decline in adults aged 70–79 and 80+ years from Mexico, Toledo, and Spain. Also, those cut points worked well in volunteers of a RCT and in users of a frailty clinic. Validation of these cut points in other populations is desirable.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

Funding

The present work was performed in the context of the Inspire Program, a research platform supported by grants from the Region Occitanie/Pyrénées-Méditerranée (reference number: 1901175) and the European Regional Development Fund (ERDF; Project number: MP0022856). This study has been partially supported through the grant EUR CARe N°ANR-18-EURE-0003 in the framework of the Programme des Investissements d'Avenir. The MAPT study was supported by grants from the Gérontopôle of Toulouse, the French Ministry of Health (PHRC 2008, 2009), Pierre Fabre Research Institute (manufacturer of the omega-3 supplement), ExonHit Therapeutics SA, and Avid Radiopharmaceuticals Inc. The promotion of this study was supported by the University Hospital Center of Toulouse. The data-sharing activity was supported by the Association Monegasque pour la Recherche sur la Maladie d'Alzheimer (AMPA) and the INSERM-University of Toulouse III Maintain Functions and Intrinsec capacities with Aging (MAINTAIN) Research team, Center for Epidemiology and population health research (CERPOP) Inserm, Université Paul Sabatier, Toulouse, France.

Conflict of Interest

None declared.

Ethics approval and consent to participate: All participants provided their informed consent. The trial protocol (ClinicalTrials.gov identifier: NCT00672685) was approved by the French Ethical Committee located in Toulouse (CPP SOOM II) and was authorized by the French Health Authority.

The scientific board of the National Institute of Public Health approved the SAGE Mexico study. The Clinical Research Ethics Committee approved the TSHA of the Toledo Hospital.

Acknowledgments

The authors thank Yuka Sumi and Ritu Sadana for their valuable inputs, Aging and Health unit. Department of Maternal, Newborn, Child & Adolescent Health and Aging World Health Organization (WHO), Geneva.

Author Contribution

E.G.-B., S.A., S.S., A.S.-R., B.M.E., L.R.-M., P.S.B., Y.R., and B.V. substantially contributed to the conception and design, analysis, and interpretation of data. E.G.-B. and P.S.B. performed statistical analyses and wrote the manuscript. E.G.-B., S.A., S.S., A.S.-R., B.M.E., L.R.-M., P.S.B., Y.R., and B.V. provided valuable intellectual inputs and reviewed the manuscript. E.G.-B., S.A., S.S., A.S.-R., B.M.E., L.R.-M., P.S.B., Y.R., and B.V. final approval of the version to be published.

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Data Availability

Documentation and metadata of the SAGE, TSHA, and MAPT studies can be accessed by contacting the study management teams of the studies on reasonable request. Data on the Frailty Clinic will not be publicly available. Code is available upon request to the corresponding author.

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