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Physical Fitness and All-Cause Mortality in Older Adults

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Abstract

IMPORTANCE Regular physical activity promotes healthy aging, yet clinical risk stratification in older adults relies largely on comorbidity burden, often overlooking functional capacity. Objective fitness assessment may serve as a clinically relevant indicator of physiological reserve, but evidence from large cohorts evaluating multiple fitness domains remains limited.

OBJECTIVE To evaluate associations between objectively measured physical fitness across multiple domains and all-cause mortality in older adults.

DESIGN, SETTING, AND PARTICIPANTS This nationwide cohort study included community-dwelling adults aged 65 years or older who completed standardized fitness assessments in Taiwan between January 11, 2015, and November 25, 2016. Participant data were linked to National Health Insurance records, with follow-up through December 31, 2022. Statistical analyses were conducted between July 1, 2025, and May 30, 2026.

EXPOSURES Physical fitness was assessed across 4 domains: cardiorespiratory fitness (2-minute step test), muscular strength (30-second arm curl and chair stand tests), flexibility (back scratch and chair sit-and-reach tests), and balance and agility (1-leg stance and 8-foot up-and-go tests). A composite fitness index was constructed by summing sex-specific percentile ranks across all 7 assessments.

MAIN OUTCOME AND MEASURES The main outcome was all-cause mortality, ascertained through linkage with the National Health Insurance death registry. Multivariable Cox proportional hazards models estimated adjusted hazard ratios (AHRs), adjusting for sociodemographic factors, comorbidities, and self-reported physical activity.

RESULTS Of 13 423 participants (mean [SD] age, 72.9 [6.1] years; 8394 female [62.5%]), 1631 (12.2%) died during a median (IQR) follow-up of 7.0 (6.7-7.1) years. Compared with the lowest performance quintile, participants in the highest performance quintile had lower all-cause mortality across 4 physical fitness assessments: 8-foot up-and-go (AHR, 0.41 [95% CI, 0.33-0.51]), 1-leg stance (AHR, 0.50 [95% CI, 0.42-0.59]), 30-second chair stand (AHR, 0.55 [95% CI, 0.46-0.65]), and 2-minute step test (AHR, 0.58 [95% CI, 0.49-0.68]). The composite fitness index showed the lowest risk of all-cause mortality (AHR, 0.39 [95% CI, 0.32-0.48]).

CONCLUSIONS AND RELEVANCE In this cohort study of older adults, objectively measured physical fitness—particularly balance and agility, lower-body strength, and cardiorespiratory fitness—was associated with lower all-cause mortality in a graded manner. These findings suggest that integrating objective fitness assessments into routine practice may refine risk stratification and guide function-oriented interventions in older adults.

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Key Points

Question Is there an association between objectively measured physical fitness and all-cause mortality among adults aged 65 years or older, in addition to self-reported physical activity?

Findings In this cohort study of 13 423 older adults, higher physical fitness was associated with lower all-cause mortality across a median 7-year follow-up. Balance and agility, lower-body strength, and cardiorespiratory fitness showed the lowest risks of all-cause mortality.

Meaning These findings suggest that incorporating objective fitness assessment into routine geriatric and internal medicine practice may enhance risk stratification and guide individualized, function-oriented interventions in older adults.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Introduction

Regular physical activity is a cornerstone of healthy aging, associated with reduced risks of cardiovascular disease, functional decline, and premature mortality.[1-6] Despite this evidence, clinical risk stratification in older adults remains limited. Current prognostic models rely largely on comorbidity burden and disease-specific indicators, which offer limited value for the broader population of older adults in preclinical stages of decline.[7]

Most epidemiologic studies of physical activity and mortality rely on self-reported activity behaviors,[8-10] which are subject to recall bias and measurement error, particularly in older adults with multimorbidity or cognitive impairment. Although recent studies have examined combinations or variety of activity types,[11-13] the resulting complex profiles are difficult to translate into routine clinical assessment, for which clinicians require simple, objective, and reproducible indicators for risk stratification and counseling.

Objective physical fitness assessment provides a complementary approach. Physical fitness reflects cumulative physiological adaptation to habitual activity, illness, and biological aging.[14] Performance-based assessments of cardiorespiratory fitness, muscular strength, balance, and mobility have been consistently associated with mortality and major clinical outcomes, in addition to or partially independent of self-reported physical activity.[15-19] Because these assessments objectively quantify physiological reserve—what an individual can functionally do, rather than just what diagnoses they have accumulated—they offer a distinct lens for risk stratification. However, evidence remains limited on whether these associations extend across multiple fitness domains, in men as well as women, and in non-Western older populations.

This functional approach complements, rather than replaces, established geriatric models of frailty[7,20,21] and sarcopenia.[22] While these models focus on comorbidity burden or pathologic muscle loss, physical fitness provides a broader, continuous measure of functional capacity across the health spectrum—from robust to frail. These distinctions underscore the potential of objective fitness measures to enable more granular risk stratification. However, few studies have simultaneously evaluated multiple fitness domains and a composite multidomain index in the same older population, and clinically actionable dose-response patterns remain insufficiently defined.

To address these gaps, we established a nationally representative cohort linking standardized fitness assessments to comprehensive mortality records in Taiwan.[23] This study evaluated associations of multidomain physical fitness with all-cause mortality in adults aged 65 years or older, after adjustment for sociodemographic factors, lifestyle behaviors, and prevalent comorbidities. By characterizing dose-response patterns across distinct fitness domains, our findings are intended to inform function-based risk stratification beyond traditional disease-centered models and support the integration of objective performance assessments into routine geriatric and internal medicine practice.

Methods

Data Sources

This cohort study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline. Data were obtained from Taiwan's National Physical Fitness Survey Database (NPFSD) and National Health Insurance Research Database (NHIRD), linked through the Health and Welfare Data Science Center using applicant-specific encryption keys following Taiwan's deidentification standards, with deterministic matching minimizing linkage error. The NPFSD, established in 2013, recruits participants annually across 46 fitness testing stations in 22 cities and counties to develop nationally representative fitness standards. Recruitment uses quota-based convenience sampling, with age- and sex-specific targets proportional to the national population distribution.[24] The present study assessed data from participants 65 years of age or older who underwent age-specific assessments[25]; anthropometric, sociodemographic, lifestyle, and self-reported health data were also collected.[24,26] This study was approved by the institutional review board of National Yang Ming Chiao Tung University, which waived the requirement for informed consent given the use of deidentified secondary data.

The NHIRD provides comprehensive population-based data from Taiwan's mandatory single-payer National Health Insurance, which covers more than 99% of the population.[27] Records include outpatient and inpatient visits, diagnoses, medications, procedures, and the death registry.[23] We retrieved medical histories from January 1, 2007, through December 31, 2022.

Study Population

The source cohort included 18 173 adults at least 65 years of age who underwent fitness assessment between January 11, 2015, and November 25, 2016, in the NPFSD. After excluding participants who could not be linked to the National Health Insurance Registry for Beneficiaries (n = 1508) or had missing fitness assessment data (n = 9), 16 656 participants remained. We further excluded participants older than 90 years; those with conditions likely to limit fitness performance (dementia, stroke, or prior limb amputation); or those holding a Catastrophic Illness Certificate, primarily for cancer, autoimmune diseases, or chronic mental health conditions. Exclusions were based on diagnoses recorded from January 1, 2007, through the index date (defined as the fitness assessment date). The final analytic sample included 13 423 participants. Vital status was ascertained through deterministic linkage with Taiwan's National Health Insurance records and the death registry, which provide effectively complete population coverage; loss to follow-up was therefore negligible. The full participant flow diagram and definitions of exclusion criteria are provided in eFigure 1, eAppendix 1, and eTable 1 in Supplement 1.

Physical Fitness Measures

Four fitness domains were assessed following the Senior Fitness Test protocol[28]: cardiorespiratory fitness (functional aerobic endurance), muscular fitness, flexibility, and balance and agility. All assessments were administered by certified examiners (H.-T. Hsu, L.-H. Lin, and C.-H. Chen) using nationally standardized procedures; detailed protocols, equipment, practice and measured trials, and examiner training are described in eMethods 1 through 6 in Supplement 1.

Cardiorespiratory fitness was assessed using the 2-minute step test, performed in place (not on a fixed external step), with the required knee-lift height individualized to each participant's anatomy at the midpoint between the anterior superior iliac spine and the midpatella; a valid step was counted only when both knees reached the marked height. Muscular fitness was evaluated using (1) the 30-second arm curl test, with nationally specified weights (2.27 kg [5 lb] for females, 3.63 kg [8 lb] for males), and (2) the 30-second chair stand test (unassisted rises from seated to standing with arms crossed at the chest). Flexibility was assessed using (1) the back scratch test, in which the distance of overlap or gap between the middle fingertips of both hands reaching behind the back was measured; and (2) the chair sit-and-reach test, in which participants reached both middle fingertips toward the toes of 1 extended leg (heel on floor, foot dorsiflexed to approximately 90°) while the other leg remained bent. For both tests, overlap was recorded as a positive value and gap as a negative value. Balance and agility were assessed using (1) the 1-leg stance test with eyes open[29] (longer time of 2 trials; maximum 30 seconds) and (2) the 8-foot up-and-go test, requiring participants to rise from a chair, walk 8 feet (2.44 m) around a cone, return, and sit (shorter time of 2 trials). Examiner demonstration and supervised practice were provided before each measured trial.

Outcome

The primary outcome was all-cause mortality through December 31, 2022. All-cause mortality was ascertained from the NHIRD death registry.

Covariates

Covariates from the NPFSD included sex, age, body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), regular physical activity (≥150 minutes/week of moderate-intensity aerobic activity[30]), monthly income (<20 000, 20 000-40 000, and >40 000 NT$; multiply by 0.032 for US dollars), educational attainment (primary school or lower; junior high; senior high; college or higher), employment status, living alone status, region of residence (north, central, south, east, outlying islands), and township urbanization (categories 1 through 4, with 1 being most urbanized).[31] Smoking status was not captured in the NPFSD during the study period and therefore could not be included as a covariate.

The NHIRD covariates included 10 comorbidities (hypertension, hyperlipidemia, diabetes, coronary heart disease, chronic kidney disease, liver disease, osteoporosis, chronic obstructive pulmonary disease, thyroid disorders, and heart failure) and the Charlson Comorbidity Index (range, 0-34, with higher numbers indicating greater comorbidity burden).[32] All comorbidities were ascertained from claims within 365 days before the index date, with individual comorbidities defined as 2 or more for outpatient diagnoses or 1 or more for inpatient diagnoses. Medication use was not required for the primary definition. *International Classification of Diseases* codes are provided in eTable 1 in Supplement 1.

Statistical Analysis

Baseline characteristics were summarized by sex and survival status. To compare fitness performance between survivors and decedents, age-adjusted mean values for each fitness assessment were estimated separately by sex using linear regression, with each raw fitness value as the outcome and age as the covariate.

For the primary analysis, each fitness assessment was categorized into sex-specific quintiles (Q, with Q1 as the reference indicating poorest performance; Q5, best performance). A composite fitness index was constructed by summing the sex-specific percentile ranks across all 7 assessments with equal weighting and was similarly categorized into quintiles. Treating quintiles as categorical variables avoided assumptions of linearity or equal spacing across the fitness distribution.

Age-adjusted cumulative all-cause mortality, calculated as 1 minus the fitted survival probability from age-adjusted Cox models, was compared across quintiles for each fitness assessment. Multivariable Cox proportional hazards models then estimated associations between fitness quintiles and all-cause mortality, adjusting for sex, age, regular physical activity, BMI, socioeconomic and geographic factors, individual comorbidities, and the Charlson Comorbidity Index. Each fitness assessment was analyzed separately because of collinearity.

To examine dose-response associations, we fit restricted cubic spline models in Cox regression with knots at the 10th, 50th, and 90th percentiles, using continuous raw fitness values and adjusting for the same covariates. The Wald test on the nonlinear spline coefficient assessed departure from linearity (*P* for nonlinearity).

In sensitivity analyses, each fitness assessment was modeled as a continuous variable in multivariable Cox models with 2 specifications: (1) a continuous percentile score (0-100) and (2) the original raw value (Wald test on this coefficient assessing linear association; *P* for linearity). Statistical significance was defined as a 2-sided $P < .05$. Analyses were conducted using R, version 4.2.2 (R Project for Statistical Computing), and SAS, version 9.4 (SAS Institute Inc), between July 1, 2025, and May 30, 2026.

Results

Baseline Characteristics

Of 13 423 participants, the median (IQR) follow-up was 7.0 (6.7-7.1) years, 8394 (62.5%) were female, and 5029 (37.5%) were male (**Table**). The median (IQR) age was 72.0 (68.0-77.0) years, and the mean (SD) age was 72.9 (6.1) years. In total, 4399 participants (32.8%) engaged in regular physical activity. The median (IQR) BMI was 24.6 (22.5-27.0). Common comorbidities included hypertension (n = 6755 [50.3%]), hyperlipidemia (n = 4012 [29.9%]), diabetes (n = 3389 [25.2%]), coronary heart disease (n = 2026 [15.1%]), and chronic kidney disease (n = 1374 [10.2%]).

Table. Baseline Characteristics of Participants Stratified by Survival Status at the End of the Study Period (December 31, 2022)

Variable	Participants, No. (%)		
	Total (N = 13 423)	Deceased (n = 1631)	Survived (n = 11 792)
Follow-up, y			
Mean (SD)	6.6 (1.1)	4.2 (1.9)	6.9 (0.3)
Median (IQR)	7.0 (6.7-7.1)	4.6 (2.8-5.9)	7.0 (6.8-7.1)
Demographics			
Sex			
Female	8394 (62.5)	783 (48.0)	7611 (64.5)
Male	5029 (37.5)	848 (52.0)	4181 (35.5)
Age, y			
Mean (SD)	72.9 (6.1)	77.2 (6.7)	72.3 (5.7)
Median (IQR)	72.0 (68.0-77.0)	77.0 (72.0-82.0)	71.0 (67.0-76.0)
With regular physical activity	4399 (32.8)	464 (28.4)	3935 (33.4)
Anthropometric characteristics			
BMI[a]			
Mean (SD)	24.9 (3.6)	24.6 (3.8)	24.9 (3.5)
Median (IQR)	24.6 (22.5-27.0)	24.3 (22.0-26.9)	24.7 (22.5-27.1)
BMI category[a]			
Underweight (<22.0)	2765 (20.6)	416 (25.5)	2349 (19.9)
Normal weight (22.0-23.9)	2914 (21.7)	348 (21.3)	2566 (21.8)
Overweight (24.0-26.9)	4361 (32.5)	480 (29.4)	3881 (32.9)
Obese (≥27.0)	3383 (25.2)	387 (23.7)	2996 (25.4)
Socioeconomic variables			
Monthly income, NT$[b]			
<20 000	10 461 (77.9)	1349 (82.7)	9112 (77.3)
20 000-40 000	2108 (15.7)	219 (13.4)	1889 (16.0)
>40 000	854 (6.4)	63 (3.9)	791 (6.7)
Educational attainment			
≤Primary school	7433 (55.4)	1084 (66.5)	6349 (53.8)
Junior high school	1615 (12.0)	161 (9.9)	1454 (12.3)
Senior high school	1741 (13.0)	134 (8.2)	1607 (13.6)
≥College	1452 (10.8)	118 (7.2)	1334 (11.3)
Unknown	1182 (8.8)	134 (8.2)	1048 (8.9)
Employed (had a job)	7394 (55.1)	1081 (66.3)	6313 (53.5)
Living alone			
No	10 131 (75.5)	1189 (72.9)	8942 (75.8)
Yes	2247 (16.7)	342 (21.0)	1905 (16.2)
Unknown	1045 (7.8)	100 (6.1)	945 (8.0)
Geographic variables			
Region of the residence			
North	4940 (36.8)	496 (30.4)	4444 (37.7)
Central	3017 (22.5)	425 (26.1)	2592 (22.0)
South	4208 (31.4)	553 (33.9)	3655 (31.0)
East or outlying islands	1258 (9.4)	157 (9.6)	1101 (9.3)
Township urbanization			
1 (Most urbanized)	2188 (16.3)	207 (12.7)	1981 (16.8)
2	3641 (27.1)	371 (22.7)	3270 (27.7)
3	4929 (36.7)	642 (39.4)	4287 (36.4)
4	2665 (19.9)	411 (25.2)	2254 (19.1)

(continued)

Table. Baseline Characteristics of Participants Stratified by Survival Status at the End of the Study Period (December 31, 2022) (continued)

Variable	Participants, No. (%)		
	Total (N = 13 423)	Deceased (n = 1631)	Survived (n = 11 792)
Medical history			
Comorbidity			
Hypertension	6755 (50.3)	1010 (61.9)	5745 (48.7)
Hyperlipidemia	4012 (29.9)	410 (25.1)	3602 (30.5)
Diabetes	3389 (25.2)	523 (32.1)	2866 (24.3)
Coronary heart disease	2026 (15.1)	296 (18.1)	1730 (14.7)
Chronic kidney disease	1374 (10.2)	300 (18.4)	1074 (9.1)
Liver disease	1296 (9.7)	167 (10.2)	1129 (9.6)
Osteoporosis	786 (5.9)	89 (5.5)	697 (5.9)
COPD	644 (4.8)	149 (9.1)	495 (4.2)
Thyroid gland disorders	419 (3.1)	32 (2.0)	387 (3.3)
Heart failure	307 (2.3)	85 (5.2)	222 (1.9)
CCI score[c]			
0	6602 (49.2)	597 (36.6)	6005 (50.9)
1	3805 (28.3)	485 (29.7)	3320 (28.2)
2	1859 (13.8)	295 (18.1)	1564 (13.3)
≥3	1157 (8.6)	254 (15.6)	903 (7.7)

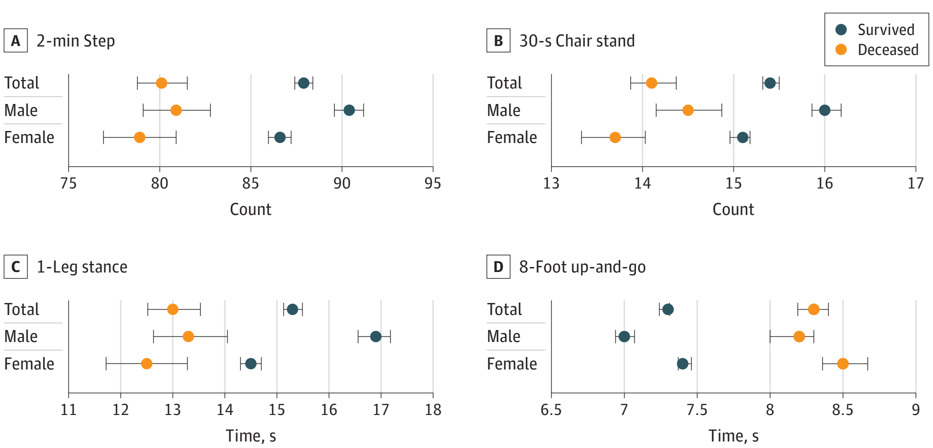
Abbreviations: BMI, body mass index; CCI, Charlson Comorbidity Index; COPD, chronic obstructive pulmonary disease.

[a] BMI calculated as weight in kilograms divided by height in meters squared.

[b] Multiply by 0.032 for US dollars.

[c] Scores ranged from 0 to 34, with higher scores indicating greater comorbidity burden.

Figure 1. Dot Plots Illustrating Age-Adjusted Physical Fitness Assessment Values by Survival Status and Sex



Circles denote means and whiskers extend to 95% CIs.

Participants who died during follow-up (n = 1631 [12.2%]) were more likely than survivors (n = 11 792 [87.8%]) to be male (n = 848 [52.0%] vs n = 4181 [35.5%]), older (median [IQR] age, 77.0 [72.0-82.0] vs 71.0 [67.0-76.0] years), physically inactive (1167 [71.6%] vs 7857 [66.6%]), socioeconomically disadvantaged (eg, monthly income <20 000 NT$, 1349 [82.7%] vs 9112 [77.3%]), living alone (342 [21.0%] vs 1905 [16.2%]), residing in less urbanized areas (411 [25.2%] vs 2254 [19.1%] for least urbanized), and to have higher comorbidity burden (Charlson Comorbidity Index score ≥3, 254 [15.6%] vs 903 [7.7%]). Sex-stratified characteristics are presented in eTable 2 in Supplement 1.

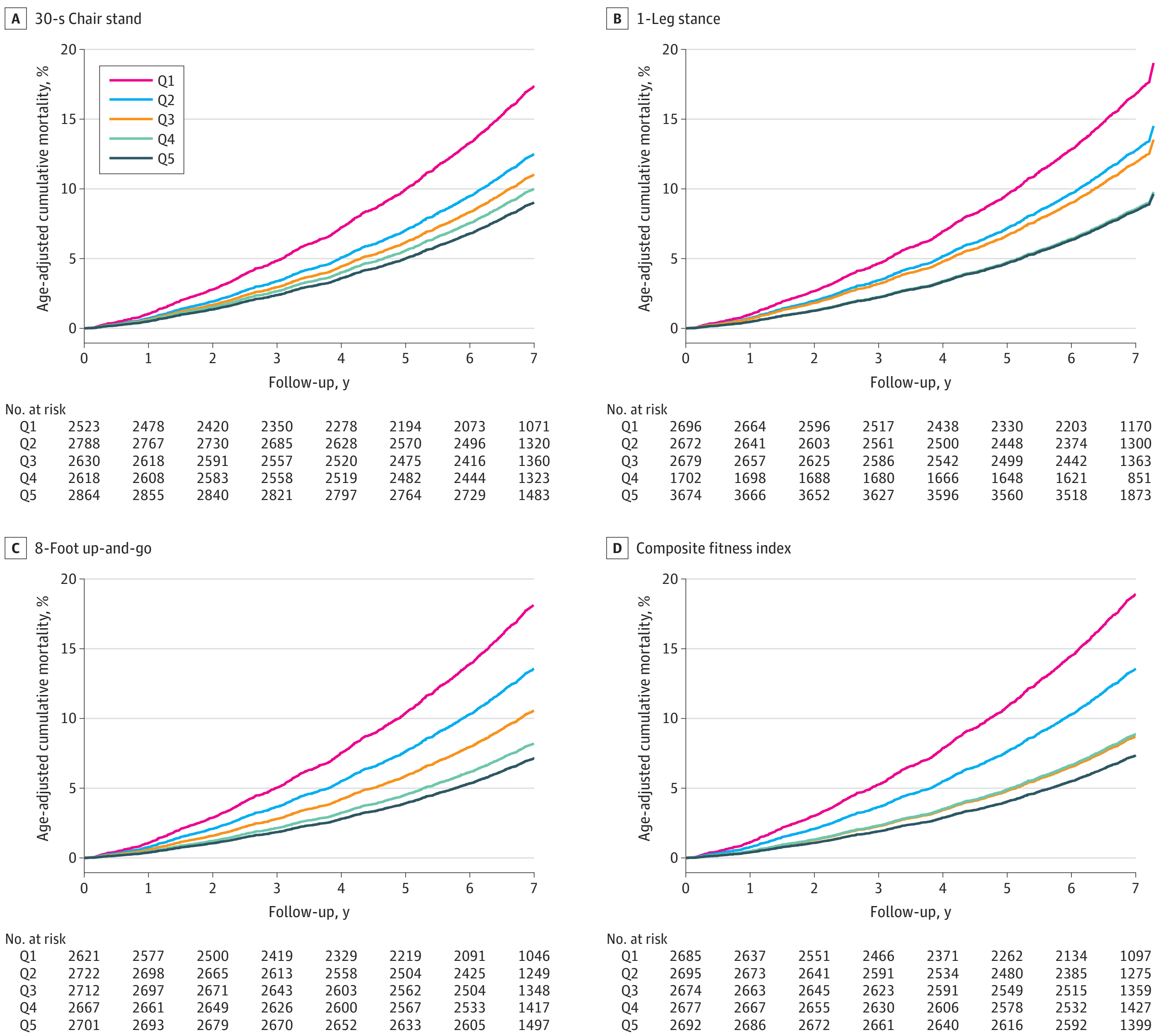
Age-Adjusted Physical Fitness by Survival Status and Sex

Figure 1 presents age-adjusted mean values for the 4 fitness assessments associated with the lowest risk of all-cause mortality in multivariable Cox models; the remaining 3 assessments are shown in eFigure 2 in Supplement 1. Higher values indicated better performance, except for the 8-foot up-and-go test, in which shorter times indicated better performance. Across all 7 assessments and both sexes, survivors had more favorable performance than participants who died during follow-up, with nonoverlapping 95% CIs. Men generally outperformed women on cardiorespiratory, lower-body muscular strength, and balance and agility assessments, whereas women showed better flexibility performance. Quintile distributions by sex are provided in eTable 3, which is described in eAppendix 2, in Supplement 1.

Age-Adjusted Cumulative All-Cause Mortality by Fitness Quintiles

Figure 2 presents age-adjusted cumulative all-cause mortality curves for the 30-second chair stand test, 1-leg stance test, 8-foot up-and-go test, and composite fitness index; the remaining 4 assessments are shown in eFigure 3 in Supplement 1. Across all assessments and the composite index, cumulative mortality increased monotonically from Q5 (best performance) to Q1 (poorest

Figure 2. Line Graphs Depicting Age-Adjusted Cumulative All-Cause Mortality by Physical Fitness Quintile



A 30-s Chair stand — No. at risk

Q1	2523	2478	2420	2350	2278	2194	2073	1071
Q2	2788	2767	2730	2685	2628	2570	2496	1320
Q3	2630	2618	2591	2557	2520	2475	2416	1360
Q4	2618	2608	2583	2558	2519	2482	2444	1323
Q5	2864	2855	2840	2821	2797	2764	2729	1483

B 1-Leg stance — No. at risk

Q1	2696	2664	2596	2517	2438	2330	2203	1170
Q2	2672	2641	2603	2561	2500	2448	2374	1300
Q3	2679	2657	2625	2586	2542	2499	2442	1363
Q4	1702	1698	1688	1680	1666	1648	1621	851
Q5	3674	3666	3652	3627	3596	3560	3518	1873

C 8-Foot up-and-go — No. at risk

Q1	2621	2577	2500	2419	2329	2219	2091	1046
Q2	2722	2698	2665	2613	2558	2504	2425	1249
Q3	2712	2697	2671	2643	2603	2562	2504	1348
Q4	2667	2661	2649	2626	2600	2567	2533	1417
Q5	2701	2693	2679	2670	2652	2633	2605	1497

D Composite fitness index — No. at risk

Q1	2685	2637	2551	2466	2371	2262	2134	1097
Q2	2695	2673	2641	2591	2534	2480	2385	1275
Q3	2674	2663	2645	2623	2591	2549	2515	1359
Q4	2677	2667	2655	2630	2606	2578	2532	1427
Q5	2692	2686	2672	2661	2640	2616	2592	1399

Age-adjusted cumulative mortality curves were calculated as 1 minus the fitted survival probability from Cox models adjusted for age. Quintile (Q)1 represents the lowest performance; Q5, the highest performance, except for the 8-foot up-and-go test in which quintiles were reverse-ranked; thus, shorter completion times correspond to higher quintiles for this latter test.

performance). The composite fitness index showed the most pronounced separation across quintiles, with the steepest gradient between Q1 and the upper quintiles.

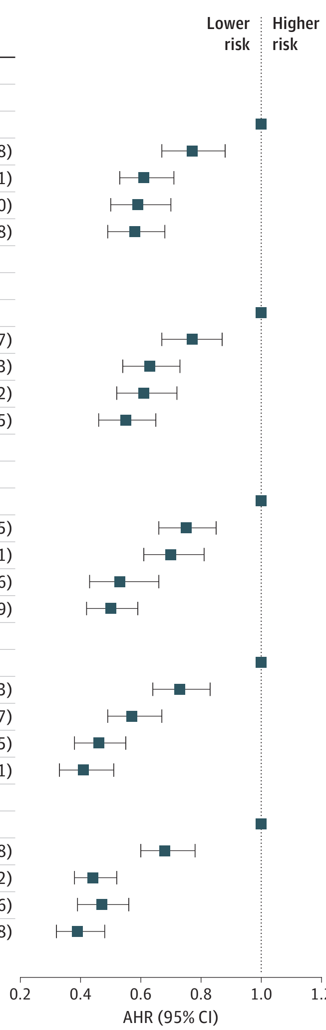
Multivariable-Adjusted Associations Between Physical Fitness and All-Cause Mortality

Figure 3 presents adjusted hazard ratios (AHRs) and 95% CIs for fitness quintiles from multivariable Cox models for the 4 fitness assessments with the lowest risks of all-cause mortality and the composite fitness index; the remaining 3 assessments are presented in eFigure 4 in Supplement 1. Higher fitness quintiles were consistently associated with lower mortality risk across all assessments.

The composite fitness index showed the lowest risk: compared with Q1, Q5 was associated with the lowest risk of all-cause mortality (AHR, 0.39 [95% CI, 0.32-0.48]), with a monotonic gradient across all quintiles. Among individual assessments, balance and agility showed the lowest risks (Q5 vs Q1: AHR, 0.41 [95% CI, 0.33-0.51] for the 8-foot up-and-go test; AHR, 0.50 [95% CI, 0.42-0.59] for the 1-leg stance test). Lower-body strength (chair stand AHR, 0.55 [95% CI, 0.46-0.65]) and cardiorespiratory fitness (2-minute step test AHR, 0.58 [95% CI, 0.49-0.68]) showed similar risks. Upper-body strength (30-second arm curl AHR, 0.63 [95% CI, 0.53-0.75]) and flexibility (eg, chair sit-and-reach AHR, 0.79 [95% CI, 0.67-0.93]) showed higher risks (eFigure 4 in Supplement 1).

Figure 3. Dot Plots Showing Multivariable-Adjusted Hazard Ratios (AHRs) for All-Cause Mortality by Physical Fitness Quintile (Q)

Measure	No. of deaths, %	Incidence rate per 100 person-years (95% CI)	Multivariable Cox model AHR (95% CI)
Cardiorespiratory fitness			
2-min Step			
Q1	579 (21.6)	3.42 (3.14-3.70)	1 [Reference]
Q2	377 (13.6)	2.07 (1.86-2.28)	0.77 (0.67-0.88)
Q3	257 (9.6)	1.44 (1.27-1.62)	0.61 (0.53-0.71)
Q4	213 (8.3)	1.24 (1.07-1.41)	0.59 (0.50-0.70)
Q5	205 (7.5)	1.11 (0.96-1.27)	0.58 (0.49-0.68)
Muscular fitness			
30-s Chair stand			
Q1	575 (22.8)	3.62 (3.33-3.92)	1 [Reference]
Q2	362 (13.0)	1.98 (1.77-2.18)	0.77 (0.67-0.87)
Q3	278 (10.6)	1.59 (1.40-1.77)	0.63 (0.54-0.73)
Q4	216 (8.3)	1.23 (1.07-1.40)	0.61 (0.52-0.72)
Q5	200 (7.0)	1.03 (0.89-1.18)	0.55 (0.46-0.65)
Balance and agility			
1-Leg stance			
Q1	626 (23.2)	3.69 (3.40-3.98)	1 [Reference]
Q2	376 (14.1)	2.15 (1.94-2.37)	0.75 (0.66-0.85)
Q3	302 (11.3)	1.70 (1.51-1.89)	0.70 (0.61-0.81)
Q4	115 (6.8)	1.00 (0.82-1.18)	0.53 (0.43-0.66)
Q5	212 (5.8)	0.85 (0.74-0.97)	0.50 (0.42-0.59)
8-Foot up-and-go			
Q1	661 (25.2)	4.07 (3.76-4.38)	1 [Reference]
Q2	397 (14.6)	2.23 (2.01-2.45)	0.73 (0.64-0.83)
Q3	264 (9.7)	1.46 (1.28-1.63)	0.57 (0.49-0.67)
Q4	176 (6.6)	0.98 (0.83-1.12)	0.46 (0.38-0.55)
Q5	133 (4.9)	0.72 (0.60-0.85)	0.41 (0.33-0.51)
Composite index			
Q1	693 (25.8)	4.17 (3.86-4.48)	1 [Reference]
Q2	395 (14.7)	2.24 (2.02-2.46)	0.68 (0.60-0.78)
Q3	213 (8.0)	1.18 (1.03-1.34)	0.44 (0.38-0.52)
Q4	193 (7.2)	1.07 (0.92-1.22)	0.47 (0.39-0.56)
Q5	137 (5.1)	0.75 (0.62-0.88)	0.39 (0.32-0.48)



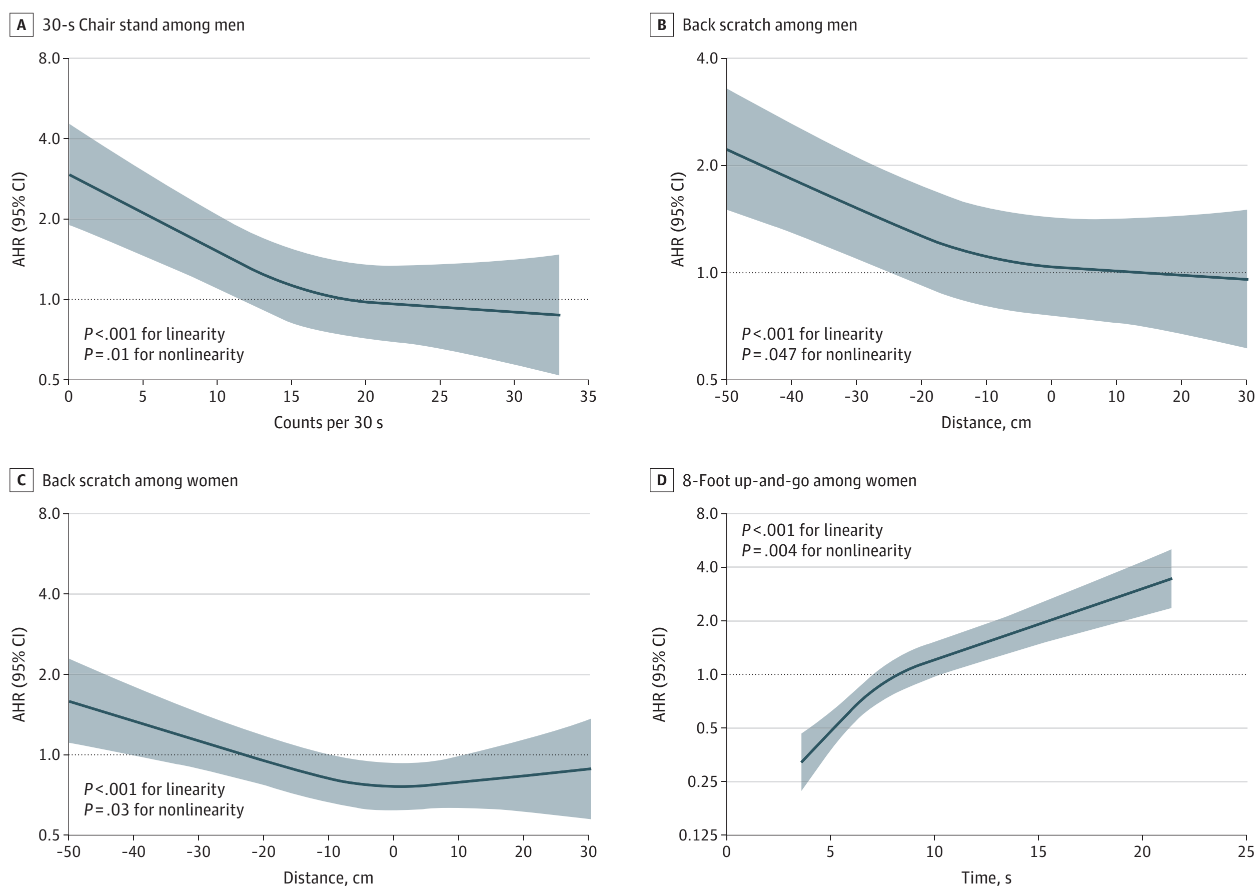
AHRs and 95% CIs are from separate multivariable Cox proportional hazards models for each fitness assessment, entered 1 at a time as the exposure. Q1 represents lowest performance and reference group; Q5, highest performance. Quintiles were reversed for the 8-foot up-and-go test (shorter completion times correspond to higher quintiles). All models were adjusted for covariates in the Table: sex, age, regular physical activity, body mass index, socioeconomic factors, geographic factors, and medical history. All AHRs from multivariable Cox models for each quintile compared with the reference were *P* <.001.

Sex-stratified analyses (eFigure 5 for men and eFigure 6 for women in Supplement 1) revealed some differences in associations. Among men, balance and agility remained associated with mortality with the lowest AHRs, followed by cardiorespiratory fitness. In women, lower-body strength was associated with mortality and had a risk similar to balance and agility, followed by cardiorespiratory fitness. Sensitivity analyses modeling each assessment as a continuous percentile score or original raw value yielded consistent inverse associations with all-cause mortality (eAppendix 3, eTable 4, and eTable 5 in Supplement 1).

Dose-Response Associations: Restricted Cubic Spline Model

Restricted cubic spline analyses further characterized the shape of the continuous associations between physical fitness and all-cause mortality across sex-specific models using original raw assessment values. Restricted cubic spline models identified nonlinear dose-response patterns for 4 assessments (**Figure 4**): the 30-second chair stand and back scratch tests among men and the back scratch and 8-foot up-and-go tests among women. For these assessments, mortality risk declined steeply at lower performance levels but plateaued at higher levels, at approximately 15 repetitions for the chair stand test, −10 cm for the back scratch test, and 7 to 8 seconds for the 8-foot up-and-go test. Spline curves for assessments without evidence of nonlinearity are presented in eFigure 7 for men and eFigure 8 for women in Supplement 1.

Figure 4. Restricted Cubic Spline Curves Showing Nonlinear Associations Between Physical Fitness Assessments and All-Cause Mortality



Adjusted hazard ratios (AHRs) and 95% CIs (shading) for sex-stratified associations between continuous values of physical fitness assessment and all-cause mortality. Statistically significant evidence of nonlinearity is $P < .05$. The reference point (AHR, 1.00) corresponds to the median performance value for each assessment. All models were adjusted for covariates in the Table: age, regular physical activity, body mass index, socioeconomic factors, geographic factors, and medical history.

Discussion

In this cohort study of 13 423 adults aged 65 years or older, higher objectively measured physical fitness was associated with progressively lower all-cause mortality across multiple domains, with balance and agility showing the lowest risks, followed by lower-body strength and cardiorespiratory fitness. These findings are consistent with the conceptual distinction between disease burden and functional reserve. While previous studies have relied on comorbidity counts or deficit-accumulation indices to estimate risk,[7,20] our results suggest that objective measures of functional capacity may offer prognostic information beyond traditional comorbidity-based metrics. The inverse gradients observed—even after adjusting for comorbidities—suggest that physical fitness captures a distinct domain of health not fully reflected in disease checklists.

The lower risks of all-cause mortality observed for balance, agility, and lower-body strength likely reflect their central role in fall prevention and injury avoidance. Impaired balance, slowed mobility, and reduced lower-body strength are established risk factors for falls and subsequent fractures, particularly hip fractures, which are leading causes of hospitalization, disability, and excess mortality in older adults.[18,33] Assessments such as the 1-leg stance and 8-foot up-and-go tests may detect early declines in neuromuscular control that precede overt disability, with lower-body strength supporting gait stability and recovery after perturbations. The dose-response associations observed support their biological relevance and clinical utility along injury-related pathways.

Sex-stratified analyses revealed that balance and agility and cardiorespiratory fitness showed the lowest risks for all-cause mortality among men, whereas lower-body strength and balance and agility had comparable risks among women. LaMonte et al[34] previously reported inverse associations of grip strength (Q5 vs Q1 AHR, 0.67) and chair stand performance (AHR, 0.63) with mortality among 5472 American women aged 63 to 99 years. Our findings extend this evidence to men, multiple fitness domains, and a non-Western population, with similarly inverse associations. Given the higher prevalence of osteoporosis in older women,[35] together with reports of a higher sarcopenia prevalence in women under certain diagnostic criteria,[36,37] preserving lower-body strength and mobility may have disproportionate implications for fall prevention and reducing injury-related mortality, warranting particular emphasis in targeted interventions. Whether sex-specific performance thresholds should inform clinical risk stratification requires further investigation.

Cardiorespiratory fitness showed a linear, graded association with mortality, supporting aerobic capacity as a marker of physiological reserve.[15-17] Even moderate improvements in aerobic performance were associated with meaningful reductions in mortality risk. In contrast, flexibility showed a threshold pattern: extreme stiffness was associated with higher mortality risk, but gains beyond a moderate functional range yielded no further survival benefit. This finding suggests that while maintaining range of motion remains important for daily function, clinical interventions for longevity may prioritize balance, strength, and cardiorespiratory fitness once a basic flexibility threshold is met.

The composite fitness index showed the steepest mortality gradient, surpassing any individual domain. Conceptually, this index parallels deficit-based frailty measures in its multisystem approach but differs by quantifying functional assets rather than health deficits.[7,20] The low, graded AHRs suggest that a multidimensional performance assessment may enhance prognostic information, offering a function-oriented complement to traditional frailty evaluation.

Most of the mortality differential was concentrated between the lowest quintile and the upper quintiles (Figure 2D), suggesting that the greatest health gains may occur when individuals move out of the lowest-performing stratum. This pattern supports prioritizing intervention for the least-fit older adults.

From a clinical perspective, physical fitness represents a modifiable marker of physiological reserve rather than a fixed consequence of aging. Randomized trials and meta-analyses have shown that structured exercise can improve aerobic capacity, muscular strength, and balance even in frail older adults.[33,38] Objective fitness assessment may therefore serve as a clinically actionable intermediate target linking exercise behavior to improved resilience and survival.

Our findings support a shift in geriatric risk assessment toward incorporating objective functional measures. Because these assessments require minimal equipment and time, they are feasible for routine internal medicine practice. Incorporating these brief assessments could allow clinicians to identify vulnerability earlier and prescribe individualized, function-oriented interventions, prioritizing balance and lower-body strength, to preserve resilience and extend survival. These assessments are intended as functional evaluations rather than maximal performance tests; clinical implementation requires standardized examiner training, consistent scoring, and pretest safety screening, particularly for balance and mobility assessments.

Limitations

This study has several limitations. First, the observational design precludes causal inference, and despite robust adjustment, residual confounding or reverse causation cannot be excluded. Second, physical fitness was assessed at a single time point; longitudinal changes in performance were not captured. Third, cause-specific mortality end points were not examined, preventing evaluation of whether associations differed by specific causes of death. Fourth, the requirement to complete physical performance tests, combined with quota-based convenience sampling at testing stations, implies a selection bias toward healthier, ambulatory older adults; although the cohort was nationally representative, extrapolation to other populations should be undertaken cautiously. Fifth, although we adjusted for BMI, direct measures of body composition (eg, lean and fat mass) were unavailable. Sixth, smoking status was not captured and could not be adjusted for directly, leaving potential for residual confounding. Although national data indicate relatively low smoking prevalence among older adults in Taiwan,[39] these population-level estimates cannot replace individual-level smoking information. Several smoking-related comorbidities, including chronic obstructive pulmonary disease, ischemic heart disease, and cerebrovascular disease, were included as adjusted covariates, which may partially mitigate confounding related to smoking-associated disease burden but cannot fully account for smoking exposure. Finally, we did not formally compare the prognostic accuracy of physical fitness with that of comorbidity-based metrics (eg, C statistic or net reclassification analyses).

Conclusions

In this cohort study of 13 423 adults aged 65 years or older, higher levels of objectively measured physical fitness across multiple domains were associated with lower all-cause mortality, with clear dose-response and domain-specific patterns. Balance and agility, lower-body strength, and cardiorespiratory fitness showed the lowest risks of all-cause mortality. These findings suggest that physical fitness may serve as a clinically relevant indicator of physiological reserve and functional aging. Integrating objective fitness assessment into routine geriatric and internal medicine care may enhance risk stratification and guide individualized strategies to preserve function and independence in older adults.

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SUPPLEMENT 1.

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SUPPLEMENT 2.
Data Sharing Statement