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Research Practice

Validation of a Claims-Based Frailty Index Against Physical Performance and Adverse Health Outcomes in the Health and Retirement Study

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Abstract

Background: A claims-based frailty index (CFI) was developed based on a deficit-accumulation approach using self-reported health information. This study aimed to independently validate the CFI against physical performance and adverse health outcomes.

Methods: This retrospective cohort study included 3,642 community-dwelling older adults who had at least 1 health care encounter in the year prior to assessments of physical performance in the 2008 Health and Retirement Study wave. A CFI was estimated from Medicare claims data in the past year. Gait speed, grip strength, and the 2-year risk of death, institutionalization, disability, hospitalization, and prolonged (>30 days) skilled nursing facility (SNF) stay were evaluated for CFI categories (robust: <0.15, prefrail: 0.15–0.24, mildly frail: 0.25–0.34, moderate-to-severely frail: ≥0.35).

Results: The prevalence of robust, prefrail, mildly frail, and moderate-to-severely frail state was 52.7%, 38.0%, 7.1%, and 2.2%, respectively. Individuals with higher CFI had lower mean gait speed (moderate-to-severely frail vs robust: 0.39 vs 0.78 m/s) and weaker grip strength (19.8 vs 28.5 kg). Higher CFI was associated with death (moderate-to-severely frail vs robust: 46% vs 7%), institutionalization (21% vs 5%), activity of daily living disability (33% vs 9%), instrumental activity of daily living disability (100% vs 22%), hospitalization (79% vs 23%), and prolonged SNF stay (17% vs 2%). The odds ratios per 1-*SD* (=0.07) difference in CFI were 1.46–2.06 for these outcomes, which remained statistically significant after adjustment for age, sex, and a comorbidity index.

Conclusion: The CFI is useful to identify individuals with poor physical function and at greater risks of adverse health outcomes in Medicare data.

Keywords: Frailty, Physical performance, Health services, Medicare claims

Frailty has emerged as a major public health problem in aging societies that affects individuals' well-being, resource allocation, and health care costs (1). Clinical care of older adults with frailty is challenged by lack of high-quality evidence to guide treatment choice. Because conducting clinical trials in frail older adults can be costly and impractical, routine health care databases (eg, claims data) can be useful to evaluate the effectiveness and safety of medical interventions (2). These databases contain data on treatments and clinical events in routine care populations, including people with frailty. Although frailty predicts prognosis and influences treatment choice in older adults, hospitals and health care providers are not required to submit this critical information to the Center for Medicare and

Medicaid Services or other insurers for reimbursement. Commonly used comorbidity indices are modestly correlated with functional status (3–5). As a result, claims-based comparative effectiveness and safety studies are subject to bias due to frailty or functional status, and they provide little guidance on how treatment should be altered by a patient's frailty level (6–8). To fill this gap, we recently proposed a claims-based frailty index (CFI) that quantifies frailty using Medicare data (9,10). The CFI, which approximates a standard deficit-accumulation frailty index derived from self-reported health information, was able to predict death, disability, falls, and health care utilization in the Medicare Current Beneficiary Survey. Yet, it has not been compared with physical performance and adverse health outcomes in an independent data set.

The objective of this study was to evaluate the association of our CFI with performance-based measures of physical function (gait speed and grip strength) and adverse health outcomes in the Health and Retirement Study (HRS). We hypothesized that our CFI would be associated with poor physical performance and future adverse outcomes.

Methods

Data Source and Study Population

The HRS is a nationally representative, longitudinal survey to study changes in health and well-being in adults over age 50 years in the United States, sponsored by the National Institute on Aging (grant number NIA U01AG009740) and conducted by the University of Michigan (11). The core survey was conducted every 2 years to assess health, psychosocial, and financial status from respondents or their proxy (approximately 9%) (11). The survey data have been linked to Medicare data to obtain information on health care costs and utilizations in over 80% of the respondents (12). We used inpatient, outpatient, skilled nursing facility (SNF), home health agency, carrier, and durable medical equipment data sets, which contained the International Classification of Diseases (ICD) diagnosis and procedure codes, Current Procedural Terminology (CPT) codes (codes for medical services and procedures), and Healthcare Common Procedure Coding System (HCPCS) codes (codes for supplies, equipment, and devices).

This study included the 2008 HRS survey respondents who were randomly selected for an enhanced face-to-face interview for measurement of physical performance. Excluded were those who were less than 65 years old, did not have Medicare data, resided in a nursing home, or had no health care encounters (inpatient or outpatient) within 12 months of their HRS interview. The Institutional Review Board at the University of Michigan approved the HRS, and the Institutional Review Board at the Brigham and Women's Hospital approved this study.

Estimating Frailty in Medicare Data

We extracted relevant ICD codes, CPT codes, and HCPCS codes from Medicare data sets during the 12-month period prior to their HRS interview. Each claims-based variable was weighted by the coefficients derived from a regression model that related variables to a standard survey-based frailty index and summed to generate a CFI (Supplementary Table 1; a SAS program is available at http://www.drugepi.org/dope-downloads/) (9). This CFI can range from 0 to 1, with higher values indicating greater frailty. In developing our CFI, we applied a deficit-accumulation approach (13) that assigns equal weights to the 56 items in the Medicare Current Beneficiary Survey to calculate a survey-based frailty index; a penalized regression was used to model the survey-based frailty index using claims data (9). We preferred this model-based approach to counting the number of conditions directly from claims data because the latter approach showed a lower correlation with the reference standard and poorer prediction for adverse outcomes (9,10). Although CFI is a continuous measure, a cutpoint of more than or equal to 0.25 has been used to define frailty (14). For the presentation purpose, we categorized frailty into robust (<0.15), prefrail (0.15–0.24), mildly frail (0.25–0.34), and moderate-to-severely frail (≥0.35).

Measurements of Health Status and Physical Performance

Respondents were asked about self-rated health (excellent, very good, good, fair, poor); the frequency and intensity of mild, moderate, and vigorous activity (15) (physical inactivity was defined as the bottom 20% for each sex); falls in the past 2 years; and ability to perform 6 activities of daily living (ADL; dressing, walking across a room, bathing, eating, transferring, toileting), 6 instrumental activities of daily living (IADL; cooking, shopping, using telephone, taking medications, doing housework, managing money), and physical tasks (walking several blocks, climbing 1 flight of stairs, lifting 10 pounds). Weight loss was defined as loss of more than 10-pound loss in measured weight over 2 years. Gait speed (m/s) was calculated from the average of 2 timed 8-feet walks at usual pace. Grip strength (kg) was measured as the average of two measurements in the dominant hand. A Charlson comorbidity index (CCI) was computed using the 12-month Medicare data prior to the HRS interview (16).

Adverse Health Outcomes

To assess the predictive validity of CFI, we used mortality, institutionalization, and incident ADL and IADL disabilities from the 2010 HRS wave. Hospitalization and prolonged SNF stay, defined as more than 30 SNF days, over 2 years were measured from Medicare data.

Statistical Analysis

Characteristics of respondents with and without health care encounters were compared using Wilcoxon rank-sum tests or chi-square tests. Across the range of CFI, we summarized prevalent health status and physical performance. Because the number of health care encounters may affect the CFI level and its relationship with health status, we conducted a sensitivity analysis to stratify analyses by the hospitalization status and median number of office visits. To examine the association of CFI with adverse outcomes, we calculated the 2-year risk of death, institutionalization, falls, incident ADL and IADL disability, hospitalization, and prolonged SNF stay for CFI categories. The odds ratios (ORs) and 95% confidence intervals associated with 1-*SD* change in CFI or CCI were estimated using logistic models that included age, sex, CCI, and CFI. We also compared the predictive ability of CFI versus CCI using C statistics (17). Analyses were performed in R software version 3.4 (R Foundation for Statistical Computing, Vienna, Austria). A two-sided p value <.05 was considered statistically significant.

Results

Among the 8,295 respondents randomly selected for an enhanced face-to-face interview, 3,642 respondents were 65 years or older, were linked to Medicare data, lived in the community, and had at least 1 health care encounter in the previous 12 months (Supplementary Figure 1). The 1,219 respondents without health care encounters were younger (74.3 vs 75.5 years), more likely to be male (46.1% vs

41.1%), and had lower prevalence of chronic conditions and functional impairments (Supplementary Table 2).

Prevalent Health and Functional Status by CFI Level

The prevalence of robust (CFI <0.15), prefrail (0.15–0.24), mildly frail (0.25–0.34), and moderate-to-severely frail state (≥0.35) was 52.7%, 38.0%, 7.1%, and 2.2%, respectively. Those with higher CFI scores were older and more likely to be female and nonwhite (Table 1). They were more likely to have poor health, physical inactivity, falls, disabilities, functional limitations, and weight loss. The mean gait speed (CFI ≥0.35 vs <0.15: 0.39 vs 0.78 m/s) and grip strength (19.8 vs 28.5 kg) were inversely associated with CFI. The results were consistent in stratified analysis by the hospitalization status and number of office visits (Supplementary Table 3).

Risk of Adverse Health Outcomes by CFI Level

The risk of adverse outcomes increased with CFI (Figure 1). Individuals with CFI more than or equal to 0.35 had the highest risk of death (46%), institutionalization (21%), ADL disability (33%), IADL disability (100%), hospitalization (79%), and prolonged SNF stay (17%). The ORs of adverse outcomes per 1-*SD* (=0.07) increase in CFI were 1.46–2.06, which were statistically significant (ORs: 1.31–1.67) after adjusting for age, sex, and CCI (Table 2). In comparison, the associations of CCI with adverse outcomes attenuated (ORs per 1-*SD* increase: 1.23–1.89 before adjustment and 0.94–1.47 after adjustment) and became statistically nonsignificant, except for death and hospitalization, when age, sex, and CFI were adjusted for. The predictive ability of CFI, assessed using C statistics (Supplementary Table 4), was superior to that of CCI for predicting disabilities and health care utilizations (CFI vs CCI: 0.62–0.72 vs 0.58–0.66; $p \leq .010$), except for death (0.68 vs 0.68; $p = .591$) and institutionalization (0.58 vs 0.54; $p = .077$).

Discussion

Our CFI was originally developed to approximate a deficit-accumulation frailty index that was calculated from self-reported health information in the Medicare Current Beneficiary Survey (9). The present study represents an independent validation of CFI in the HRS cohort against health and functional status measures, including physical performance and future adverse outcomes. Individuals with higher CFI had more functional limitations, lower physical performance, and greater risks of death, institutionalization, disabilities, hospitalization, and prolonged SNF stay, independently of age, sex, and CCI. Once CFI was adjusted for, the CCI was not statistically significantly associated with institutionalization, disabilities, and prolonged SNF stay. These results suggest that our CFI measures risk uncaptured by a traditional comorbidity index.

Our study shows that a validated CFI can be useful for evaluation of treatment effectiveness and safety in frail older adults and for population health management. Older adults with frailty may be at increased risk for treatment-related adverse events (eg, falls after taking psychoactive drugs, poor recovery after surgical procedures). While a bedside assessment is the most reliable and accurate way to measure frailty, information on standardized assessment is only available for Medicare beneficiaries in specific care settings, such as inpatient rehabilitation care (Inpatient Rehabilitation Facility-Patient Assessment Instrument), home health care (Outcome and Assessment Information Set), and long-term care (Minimum Data Set). Previous research showed that combining a comorbidity index with functional status information from the Medicare Inpatient Rehabilitation Facility data set improved prediction of community discharge and readmission in beneficiaries with stroke, fracture, and joint replacement (4,5). Our CFI can be calculated for community-dwelling, fee-for-service Medicare beneficiaries with at least one health care encounter in the past year.

Moreover, people with severe frailty are usually excluded from clinical trials (18), and frailty is not routinely measured at the trial baseline. Our CFI offers a major advantage of identifying those who are likely to be frail on a population scale. We will be able to evaluate whether a treatment provides different benefits and risks in older adults with a different level of frailty by linking existing clinical trial data to Medicare data and by analyzing routine health care databases (eg, claims data) that include those with severe frailty. Using the CFI, health care organizations can use their members' Medicare

Table 1. Prevalent Health and Functional Status According to Claims-Based Frailty Index

Characteristics	<0.15 (*n* = 1,919)	0.15–0.24 (*n* = 1,383)	0.25–0.34 (*n* = 261)	≥0.35 (*n* = 79)
Claims-based frailty index	0.12 ± 0.02	0.19 ± 0.03	0.28 ± 0.03	0.41 ± 0.06
Age, years	74.2 ± 6.8	76.5 ± 7.4	78.8 ± 7.7	79.2 ± 9.2
Male	846 (44.1)	530 (38.3)	89 (34.1)	31 (39.2)
White race	1,659 (86.5)	1,160 (83.9)	213 (81.6)	56 (70.9)
Poor self-rated health	84 (4.4)	212 (15.3)	72 (27.7)	33 (41.8)
Physical inactivity	175 (9.1)	254 (18.4)	90 (34.5)	57 (72.2)
Fall in the past 2 years	610 (31.8)	657 (47.5)	164 (62.8)	62 (78.5)
ADL disability	248 (12.9)	389 (28.1)	145 (55.6)	63 (79.7)
IADL disability	570 (29.7)	733 (53.0)	195 (74.7)	74 (93.7)
Difficulty walking several blocks	506 (26.4)	754 (54.6)	202 (77.4)	73 (92.4)
Difficulty climbing a flight of stairs	287 (15.0)	480 (34.8)	153 (58.6)	61 (77.2)
Difficulty lifting 10 pounds	387 (20.2)	594 (43.0)	177 (67.8)	63 (79.7)
Weight loss >10 pounds	98 (5.3)	105 (7.9)	35 (14.1)	9 (15.0)
Gait speed, m/s	0.78 ± 0.24	0.66 ± 0.24	0.51 ± 0.25	0.39 ± 0.18
Grip strength, kg	28.5 ± 10.2	25.3 ± 9.8	21.4 ± 8.0	19.8 ± 8.7

Note: Data were presented in mean ± *SD* or *n* (%). Data were missing in 1 for self-rated health, 3 for difficulty walking several blocks, 2 for difficulty climbing a flight of stairs, 3 for difficulty lifting 10 pounds, 123 for weight loss, 866 for gait speed, and 604 for grip strength. Abbreviations: ADL = activity of daily living; IADL = instrumental activity of daily living.

data from the previous year to screen for high-risk frail patients to target resource-intensive programs.

Measuring frailty in administrative data that do not contain detailed clinical information has been a great interest to researchers in health services research and pharmacoepidemiology. In previous studies, frailty was defined as presence of diagnosis codes that had face validity (19–24) based on clinical knowledge (eg, dementia, malnutrition, pressure ulcer, incontinence, hip fracture, mobility impairment, falls), without a formal validation against an accepted frailty definition. Only a few indices have been validated against the frailty phenotype (25,26), a deficit-accumulation frailty index (9), the Vulnerable Elder Survey (27), or ADL disability (28–31). Among them, Segal and colleagues developed a multivariable model for dichotomous phenotypic frailty based on age, sex, race, CCI, hospitalizations, and diagnosis codes during the past 6 months (25). Because demographic variables were used to predict frailty, age and sex adjustment accounted for much of the association with adverse outcomes in their study. In comparison, adjustment for age, sex, and even CCI modestly attenuated the association between our CFI and adverse outcomes (9). In several cohort studies, a deficit-accumulation frailty index offers better risk discrimination than frailty phenotype (32–34), which may be subject to ceiling or floor effect due to its limited range. Finally, some may criticize that our CFI did not follow the standard deficit-accumulation approach (ie, equal weighting of items) and that a similar frailty index could be calculated by counting the number of conditions directly from claims data. Others may disagree with using receipt of treatments or health care services as proxy of health deficits. We have previously shown that a direct implementation of deficit-accumulation approach in claims data did not provide a good approximation of the standard frailty index; its ability to predict mortality was not as good as the model-based prediction of the standard frailty index (9).

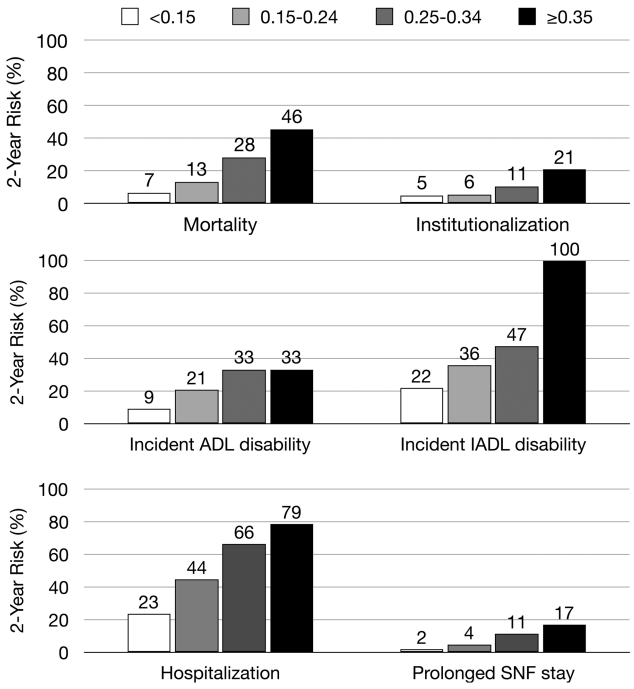

Figure 1. Two-year risk of adverse health outcomes according to claims-based frailty index. Abbreviations: ADL = activity of daily living; IADL = instrumental activity of daily living; SNF = skilled nursing facility.

Our findings should be interpreted with consideration of the following limitations. To calculate a CFI, a health care encounter within the past 12 months was required to allow capture of health status; CFI could not be estimated for those who were in stable health and did not have any health care encounter in the past year. Such exclusion is unlikely to be an issue in studies of treatment effectiveness and safety, which by design require at least one or two claims with specific diagnoses prior to their treatment initiation. Additionally, higher CFI may be related to frequent health care encounters, which can lead to more opportunities for coding, rather than the actual severity of frailty. However, our stratified analysis (Supplementary Table 3) suggests that CFI is mainly affected by health status, not by the number of office visits or hospitalization status. Finally, more than a quarter of HRS respondents could not complete physical performance tests, which might have underestimated the difference in performance across CFI levels.

These limitations notwithstanding, our results support the validity of our CFI by showing its association with poor physical performance, functional limitations, and greater risks of death, institutionalization, disabilities, and health care utilization. Future research should evaluate the usefulness of CFI in comparative effectiveness and safety studies of treatments and population health management in Medicare beneficiaries.

Table 2. Association of Claims-Based Frailty Index and Charlson Comorbidity Index with Adverse Health Outcomes in 2 Years

	Unadjusted OR (95% CI)		Adjusted OR (95% CI)*	
Outcomes	CFI	CCI	CFI	CCI
Death	1.78 (1.63 to 1.94)	1.79 (1.65 to 1.96)	1.31 (1.17 to 1.47)	1.47 (1.31 to 1.64)
Institutionalization	1.45 (1.27 to 1.64)	1.23 (1.06 to 1.41)	1.36 (1.14 to 1.62)	0.94 (0.77 to 1.15)
Incident ADL disability	2.01 (1.76 to 2.30)	1.53 (1.36 to 1.71)	1.67 (1.41 to 1.98)	1.13 (0.97 to 1.31)
Incident IADL disability	1.81 (1.58 to 2.09)	1.39 (1.23 to 1.56)	1.58 (1.32 to 1.89)	1.05 (0.90 to 1.22)
Hospitalization	2.06 (1.91 to 2.24)	1.89 (1.75 to 2.04)	1.64 (1.48 to 1.81)	1.37 (1.25 to 1.51)
Prolonged SNF stay	1.76 (1.56 to 1.98)	1.50 (1.32 to 1.70)	1.46 (1.24 to 1.72)	1.16 (0.96 to 1.39)

Notes: The OR and 95% CIs per 1 *SD* increase in CFI (=0.07) or CCI (=2.0) were presented. Abbreviations: ADL = activity of daily living; CCI = Charlson comorbidity index; CFI = claims-based frailty index; CI = confidence interval; IADL = instrumental activity of daily living; OR = odds ratio; SNF = skilled nursing facility.

*Adjusted for age, sex, CCI (for analysis of CFI), and CFI (for analysis of CCI).

Supplementary Material

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

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D.H.K., S.S., and J.A. contributed to conception, design, and acquisition of data. D.H.K. analyzed data and drafted the manuscript. A.P. created a SAS program for claims-based frailty index estimation. All authors interpreted data, critically revised the manuscript for important intellectual content, and read and approved the final manuscript for submission. An early version of this work was presented at the 33rd International Conference on Pharmacoepidemiology & Therapeutic Risk Management, Montreal, Canada, in August 2017.

Conflict of Interest

D.H.K. provides paid consultative services to Alosa Health, a nonprofit educational organization with no relationship to any drug or device manufacturers. K.R. is founder and Chief Scientific Officer of DGI Clinical, which has contracts with several companies for individualized outcome measures and advanced data analytics. Through the Dalhousie Technology Transfer Office, he has asserted copyright of the Clinical Frailty Scale, not otherwise discussed here. S.S. is a consultant to WHISCON, LLC, Newton, Massachusetts, and to Aetion, Inc, New York, New York, a software manufacturer of which he also owns equity. He is the principal investigator of investigator-initiated grants to the Brigham and Women's Hospital from Novartis, Basel, Switzerland; Genentech, San Francisco, California; and Boehringer Ingelheim, Ingelheim am Rhein, Germany, unrelated to the topic of this study. The other authors declare no competing interests.

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