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Frailty and Determinants of Health Among Older Adults in the United States 2011–2016

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Abstract

Objective: To characterize frailty phenotype in a representative cohort of older Americans and examine determinants of health factors. **Methods:** Retrospective analysis of data from 5,553 adults ≥60 years old in the 2011–2016 cross-sectional National Health and Nutrition Examination Survey (NHANES). World Health Organization "*Determinants of Health*" conceptual model was used to prioritize variables for multinomial logistic regression for the outcome of modified Fried frailty phenotype. **Results:** 482 participants (9%) were frail and 2432 (44%) prefrail. Four factors were highly associated with frailty: difficulty with ≥1 activity of daily living (77%; OR 24.81 $p < 0.01$), ≥2 hospitalizations in the previous year (17%, OR 3.94 $p < 0.01$), having >2 comorbidities (27%; OR 3.33 $p < 0.01$), and polypharmacy (66%; OR 2.38 $p < 0.01$). **Discussion:** A modified Fried frailty assessment incorporating five self-reported criteria may be useful as a rapid nursing screen in low-resource settings. These assessments can streamline nursing care coordination and case management activities, thereby facilitating targeted frailty interventions to support healthy aging in vulnerable populations.

Keywords

Fried phenotype, frailty, social determinants of health (SDOH), case management, nursing

Introduction

In the coming decades, individuals will spend greater proportions of their lives beyond the age of 65 years old. Despite presence of COVID-19 uncertainty, global population aging is forecasted to significantly increase from 727 million persons aged >65 years in 2020 to 1.5 billion in 2050, and will especially impact developing countries (United Nations, 2020; World Health Organization, 2021). In anticipation of these significant population demographic transitions, policymakers are evaluating how to best promote healthy aging and vitality throughout an extended lifespan, and overcome serious health policy and system gaps exposed by the COVID-19 pandemic (Fried, 2016; National Academies of Sciences, Engineering, and Medicine, 2021; World Health Organization, 2021).

Frailty is an aging-related medical syndrome characterized by multiple physiological system declines and is a predominant health concern (Walston, 2020). Frailty results in poor tolerance to external stressors and heightened vulnerability to adverse events, falls, hospitalizations, institutionalized care, and mortality (Clegg et al., 2013). A physical frailty phenotype was established and validated in community dwelling older adults in the Cardiovascular Health Study. This study defined the "Fried physical frailty phenotype" as the presence of five criteria: weight loss, exhaustion, slowness, low activity level, and weakness (Fried et al., 2001). Physical frailty syndrome occurs from accumulated cell damage over a person's life culminating in several cascading cyclic inflammatory-mediated processes (Fried, 2016). These include sarcopenia, mitochondrial dysregulation, decreased insulin sensitivity, and osteopenia, which drive decreased resilience to stressors and increased susceptibility to dependency, disability, falls, and injuries (Fried, 2016). During COVID-19, the presence of frailty and presence of related pre-existing chronic medical conditions greatly increased individual risk to hospitalizations, death, and social isolation as age increased, particularly in

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unvaccinated persons (Centers for Disease Control and Prevention, 2021; Farrell et al., 2020a, 2020b; World Health Organization, 2020).

The absence of agreement on the precise clinical definition of frailty presents a challenge to full integration of its measurement and evaluation into clinical practice. Presently, 67 frailty assessments exist that span complex clinical research measurements to rapid screening tools (Buta et al., 2016). For example, a complementary and leading alternative to the Fried physical frailty phenotype is Rockwood's deficit accumulation model or Frailty Index (FI), validated in the Canadian Study of Health and Aging. The FI characterizes frailty as the presence of an accumulation of up to 20–70 checklist items of measurable physiological deficits, clinical diseases, laboratory parameters, and patient symptoms (Cesari et al., 2014). The advantages of the FI are that it covers additional components on continuous measures extracted from an electronic health record (EHR). However, FI requires a baseline measurement performed during a comprehensive geriatric assessment (CGA). Heterogeneous assessment tools, clinical, and conceptual definitions thus hinder ease of clinical frailty evaluation.

Furthermore, four of the five validated Fried physical frailty measurement criteria require clinical measurements involving adequate clinical staff and time, physical measurement space (i.e., the walking speed test requires >15 feet, repeated for accuracy), and specialized equipment (i.e., a hand dynamometer to evaluate hand grip strength), (Fried et al., 2001). To expand measurement of physical frailty beyond clinical and translational research settings, recent studies developed and validated modified Fried criteria involving greater use of self-reported criteria in meta-analyses, population studies, and longitudinal research cohorts (Bandeen-Roche et al., 2015; Crow et al., 2018; Hanlon et al., 2018; Op Het Veld et al., 2018; Wilhelm-Leen et al., 2009). Challenges to gleaning definitive meaning from these efforts include small sample sizes, use of frailty research participant data from the 1990s–2000s, and multiple operationalizations of the modified Fried phenotype.

Nevertheless, modified measurement approaches are a recommended approach to gerontological healthcare in older adults >70 years (Morley et al., 2013). These approaches can facilitate rapid screening of older adult individuals who are in need of a CGA or targeted therapies. Clinical interventions for frailty exist across the entire frailty spectrum in older adults and range from simple symptom management to hospice care (Walston, 2020). The frailty syndrome is its own clinical state that is distinctly separate from chronic multi-morbidity and extends into several medical subspecialties including heart failure, end-stage kidney disease, HIV infection, and others (Walston et al., 2017). Key clinical interventions with the greatest amount of scientific support demonstrating moderate efficacy and confirmed by geriatric scientific consensus statements include: exercise (resistance and aerobic), caloric and protein support, vitamin D supplementation, and reduction of polypharmacy (Morley et al., 2013).

Improved detection of frailty in clinical practice through standardized measurement will contribute to enhanced implementation of these key interventions for older adults and also inform holistic health aging policy. The World Health Organization (WHO) defines healthy aging as "the process of developing and maintaining the functional ability that enables well-being in older age," and depends on the interactions between a person's physical, mental, and psychosocial characteristics in concert with their physical, social, environmental, and policy contexts (World Health Organization, 2020). Two distinct systems are recognized as equally important for policy consideration in promoting healthy aging: (1) a person's biological status and physical environment, and (2) a person's social determinants of health (SDOH), including health care system adequacy (Sadana et al., 2016). SDOH are "the conditions in which people are born, grow, work, live, and age," account for ~80% of modifiable contributors for a healthy population, and drive health utilization and outcome disparities (Magnan, 2017; National Academies of Sciences, Engineering, and Medicine, 2021).

The recent COVID-19 pandemic placed renewed focus on addressing the significant role of SDOH in managing the care of older adults, particularly as a function of their increased susceptibility to severe illness, hospitalization, death, and social isolation during a time of acute resource allocation challenges (Farrell et al., 2020a, 2020b). In response to exposed COVID-19 healthcare disparity gaps, nurses were empowered to provide improved services to marginalized and vulnerable populations, specifically in racial minorities and older adults. Examples include Centers for Medicare & Medicaid Services regulatory adjustments allowing nurse practitioners in provider shortage areas to proactively manage patient symptoms and provide targeted healthcare to avoid disease progression in at-risk dual-eligible patients in rural settings with heavy burdens of chronic conditions (National Academies of Sciences, Engineering, and Medicine, 2021).

To create inclusive and holistic public policy approaches for older adults' wellbeing, implementation of SDOH frameworks that involve nursing contributions are essential (Martinson & Berridge, 2015; National Academies of Medicine, 2019; National Academies of Sciences, Engineering, and Medicine, 2021). A noted gap in the frailty field is the lack of a screening tool for use in vulnerable and marginalized ethnic populations. Available national, international epidemiology research population databases are a valuable resource to identify novel standardized assessment tools for use in vulnerable and ethnic sub-populations because of their sampling emphasis on marginalized groups. Thus, screening tools incorporating principles of leading assessments such as the Fried phenotype and/or FI based on these large research populations could expedite clinical implementation in at-risk and vulnerable communities in under-resourced health care sites.

To address this gap, we used epidemiological data from the Centers for Disease Control and Prevention (CDC) National Health and Nutrition Examination Survey (NHANES) 2011–2016, and Dahlgren and Whitehead's WHO *"Determinants of Health"* population conceptual model, to ask the following research questions (Dahlgren, 2007):

1. What was the prevalence of physical frailty phenotype (prefrail and frail) using a new combination of exclusively self-reported symptom and clinical criteria elements?
2. Which determinants of health were most strongly associated with modified Fried prefrailty and frailty for this cohort?

The goals of this study were to use a widely recognized WHO population conceptual model to select and prioritize relevant frailty determinants of health; provide an update to NHANES frailty investigations from earlier data cycles (1994–2006); and define a rapid frailty clinical assessment tool using self-reported measurement criteria from a large research sample that will be easy to validate. Lastly, results from this study can help inform and guide domestic and global health services research evaluations against frailty diagnostic reference standards in resource poor clinical settings and health care systems.

Methods

Study Sample and Design

We performed a secondary retrospective analysis of National Center for Health Statistics (NCHS) CDC NHANES 2011–2012, 2013–2014, and 2015–2016 data. NHANES is a bi-yearly federal program using a cross-sectional multistage probability design to examine the health and nutritional status of non-institutionalized community dwelling US children and adults using information from survey questionnaires, physical examinations, and laboratory data. Data collection procedures for particular cycles are reported at https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx. The NCHS Research Ethics Review Board (ERB) approved the research for all cycles used in this study: NHANES 2011–2012 (Protocol #2011–17); NHANES 2013–2014 (Continuation of Protocol #2011–17); and NHANES 2015–2016 (Continuation of Protocol #2011–17). We extracted data for all NHANES participants satisfying the following criteria: completed an interview between 2011 and 2016 and were 60 years or older. Continuous NHANES data are available at https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx.

Modified Fried Frailty Phenotype

To overcome the challenge of the absence of agreement on the precise clinical definition of frailty, we modified one of the most commonly used definitions, the Fried frailty phenotype. When it cannot be obtained directly through direct physical measurement, the modified Fried frailty phenotype is an acceptable alternative in large research populations (Blodgett et al., 2015; Hanlon et al., 2018). Similar to previous reports, we constructed a modified Fried physical frailty phenotype customized from available 2011–2016 NHANES measurements to measure presence of physical frailty and prefrailty (Crow et al., 2018):

1. Weakness: self-reported lifting or carrying difficulty (PFQ061E = 2/3/4);
2. Low physical activity: highest quintile of age group for self-reported minutes of sedentary activity (PAD680);
3. Exhaustion: self-reported feelings of tiredness, little energy (DPQ040 = 2/3);
4. Slow walking speed: self-reported walking difficulty between rooms on the same floor (PFQ061H = 2/3/4); and
5. Unintentional weight loss: self-reported weight loss of ≥10 lbs in the previous 1 year (WHD020, WHD050, and WHQ060).

Frail individuals demonstrated three or more criteria, prefrail individuals demonstrated one or two criteria, and robust individuals demonstrated zero criteria.

Determinants of Health Operationalization and Variable Selection

Dahlgren and Whitehead's WHO *"Determinants of Health"* population conceptual model was used to select, categorize, and analyze demographic, functional, biological, and SDOH characteristics (Dahlgren, 2007). First level factors included NHANES participants' self-reported: gender, age, race/ethnicity, and body mass index (BMI). Age groups included: 60–69, 70–79, and over 80 years old. Race and ethnicity were grouped as: non-Hispanic white, non-Hispanic Black, non-Black Hispanic, Asian, and other (mixed race). Second level factors included NHANES participants' self-reported lifestyle habits, choices, and comorbidities including alcohol use by gender (moderate or greater than moderate daily alcohol intake); smoking (current or past smoker); comorbidities (diabetes mellitus, arthritis, congestive heart failure, coronary heart disease, cancer, and stroke); polypharmacy (use of ≥5 prescription medications in the past month); activities of daily living (ADL, getting in and out of bed, using fork and knife, drinking from cup, and dressing with difficulty); and instrumental activities of daily living (IADL, difficulty with the management of finances, house chores, and preparing meals). ADL/IADL disablement, multi-comorbidity, and the disablement process are related to and overlap with frailty geriatric syndrome but are each distinctly separate clinical entities whose contributions

should be considered for their role in predicting poor health outcomes (Espinoza et al., 2018; Fried et al., 2001). Third level factors included NHANES participants' self-reported social and community networks: marital status (married/living with partner and widowed/divorced/separated) and number of household members (lives alone or lives with at least one other person). Fourth level factors included NHANES participants' self-reported: income level (<130% of poverty level); housing (owns home or other living arrangement); community meal assistance (receives assistance or does not receive assistance); education level (less than high school or high school graduate and above); health insurance (no insurance, private, Medicare/Medicaid, other public insurance such as military, state, or Indian Health Service); hospital utilization (two or more overnight hospitalizations in the previous 12 months); and outpatient healthcare utilization (greater than three office visits to a health care provider in the previous 12 months).

Statistical Analysis

Descriptive statistics were examined for the study's outcome variable, frailty, and prefrailty phenotype status, each of the individual Fried phenotype criteria components, demographic, functional, biologic, and SDOH characteristic variables. Unadjusted bivariate logistic regression modeling analyses were performed on frailty outcome status (robust, prefrail, and frail) by determinants of health variables. Prior to multivariable logistic regression analysis, determinant of health variables were tested for collinearity using a diagnostic procedure in SAS 9.3. Statistically redundant items were removed, including IADL, outpatient visits with hospitalizations, and assistance with meals. Multinomial logistic regression was performed to evaluate the relationship between health determinant characteristics and frailty. Frail and prefrail individuals were compared to individuals who were robust according to the modified Fried frailty phenotype. Predictor variables were dichotomized for multivariable logistic regression model building. All statistically significant variables from the bivariate analysis were included in the initial multivariable model. The most parsimonious multivariable model was developed using backward elimination and included those variables that were statistically significant or were potential confounders. Statistical significance was designated a priori at $p < 0.05$. Analyses were performed using SAS v9.3.

Results

From the 29,905 Americans who participated in NHANES 2011–2016, there were 5,533 individuals aged 60 years and older. Table 1 presents results for demographic, functional, biologic, and SDOH characteristics for the overall study population. Findings are structured by physical frailty phenotype category, WHO population conceptual model factor level, and unadjusted bivariate logistic regression modeling output.

Our overall sample was 51% female and 43% non-Hispanic white, with mean age of 70.1 years old and mean BMI of 29.1 kg/m^2. In the sample, 47% ($n = 2619$) met the modified Fried frailty phenotype criteria for robust, 44% ($n = 2432$) for prefrail, and 9% ($n = 482$) for frail. Elevated mean BMI was observed in both prefrailty 29.6 kg/m^2 ($SD = 6.8$ kg/m^2) and frailty 31.4 kg/m^2 ($SD = 8.6$ kg/m^2). Most frail and prefrail participants were white, followed by non-Hispanic Black, non-Black Hispanic, Asian, and other mixed-race participants (Table 1). Non-Hispanic Black adults demonstrated a higher proportion of prefrailty (47.9%) outcome compared to other ethnic groups. 30% of the total sample, 33% of prefrail and 44% of frail community dwelling older adults in this sample had income levels that were ≤130% the federal poverty level. To follow up on our significant race finding for the modified Fried frailty outcome, we performed a Mantel-Haenszel subgroup analysis to examine if dichotomous social determinants (education level and insurance status) differed by ethnicity group. Although a significant association existed between frailty and the selected social determinants by ethnic subgroup ($p < 0.01$), the largest association could be considered for practical purposes, weak (phi coefficient = 0.41).

Most of the participants who used greater than five medications in the last month scored as robust or prefrail (84.6%). However of the 482 participants who were frail, those with polypharmacy (5.7%) were nearly twice as those without polypharmacy (2.9%), (Figure 1). Moreover, polypharmacy medication use was greater in women (prefrail 10.8% and frail 3.5%) compared to men (prefrail 9.2% and frail 2.2%), (Figure 1). Modified Fried phenotype criteria distribution for NHANES participants is shown in Table 2. Of the 2,914 NHANES participants that were either prefrail or frail, 50% experienced weakness, followed by low physical activity (41%), exhaustion (30%), slowness (25%), and unintentional weight loss of at least 10 pounds (18%).

Adjusted multivariable logistic regression results are presented in Table 3. In the multivariable analysis, the health determinant found to have the greatest association with the modified Fried prefrailty and frailty phenotype was difficulty with at least 1 ADL (prefrailty 32%; $p < 0.01$ [OR 4.02; 95% CI, 13.39–4.76], frailty 77%; $p < 0.01$ [OR 24.81; 95% CI, 18.97–32.45]). Other health determinant factors strongly associated with the prefrailty and frailty outcome had ≥2 hospitalizations in the previous year (prefrailty 7%; $p < 0.01$ [OR 1.93; 95% CI, 1.40–2.65], frailty 17%; $p < 0.01$ [OR 3.94; 95% CI, 2.61–5.94]); had >2 comorbidities (prefrailty 14%; $p < 0.01$ [OR 1.79; 95% CI, 1.41–2.28], frailty 27%; $p < 0.01$ [OR 3.33; 95% CI, 2.12–5.23]); and had polypharmacy (prefrailty 45%; $p < 0.01$ [OR 1.74; 95% CI 1.52–1.99], frailty 66%; $p < 0.01$ [OR 2.38; 95% CI, 1.85–3.05]). Factors associated with lower odds of having prefrailty or frailty were being married or living with a partner (prefrailty 51%; $p < 0.01$ [OR 0.63, 95% CI 0.56–0.70]; frailty 39% [OR 0.38;

Table 1. NHANES 2011-2016 Participant Summary Characteristics by Prefrailty and Frailty Status, WHO *"Determinants of Health"* Population Conceptual Model Factor Level, and Unadjusted Bivariate Logistic Regression Results.

Characteristics	Total[a] *N* = 5533 *n* (%)	Robust[b] *N* = 2619 *n* (%)	Prefrail *N* = 2432 *n* (%)	Frail *N* = 482 *n* (%)	Prefrail versus Robust *p*-value	Prefrail versus Robust OR (95% CI)	Frail versus Robust *p*-value	Frail versus Robust OR (95% CI)
1. Age, Gender, and Constitutional Factors								
Male	2705 (49)	1392 (53)	1121 (46)	192 (40)	<0.01	0.76 (0.68–0.84)	<0.01	0.58 (0.48–0.71)
Female	2828 (51)	1227 (47)	1311 (54)	290 (60)	—	—	—	—
Age in years, mean (SD)	70.1 (7.0)	69.5 (6.7)	70.3 (7.0)	72.6 (7.3)	<0.01	1.02 (1.01–1.03)	<0.01	1.07 (1.05–1.08)
60–69	2797 (51)	1412 (54)	1207 (50)	178 (37)	—	—	—	—
70–79	1645 (30)	801 (31)	715 (29)	129 (27)	0.50	1.04 (0.92–1.19)	0.05	1.28 (1.00–1.63)
80 and older[c]	1091 (20)	406 (16)	510 (21)	175 (36)	<0.01	1.47 (1.26–1.71)	<0.01	3.42 (2.70–4.33)
White	2384 (43)	1107 (42)	1040 (43)	237 (49)	0.72	1.02 (0.91–1.14)	<0.01	1.32 (1.09–1.61)
Black	1239 (22)	532 (20)	594 (24)	113 (23)	—	—	—	—
Hispanic	1294 (23)	644 (25)	556 (23)	94 (20)	—	—	—	—
Asian	503 (9)	295 (11)	187 (8)	21 (4)	—	—	—	—
Other[d]	113 (2)	41 (2)	55 (2)	17 (4)	—	—	—	—
BMI, mean (*SD*)[e]	29.1 (6.4)	28.3 (5.4)	29.6 (6.8)	31.4 (8.6)	<0.01	1.03 (1.03–1.04)	<0.01	1.07 (1.06–1.09)
2. Lifestyle Factors								
Comorbidities								
Diabetes mellitus	1399 (25)	534 (20)	681 (28)	184 (38)	—	—	—	—
Arthritis	2686 (49)	1007 (38)	1322 (54)	357 (74)	—	—	—	—
Congestive heart failure	441 (8)	116 (4)	244 (10)	81 (17)	—	—	—	—
Coronary heart disease	555 (10)	193 (7)	285 (12)	77 (16)	—	—	—	—
Cancer	1140 (21)	514 (20)	518 (21)	108 (22)	—	—	—	—
Stroke	467 (8)	104 (4)	257 (11)	106 (22)	—	—	—	—
No comorbidities	1587 (29)	995 (38)	550 (23)	42 (9)	—	—	—	—
1–2 comorbidities	3297 (60)	1454 (6)	1535 (63)	308 (64)	<0.01	1.91 (1.68–2.17)	<0.01	5.02 (3.60–7.00)
>2 comorbidities	649 (12)	170 (6)	347 (14)	132 (27)	<0.01	3.70 (2.99–4.56)	<0.01	18.40 (12.54–26.99)
Increased alcohol consumption	812 (15)	410 (16)	351 (14)	51 (11)	0.23	0.91 (0.78–1.06)	<0.01	0.64 (0.47–0.87)
Current or past smoker	2801 (51)	1245 (48)	1291 (53)	265 (55)	<0.01	1.25 (1.12–1.40)	<0.01	1.35 (1.11–1.64)
≥5 prescription medications in past 30 days	2084 (38)	660 (25)	1105 (45)	319 (66)	<0.01	2.47 (2.19–2.78)	<0.01	5.81 (4.72–7.15)
Difficulty with at least 1 ADL	1365 (25)	220 (8)	773 (32)	372 (77)	<0.01	5.08 (4.32–5.98)	<0.01	36.88 (28.62–47.52)
Difficulty with at least 1 IADL	1580 (29)	232 (9)	951 (39)	397 (82)	<0.01	6.61 (5.64–7.73)	<0.01	48.05 (36.67–62.96)
3. Social and Community Factors								
Married or living with a partner	3085 (56)	1646 (63)	1251 (51)	188 (39)	<0.01	0.63 (0.56–0.70)	<0.01	0.38 (0.31–0.46)
Lives alone	1413 (26)	586 (22)	667 (27)	160 (33)	<0.01	1.31 (1.15–1.49)	<0.01	1.73 (1.40–2.13)
4. SECEC[f]								
Less than high school education	1659 (30)	696 (27)	773 (32)	190 (39)	<0.01	1.29 (1.14–1.45)	<0.01	1.80 (1.47–2.20)
Income ≤130% federal poverty level	1665 (30)	641 (24)	812 (33)	212 (44)	<0.01	1.55 (1.37–1.75)	<0.01	2.42 (1.98–2.96)
Medicaid or medicare health insurance, only	2170 (39)	870 (33)	1026 (42)	274 (57)	<0.01	1.47 (1.31–1.65)	<0.01	2.65 (2.17–3.23)
No insurance/private insurance/ other public insurance	3363 (61)	1749 (67)	1406 (58)	208 (43)	—	—	—	—
Healthcare utilization								
≥2 hospitalizations in past year	304 (5)	62 (2)	162 (7)	80 (17)	<0.01	2.94 (2.19–3.97)	<0.01	8.21 (5.80–11.62)
≥4 outpatient visits in past year	2985 (54)	1137 (43)	1491 (61)	357 (74)	<0.01	2.06 (1.85–2.31)	<0.01	3.72 (2.99–4.63)
Does not own home	4016 (73)	2042 (78)	1667 (69)	307 (64)	<0.01	1.62 (1.43–1.84)	<0.01	2.02 (1.64–2.48)
Receives community meal assistance	558 (10)	201 (8)	274 (11)	83 (17)	<0.01	1.53 (1.26–1.85)	<0.01	2.50 (1.90–3.30)

Note. ADL = activities of daily living; IADL = instrumental activities of daily living.
[a]Level 1 characteristic percentages do not total 100% due to rounding.
[b]Within column percentages are shown for Level 1-4 characteristics across total, robust, prefrail, and frail outcomes.
[c]To protect patient confidentiality, participants in NHANES ≥80 years old are top-coded at 80 and do not have age in years specified.
[d]Includes mixed race.
[e]BMI data is missing for 366 participants.
[f]Socio-Economic, Cultural, and Environmental Conditions.

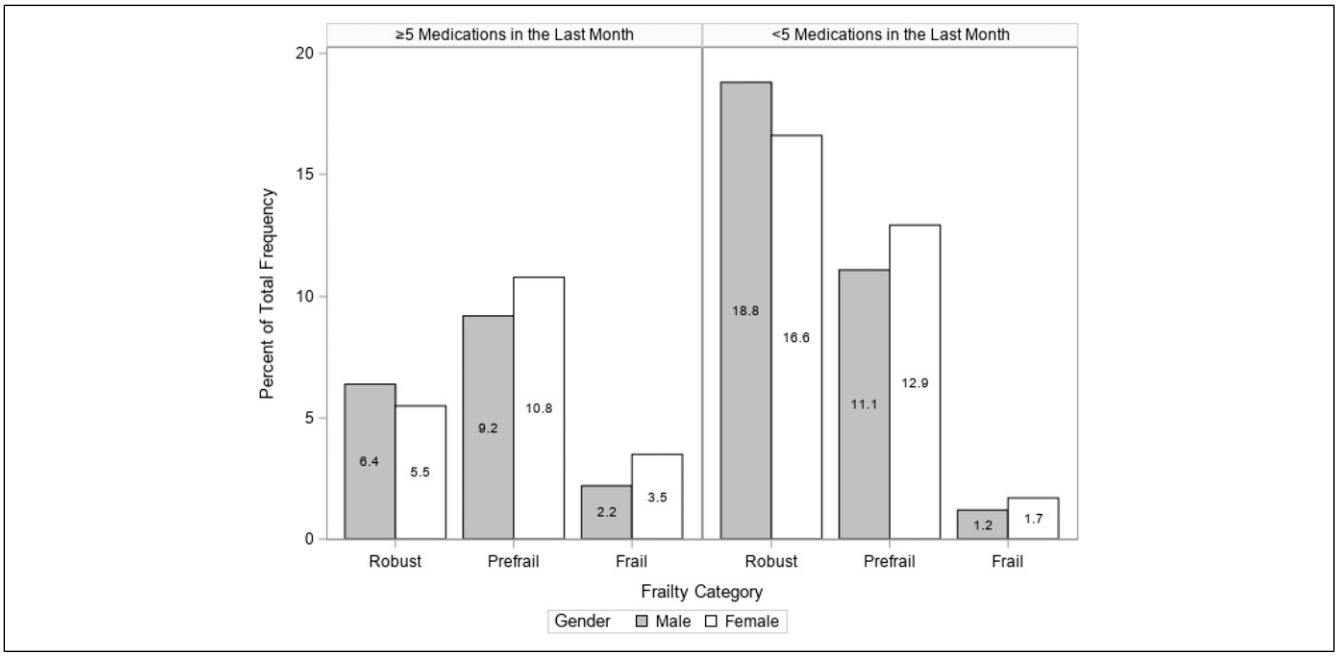

Figure 1. Distribution pattern of polypharmacy in frailty by gender.
Note. Figure 1 is a summary of polypharmacy (≥5 prescription medications used in past 30 days) in frailty status by gender, as percent of total frequency (n = 5533). Polypharmacy was greater in prefrail and frail women compared to men.

Table 2. 2011–2016 NHANES Participant Distribution for Modified Fried Phenotype Criteria.

	Robust[a]	Prefrail[b] (PF)	Frail[b] (F)	PF, F Total
Frailty Criteria	N = 2619 (%)	N = 2432 (%)	N = 482 (%)	N = 2914 (%)
Weakness	0 (0)	1016 (42)	449 (93)	1465 (50%)
Highest quintile of sedentary physical activity in minutes	0 (0)	904 (37)	297 (62)	1201 (41%)
Exhaustion	0 (0)	595 (24)	290 (60)	885 (30%)
Slowness	0 (0)	339 (14)	380 (79)	719 (25%)
Unintentional weight loss ≥10 lbs	0 (0)	360 (15)	156 (32)	516 (18%)

[a]Individuals were characterized as robust if they exhibited no frailty criteria components.
[b]Within column percentages are shown for prefrail and frail outcome.

95% CI 0.31–0.46)] and not owning a home (prefrailty 69%; $p < 0.01$ [OR 1.62, 95% CI 1.43–1.84]; frailty 64%; $p < 0.01$ [OR 2.02, 95% CI 1.64–2.48]. Age in years was significantly associated with frailty in adults >80 years old but the effect was small (frailty 36%; $p < 0.01$ [OR 1.60, 95% 1.24–2.07]. While high school education level was not associated with either prefrailty or frailty status, it was identified as a potential confounder and therefore remained in the final multivariable model (prefrailty 32%; $p = 0.48$ [OR 1.05, 95% CI, 0.91–1.21], frailty 39%; $p = 0.14$ [OR 1.21, 95% CI, 0.94–1.56]).

Discussion

From 2011–2016, the prevalence of frailty and prefrailty among older American adults who participated in NHANES was 9% and 44%. These findings are approximately consistent with reported scientific and clinical practice trends in community dwelling older adults >65 years as reported elsewhere (Bandeen-Roche et al., 2006; Fried et al., 2001; Walston, 2020). North American prevalence for physical frailty and prefrailty in community dwelling older adults >65 years old is estimated at 15% and 45% (Bandeen-Roche et al., 2015), and a systematic, meta-analysis of physical frailty in longitudinal cohorts of 61,500 community dwelling older adults cited an estimated population prevalence of 10.7% (Collard et al., 2012). Previous studies utilizing pre-2011 NHANES data identified a comparable prevalence using modified Fried criteria for physical frailty and prefrailty [10.8% and 44% (NHANES 1999–2004, modified 5-Fried criteria (Crow et al., 2018)); 3.6% and

Table 3. Adjusted Multivariable Logistic Regression Results of the Relationship Between Frailty and Determinants of Health in 2011–2016 NHANES Participants.

	Prefrail versus Robust		Frail versus Robust	
Characteristics[a]	*p*-value	aOR[b] (95% CI)	*p*-value	aOR[b] (95% CI)
ASCF[c]				
Male	<0.01	0.73 (0.64–0.83)	<0.01	0.56 (0.44–0.72)
Age in years				
70–79	0.15	0.90 (0.79–1.04)	0.83	1.15 (0.96–1.36)
80 and older	0.12	1.15 (0.96–1.36)	<0.01	2.02 (1.49–2.72)
White	0.21	1.09 (0.95–1.25)	<0.01	1.60 (1.24–2.07)
Lifestyle				
Comorbidities				
1–2 comorbidities	<0.01	1.40 (1.22–1.61)	<0.01	2.17 (1.51–3.14)
>2 comorbidities	<0.01	1.79 (1.41–2.28)	<0.01	3.33 (2.12–5.23)
Current or past smoker	<0.01	1.25 (1.10–1.41)	<0.01	1.40 (1.10–1.78)
≥5 prescription medications in past 30 days	<0.01	1.74 (1.52–1.99)	<0.01	2.38 (1.85–3.05)
Difficulty with at least 1 ADL	<0.01	4.02 (3.39–4.76)	<0.01	24.81 (18.97–32.45)
Social and community				
Married or living with a partner	0.01	0.77 (0.68–0.88)	<0.01	0.59 (0.46–0.76)
SECEC[d]				
Less than high school education	0.48	1.05 (0.91–1.21)	0.14	1.21 (0.94–1.56)
Income ≤130% federal poverty level	0.08	1.14 (0.98–1.31)	0.02	1.36 (1.06–1.76)
≥2 hospitalizations in past year	<0.01	1.93 (1.40–2.65)	<0.01	3.94 (2.61–5.94)
Does not own home	<0.01	0.75 (0.65–0.87)	0.03	0.74 (0.57–0.97)

Note. ADL = activities of daily living.
[a]Reference categories not shown.
[b]aOR is adjusted Odds Ratios from multivariable multinomial logistic regression.
[c]Socio-economic environmental conditions.
[d]Age, gender, and constitutional factors.

26.8% (NHANES 2003–2006, modified 4-Fried criteria (Blodgett et al., 2015)); and 2.8% frailty (NHANES 1994–1998, modified 5-Fried criteria (Wilhelm-Leen et al., 2009))]. Differences from our study's 2011–2016 findings are likely due to 1994–1998, 1999–2004, and 2003–2006 NHANES cycle variations in data collection processes for physical frailty, and previous customized modified Fried symptom criteria construction. A recent population study examined the relationship of the modified Fried phenotype in middle aged and older adults (37–73 years old) with 7-year all-cause mortality in a sample of n = 493,737 UK Biobank participants (Hanlon et al., 2018). Their modified Fried criteria also included self-reported weight loss, with frailty, and prefrailty prevalence reported at 5% and 42% in 36,623 adults 65–73 years old. Our study used a sampling threshold of 60 years old to ensure adequate representation of the frailty outcome in ethnic minority subgroups, especially non-Hispanic Black (n = 113), non-Black Hispanic (n = 94), and Asian (n = 21) participants, and is consistent with previous NHANES modified frailty phenotype investigations (Blodgett et al., 2015; Crow et al., 2018).

We identified increased prevalence of frailty and prefrailty in female participants, which is attributable to decreased lean body mass and muscle strength in women compared to men (Collard et al., 2012). Lifespan expectancy is slightly greater for women than for men, so examination of frailty specific to gender is important (Bandeen-Roche et al., 2006; World Health Organization, 2021). We also observed increased BMI across frailty categories which is counter to the Fried phenotype. Obese-frailty and sarcopenic obesity are known sub-phenotype variations of the frailty syndrome involving deregulated fat and muscle tissue functions; however, the basic science mechanism behind these alternative metabolic presentations remains unclear (Buch et al., 2016). Our study's mean BMI results were slightly higher than previous NHANES frailty reports which may correspond to population trends of increasing weight gain over time (Buch et al., 2016; Crow et al., 2018).

Increased frailty and prefrailty by age group was observed for non-Hispanic whites only. NHANES' purposeful oversampling of ethnic minorities should make it easier to detect existing frailty associations. However, previous reports suggest that increased frailty outcome in NHANES' ethnic minority groups could be impacted by the multistage probability design for these cycles, which featured oversampling of these groups. Posited critiques are that classified ancestral sub-populations (e.g., Chinese, Indian, and Filipino, all categorized as Asian) could mask broader trends in each

singular group; and national level NHANES data aggregation could mask regional variations reported in separate US drill-down examinations (Bandeen-Roche et al., 2015; Beasley et al., 2020). We observed significant differences in frailty and prefrailty according to race and ethnicity. Whites experienced frailty at 9.9% followed by non-Hispanic Black (9.1%), non-Black Hispanic (7.3%), Asian (4.2%), and other races (15%). Prefrailty rates were highest in non-Hispanic Black (47.9%) and other races (48.7%). Prior research indicates African Americans are impacted by higher rates of prefrailty and frailty, early progression trajectories and mortality, and that these observations can overlap with chronic disease burdens (e.g., obesity and diabetes), or be confounded by lower levels of education (Bandeen-Roche et al., 2015; Usher et al., 2021).

Difficulty with at least one ADL was the most strongly associated characteristic with prefrailty and frailty. Frailty, disability, and comorbidities are separate entities but overlap considerably (Espinoza et al., 2018; Fried et al., 2001). We observed increased ADL and IADL disability along the frailty spectrum with highest rates in the frail participants (77% with ADL disability, 82% with IADL disability); however, this was not always the case for comorbidities. Our results are consistent with a recent systematic review and meta-analysis of 20 studies in community dwelling older adults indicating frailty presence is a significant predictor of developing and worsening ADL and IADL disability (Kojima, 2017). Lastly, individuals with frailty may not be ADL disabled, and as such both ADLs and comorbidities must be examined separately which is why we included both in our final adjusted multinomial model (Wong et al., 2010).

Our adjusted model results showed that polypharmacy (≥5 prescription medications in previous month) and other measures of self-reported healthcare utilization (hospitalization and outpatient visits in previous 12 months) increased across the robust, prefrailty, and frailty categories. We found the polypharmacy result compelling. It is an area of healthcare safety and patient morbidity with great relevance to the well-being of older adults and is a powerful area of nursing assessment, patient education, and care management in most healthcare settings (National Academies of Sciences, Engineering, and Medicine, 2021; Quinn & Shah, 2017; World Health Organization, 2019). A recent systematic review of polypharmacy identified it as significantly associated with frailty; however, causality is difficult to determine (Gutierrez-Valencia et al., 2018). Cautious interpretation suggests reduction of polypharmacy should be explored as a policy strategy in prefrail and frail older adults.

In our study, multiple determinants of health were significantly associated with individuals who were frail and prefrail. Identifying predictive determinants of health factors for frailty is suggestive for meaningful points of early intervention. However, many of these determinants are not incorporated into US health care system infrastructure in a uniformly structured way. This presents significant analytic challenges in terms of which extracted health record components can be used for evaluating utilization patterns, morbidity, and mortality. For example, while approximately 80% of contributors to health outcomes can be explained by SDOHs, they comprise a wide range of clinical evaluation approaches involving varying time, cost, and effort (Hammond and Joynt Maddox, 2019; Magnan, 2017). Many SDOHs cannot be evaluated and addressed in a 10-minute office visit without adequate health care system infrastructure including EHR capacity, performance measures linked to readmissions, adequate social work evaluation, and the presence of skilled nursing care coordination and documentation to assist in the ranking and prioritization of which are most important (Hammond and Joynt Maddox, 2019; National Academies of Sciences, Engineering, and Medicine, 2021).

The modified Fried frailty criteria and health determinant factors we examined may be useful in designing rapid nursing assessments to identify at-risk individuals in integrated health care services and case management of community dwelling older adults to promote improved health equity (National Academies of Sciences, Engineering, and Medicine, 2021; Puts et al., 2017; Sadler et al., 2018). We did not study the validity and reliability of our screening test in clinical care coordination models. Future work should examine its suitability in rapid nursing telehealth (or mHealth) screens for use in low technology clinical environments including rural and urban community settings. For example, persons with a positive frailty or prefrailty screen in case management, disease management, or care coordination programs can be reviewed by their nurses to identify need for tailored multidisciplinary care plans (e.g., medication management, fall risk assessment, nutrition consultation for weight loss/gain, and exercise or physical therapy strength conditioning) and healthcare provider referrals for CGAs (National Academies of Sciences, Engineering, and Medicine, 2021; Michel et al., 2015; Walston, 2020).

Use of telehealth for case management and care coordination in US rural settings is receiving increased policy emphasis due to older adults' higher rates of poverty, chronic conditions, and age-adjusted mortality for all causes in these settings, particularly during COVID-19 (Department of Health and Human Services, 2020; National Academies of Sciences, Engineering, and Medicine, 2021; National Advisory Committee on Rural Health and Human Services, 2019). Nursing care management models such as the Transitional Care Model (Assessing/Managing Risks and Symptoms) may be able to incorporate modified Fried screening to better monitor older adult symptoms to prevent poor functional outcomes across a wide range of rural and urban clinical settings and health system care model designs to achieve improved health equity outcomes (Hewner et al., 2021; Hirschman et al., 2015; National Academies of Medicine, 2017; National Academies of Sciences, Engineering, and Medicine, 2021).

Strengths and Limitations

Strengths

This study provides a snapshot of US frailty and prefrailty prevalence and population-level health determinants during 2011–2016 and is a helpful update to 1994–2006 NHANES frailty investigations. This study's primary strength is use of NHANES data, which is a valuable and no-cost open access resource to inform population health for US older adults because it features data that may not be captured by other health utilization and pharmacy databases (Kantor et al., 2015; Seeman et al., 2010). Use of a widely recognized WHO population conceptual model helped inform and prioritize variable selection for a final multivariate logistic regression model (National Academies of Sciences, Engineering, and Medicine, 2019). Use of a modified Fried physical frailty phenotype from self-reported criteria in a large (n = 5533) nationally representative community dwelling older adult research sample allowed us to examine differences in several racial and ethnic minority groups with sufficient statistical power. If these criteria can be verified as a suitable rapid screening tool in low resource clinical settings, it may foster improved population health nurse monitoring and multi-sector collaborations in current chronic care models for older adults (Akpan et al., 2018 National Academies of Sciences, Engineering, and Medicine, 2021). Without reasonably accurate and efficient frailty measures, screening methods and data quality, use of artificial intelligence and machine learning techniques in older adult frailty research may be hampered (Ambagtsheer et al., 2020).

This study also provided an improved understanding of the developing link between social determinants and frailty in older adults, or "social frailty." While social frailty is an emerging term, social isolation and loneliness in frailty geriatric syndromes is an area of policymaking interest to strengthen financing through improved relationships and environments (National Academies of Sciences, Engineering, and Medicine, 2019, 2020; World Health Organization, 2021). Social frailty can be defined as "the continuum for which an individual is at risk for losing resources needed to fulfill one's basic social needs during the lifespan" and includes social resources, general resources, behavior, and activities (Bunt et al., 2017). Social frailty concepts relevant to older adults not examined in this study included employment, religiosity, neighborhood composition, affinity, deprivation, and involvement, volunteering, caregiver status, elder abuse, talking with someone every day, total expenses, presence of confidant, occupational history, healthcare expenditures, social network support and social ties, number of living children, presence of warm, and trusting relationships, contacts with family/friends/neighbors, parent education, childhood socioeconomic status level, and leisure activities (Bunt et al., 2017).

Limitations

This was a retrospective analysis of cross-sectional data for which no causation or long-term implications can be inferred. We used modified Fried phenotype criteria customized to NHANES 2011-2016 data availability in contrast to the physical measurements of the gold diagnostic standard which impacts accuracy (Fried et al., 2001). Modified Fried measurements using self-reported criteria are well documented as a reasonable alternative when physical data are unavailable (Blodgett et al., 2015; Crow et al., 2018; Wilhelm-Leen et al., 2009). There is sufficient consensus (~80%) and adequate precedent in the frailty literature for using rapid screens for individuals >70 years old (Morley et al., 2013). Sensitivity, specificity, positive and negative predictive values of the modified Fried phenotype were not calculated in this study, but it is reported elsewhere in smaller study samples (n = 124, n = 135, and n = 196), (Aprahamian et al., 2017; Op Het Veld et al., 2018; Van der Elst et al., 2020). We examined only three NHANES data cycles, and age groups were a categorical variable since the oldest age that could be reported was 80 years. We did not link to identifiable data and we did not examine the Rockwood FI, a leading frailty alternative that incorporates multidimensional aspects including psychological and to a lesser extent, social deficits (Blodgett et al., 2015). Although several ethnicities were included, white participants comprised 43% of the sample and comprised the largest subgroup in the cohort. Although our study was limited to NHANES data availability and WHO conceptual model prioritizations, these point to important patterns for further domestic and global aging health policy research.

The findings of this study are not necessarily generalizable to the general US or global population; but its large sample size meaningfully contributes to the modified Fried frailty phenotype evidence base. Specifically, prefrailty and frailty outcomes and measure components in older community dwelling adults 60–80 years old for non-Hispanic whites and non-Hispanic Blacks, and to a lesser extent non-Black Hispanics, can be compared to other similar epidemiologic study cohorts.

Conclusion

Frailty and strategic incorporation of SDOH into policy evaluation and planning are needed areas of aging policy, especially to identify and reduce health disparities in low resource clinical settings. We demonstrated successful use of five self-reported modified Fried frailty phenotype criteria in NHANES 2011–2016 participants for detection of frailty (9%) and prefrailty (44%) and included evaluation of vulnerable ethnic minority populations. We used a widely recognized WHO population health conceptual model to prioritize relevant health determinants to better understand significant associations with frailty.

Our self-reported criteria must be compared to the gold standard Fried physical performance measures to determine suitable accuracy as a rapid screen. While modified physical frailty measures offer a reasonable alternative when physical data are unavailable, they may result in moderate detection thresholds and be inappropriate for diagnostic purposes. We are hopeful that the modified self-report criteria we identified may confer sufficient validity to inform patient criteria and symptom tracking by nursing staff between CGAs or for rapid screening in case management programs. Alternatively, they may be useful for advancing internal performance improvement initiatives for detection and monitoring of frailty criteria in health care systems and older adult public health aging policy initiatives and services. Using rapid-screen frailty assessments in case management, health promotion models, and analytics initiatives could enhance multi-sector nursing care coordination by identifying who could benefit most from targeted interventions to maintain health (i.e., CGAs, urgent sick visits, medication management and nutrition consults).

Findings presented here continue to add to the NHANES body of knowledge on the health status of older US adults 2011–2016. They also contribute to the SDOH dialogue, the frailty literature base, and assist in the formation of domestic and global aging health policy, health services research and population health program measurement evaluations.

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