# Ethnicity and Changing Functional Health in Middle and Late Life: A Person-Centered Approach

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***Objectives.*** Following a person-centered approach, this research aims to depict distinct courses of disability and to ascertain how the probabilities of experiencing these trajectories vary across Black, Hispanic, and White middle-aged and older Americans.

***Methods.*** Data came from the 1995–2006 Health and Retirement Study, which involved a national sample of 18,486 Americans older than 50 years of age. Group-based semiparametric mixture models (Proc Traj) were used for data analysis.

***Results.*** Five trajectories were identified: (a) excellent functional health (61%), (b) good functional health with small increasing disability (25%), (c) accelerated increase in disability (7%), (d) high but stable disability (4%), and (e) persistent severe impairment (3%). However, when time-varying covariates (e.g., martial status and health conditions) were controlled, only 3 trajectories emerged: (a) healthy functioning (53%), moderate functional decrement (40%), and (c) large functional decrement (8%). Black and Hispanic Americans had significantly higher probabilities than White Americans in experiencing poor functional health trajectories, with Blacks at greater risks than Hispanics.

***Conclusions.*** Parallel to the concepts of successful aging, usual aging, and pathological aging, there exist distinct courses of changing functional health over time. The mechanisms underlying changes in disability may vary between Black and Hispanic Americans.

***Key Words:*** Group-based mixture models—Health disparities—Minority aging (race/ethnicity).

RESEARCH on ethnic variations in health changes among older adults could be significantly improved by being more dynamic. Although cross-sectional studies have shown that older Latinos and African Americans experience greater disability and health disadvantage relative to older White Americans (Carrasquillo, Lantigua, & Shea, 2000; Zsembik, Peek, & Peek, 2000), intrapersonal and interpersonal differences are confounded in such analyses. Meanwhile, longitudinal studies have documented that Black Americans are more likely to experience a health decline than White Americans (Angel, Angel, & Himes, 1992; Mendes de Leon et al., 1997; Peek, Coward, Henretta, Duncan, & Dougher, 1997). Although these studies yield very useful information concerning health transitions, they provide little information on the underlying growth curve or trajectory. Focusing on changes between two points in time, a transition differs significantly from a trajectory, a pathway charted by a series of transitions, which can be linear or nonlinear. A more complete understanding of the disablement process requires an analysis of the level, velocity, and its acceleration associated with a health trajectory.

Current research on health trajectories in old age has been dominated by the variable-centered approach (Kelley-Moore & Ferraro, 2004; Mendes de Leon, Barnes, Bienias, Skarupski, & Evans, 2005; Taylor & Lynch, 2004). Based on the assumption that the population is homogeneous with respect to how the predictors operate on the outcomes, this approach identifies the average developmental tendencies, calibrates variability about the average, and explains that variability in terms of covariates of interest. For instance, the population distribution of development is assumed to be continuous in growth curve models (e.g., hierarchical linear models and latent growth curve modeling) (Muthén & Muthén, 2000; Raudenbush & Bryk, 2002).

In contrast, a pattern or person-centered approach emphasizes subgroup heterogeneity that reflects qualitatively distinct subpatterns of changes (Muthén & Muthén, 2000; Ryff, Singer, Love, & Essex, 1998). As an example, the mixture modeling strategy (e.g., semiparametric group-based approach) is designed to identify distinctive prototypal developmental trajectories within the population, to calibrate the probability of population members following each such trajectory, and to relate those probabilities to covariates of interest (Nagin, 2005).

A person-centered approach is useful in understanding heterogeneity in health trajectories. Although some older persons are very sick and disabled, others are free of illness and disability (Rowe & Kahn, 1987). Williams (2005) has observed that inadequate attention has been directed to diverging patterns of health over time in racial/ethnic

minority populations. Indeed, the disablement process may acquire a distinct natural history for any given ethnic group, which entails a unique configuration of health changes (Zsembik et al., 2000).

An increasing number of studies have documented the multitude of health trajectories in old age. These range from studies on catastrophic versus progressive decline in activities of daily living (ADLs; Ferrucci et al., 1996) and distinct trajectories at the end of life (Chen, Chan, Kiely, Morris, & Mitchell, 2007; Lunney, Lyn, Foley, Lipson, & Guralnik, 2003) to those concerning multiple courses of changing functional health among older adults in general (Deeg, 2005; Dodge, Du, Saxton, & Ganguli, 2006; Mavandadi, Rook, & Newsom, 2007). However, ethnic differences have not been a primary focus; hence, some important research questions remain unanswered. How do Blacks, Hispanics, and Whites vary in the likelihood of following various health trajectories? Are there any differences in the mechanisms underlying ethnic variations in health across these three groups? Moreover, current research has been largely confined to a contrast between two groups involving White Americans versus non-White, Black, or Hispanic Americans. There is little knowledge regarding the similarities and differences between Blacks and Hispanics, and how Hispanics stand in relation to the Black and White differentials in health.

Furthermore, research on trajectory groups could be advanced by incorporating time-varying covariates. This is because explanatory variables of functional status (e.g., marital status and prior health conditions) may change substantially over time. This is particularly true if a long period of observation is involved. Prior studies of trajectory groups of functional status included only time-constant covariates often derived from samples confined to a limited geographic area or region.

The present study contributes to current knowledge in three respects. We first identify the multiple trajectories of functional health in a national probability sample of Americans older than 50 years using an improved methodology involving group-based mixture models (Nagin, 2005). Second, we ascertain differences in the probabilities associated with various functional trajectories across Black, Hispanic, and White Americans. Third, relative to White Americans, we explore how Black and Hispanic Americans differ in the mechanisms underlying ethnic variations in the trajectories of functional disability.

## HYPOTHESES

Although many physiological measures show substantial losses with advancing age, there is substantial variability. Many older people suffer minimal physiological loss or none at all. These individuals might be viewed as aging successfully and should be differentiated from those who show nonpathological age-linked losses that can be designated as usual or normal aging (Rowe & Kahn, 1987). Other investigators have distinguished normal aging from pathological aging, which is a result of diseases (Kane, Ouslander, & Abrass, 1999, pp. 4–7; Schaie, 1996). Finally, there is some evidence that functional limitations and instrumental activities of daily living (IADLs) have evolved over time by the following three distinct courses: (a) no decline, (b) moderate decline, and (c) sharp decline (Dodge et al., 2006; Mavandadi et al., 2007). Hence, we hypothesize that at least three distinct trajectories exist, parallel to successful aging, usual aging, and pathological aging ($H_1$).

A key factor leading to ethnic difference in health is racial/ethnic stratification, a system involving ethnic groups interacting in patterns of dominance and subordination (Jackson, Antonucci, & Gibson, 1990; Williams, 1997). Such stratification may influence health through several mechanisms, including (a) less advantaged socioeconomic circumstances, (b) constraints placed on lifestyle choices, or (c) stress as a result of perception of discrimination (Crimmins, Hayward, & Seeman, 2004; Robert & House, 2000).

Most national surveys have suggested that functional limitations and disability among Hispanic elders are similar to or slightly greater than among Whites but lower than among Blacks (Carrasquillo et al., 2000). In addition, there is evidence that Blacks were more likely to experience health decline than Whites (Angel et al., 1992; Peek et al., 1997). Finally, according to Liang and colleagues (2008), both African and Hispanic Americans had a higher level of disability than their White counterparts. Whereas Blacks had a greater rate of functional decline relative to Whites, there was no difference between Hispanics and Whites. Extrapolating from these findings, we hypothesize that Black and Hispanic Americans are more likely than their White counterparts to experience trajectories of poorer functional health, whereas Hispanics tend to experience better health trajectories than Blacks ($H_2$).

How socioeconomic status (SES) and prior health are associated with health trajectories may vary between Blacks and Hispanics. Liang and colleagues (2008) found that with education and prior health conditions controlled, there were no differences between Hispanics and Whites in the trajectory of disability, whereas the differences between Blacks and Whites persisted. In contrast, there is evidence that when SES is controlled, the differences in biological risk profiles between Whites and Mexican immigrants aged 40 years and older disappear, but the differences between Whites and Blacks or U.S.-born Mexican Americans remain (Crimmins, Kim, Alley, Karlamangla, & Seeman, 2007). We hypothesize that education and prior health would account for more Hispanic–White differences than Black–White disparities in disability trajectories based on prior empirical observations ($H_3$).

The aforementioned hypotheses will be evaluated within the following conceptual framework. In particular, gender, age, ethnicity, and SES are viewed as key dimensions of

social stratification, with SES as a function of the other three. Furthermore, differences in functional health across dimensions of social stratification are partially mediated by social networks and prior health status. This framework has been articulated by a number of investigators (Crimmins & Seeman, 2001; House, Lantz, & Herd, 2005).

## METHODS

### Design and Data

Data came from the Health and Retirement Study (HRS), which began in 1992 by surveying a national sample of more than 12,600 persons born in 1931–1941. In 1993, the "Asset and Health Dynamics Among the Oldest Old" (AHEAD) study was launched with a national sample of individuals aged 70 years and older (i.e., born before 1924). Biennial follow-ups have been made of the HRS and AHEAD respondents thereafter. Starting from 1998, HRS and AHEAD surveys were fully integrated and two new subsamples were added in 1998: Children of the Depression Age (CODA)—persons born in 1924–1930—and War Baby (WB)—persons born in 1942–1947. As of 2006, these four components of HRS yielded a total of 26,988 respondents, representing all individuals older than 50 years in the United States. Extensive documentation of HRS, including response rates and mortality, is available at its Web site (http://hrsonline.isr.umich.edu).

In the present study, baseline data were obtained from respondents in 1995 for AHEAD, in 1996 for HRS, and in 1998 for CODA and WB. Follow-up data were gathered in 1998 (for AHEAD and HRS cohorts), 2000, 2002, 2004, and 2006. Hence, up to five or six repeated observations were obtained for each admission cohort over a period of 8–11 years. HRS data collected in 1992 and 1994 and AHEAD data in 1993 were excluded because of incomparable measures of functional status.

### Measures

Functional status entailed a count of difficulties with six ADLs (i.e., dressing, walking, bathing or showering, eating, getting in or out of bed, and using the toilet) and five IADLs (i.e., preparing hot meals, grocery shopping, making phone calls, taking medications, and managing own money and expenses). A higher score represented greater functional impairment. Spector and Fleishman (1998) showed that ADL and IADL items could be combined to measure functional status with enhanced range and sensitivity.

Several measures of social stratification were included. Age differences were measured by age in 1995. Dummy variables of gender and ethnicity (i.e., non-Hispanic White, non-Hispanic Black, and Hispanic) were created. Education was indexed by years of schooling.

Our specifications incorporated several time-varying covariates including proxy interview status, marital status, self-rated health status, number of chronic diseases, and the *Center for Epidemiological Studies-Depression* (CES-D) score. As an indicator for social networks, marital status was constructed as a dummy variable (1 = married or living with a partner). Diseases were a count of seven health conditions (i.e., heart disease, cancer, stroke, diabetes, hypertension, lung disease, and arthritis). Self-rated health was a single item rating of the respondent's health (1 = excellent, 2 = very good, 3 = good, 4 = fair, and 5 = poor). Depressive symptoms were represented by a count of nine dichotomous items (i.e., depressed, everything an effort, restless sleep, happy, lonely, enjoy life, sad, could not get going, and a lot energy) drawn from the CES-D (Radloff, 1977). A higher score reflected greater depressive symptoms. Finally, in each wave of the survey, whether the observation was obtained through a proxy interview was coded as a dummy variable.

To ensure that a clear time sequence is defined between the time-varying covariates and the outcome measure, our model involved the lagged measure (i.e., observation from the last interview) and the change term (i.e., change between the previous observation and the current observation) for each of the time-varying covariates. For instance, marital status was included as a lagged covariate and as the change in status (−1 for dissolutions, 0 for no change, and 1 for the acquisition of a partner). Table 1 presents the descriptive statistics of all the measures.

### Data Analysis

We used group-based semiparametric mixture models (hereafter referred to as group-based trajectory model) to identify distinctive clusters of individual trajectories within the population, which entails a multinomial modeling strategy designed to identify relatively homogeneous clusters of developmental trajectories (Jones, Nagin, & Roeder, 2001; Nagin, 2005). It includes two components. The first component is a basic group model that depicts clusters of individuals with similar trajectories. Trajectory parameters are derived by a latent class analysis through maximum likelihood estimation with the following specifications:

$$Y_{iT}^{*g} = \beta_0^g + \beta_1^g \text{ Time}_{iT} + \sum \beta_k^g X_{kiT} + \varepsilon_{iT}^* \quad k = 1, ..., K; i = 1, ... n \quad (1)$$

$Y_{iT}^{*g}$ is a latent variable representing the underlying functional status of individual $i$ at time $T$ (e.g., 1998) given membership in group $g$. *Time* refers to the timing of assessment from the baseline. $X_{kiT}$ is the time-varying covariate (e.g., lagged measures of prior health status and their corresponding change terms) associated with individual $i$ at time $T$. $\beta_0^g$, $\beta_1^g$, and $\beta_k^g$ are the coefficients associated with the intercept and rate of change in functional status and the effects of $K$ time-varying covariates for individuals in group $g$. $\varepsilon_{iT}^*$ is a disturbance term assumed to be normally distributed with zero mean and constant variance.

Table 1. Descriptive Statistics of Time-Varying and Time-Constant Covariates

| Time-varying covariates | 1998 ($n = 14,553$) | 2000 ($n = 16,543$) | 2002 ($n = 14,587$) | 2004 ($n = 13,352$) | 2006 ($n = 12,089$) |
|---|---|---|---|---|---|
| Functional status | 0.62 ± 1.74 | 0.56 ± 1.63 | 0.76 ± 1.80 | 0.78 ± 1.81 | 0.74 ± 1.77 |
| Time since baseline (in years) | 2.37 ± 0.48 | 3.79 ± 1.07 | 5.75 ± 1.06 | 7.71 ± 1.05 | 9.68 ± 1.03 |
| Proxy status (lagged), $n$ (%) | 932 (6) | 1,074 (6) | 997 (7) | 948 (7) | 695 (6) |
| Change in proxy status (since last interview) | 0.02 ± 0.22 | 0.02 ± 0.20 | 0.01 ± 0.21 | −0.001 ± 0.20 | −0.01 ± 0.20 |
| Marital status (lagged), $n$ (%) | 10,496 (72) | 11,756 (71) | 9.894 (68) | 8,910 (67) | 7,964 (66) |
| Change in marital status (since last interview) | −0.02 ± 0.14 | −0.05 ± 0.26 | −0.03 ± 0.21 | −0.02 ± 0.20 | −0.03 ± 0.20 |
| Self-rated health (lagged) | 2.71 ± 1.14 | 2.85 ± 1.14 | 2.74 ± 1.11 | 2.79 ± 1.09 | 2.84 ± 1.09 |
| Change in self-rated health (since last interview) | 0.26 ± 0.94 | −0.03 ± 0.92 | 0.11 ± 0.90 | 0.12 ± 0.88 | 0.07 ± 0.88 |
| Diseases (lagged) | 1.56 ± 1.22 | 1.63 ± 1.25 | 1.71 ± 1.25 | 1.86 ± 1.27 | 1.99 ± 1.29 |
| Change in diseases (since last interview) | 0.21 ± 0.57 | 0.14 ± 0.59 | 0.21 ± 0.61 | 0.18 ± 0.61 | 0.17 ± 0.60 |
| Depressive symptoms (lagged) | 1.76 ± 1.96 | 1.98 ± 2.11 | 1.94 ± 2.09 | 1.90 ± 2.13 | 1.83 ±2.11 |
| Change in depressive symptoms (since last interview) | 0.39 ± 2.04 | 0.06 ± 2.03 | 0.04 ± 2.02 | 0.03 ± 2.00 | 0.11 ± 1.95 |

| Time-constant covariates | Total ($N = 18,486$) | White ($n = 14,552$) | Black ($n = 2,567$) | Hispanic ($n = 1,367$) | $p$ Value |
|---|---|---|---|---|---|
| Died (between baseline and 2006), $n$ (%) | 4,755 (26) | 3,704 (25) | 731 (28) | 320 (23) | .0007 |
| Ever attrited (between baseline and 2006), $n$ (%) | 1,705 (9) | 1,248 (9) | 295 (11) | 162 (12) | <.0001 |
| Female, $n$ (%) | 10,505 (57) | 8,124 (56) | 1,603 (62) | 778 (57) | <.0001 |
| Age (years, in 1995) | 64.28 ± 10.23 | 64.57 ± 10.23 | 63.31 ± 10.25 | 62.94 ± 9.84 | <.0001 |
| Education | 11.94 ± 3.37 | 12.54 ± 2.82 | 10.63 ± 3.64 | 8.04 ± 4.67 | <.0001 |
| Baseline marital status, $n$ (%) | 13,222 (72) | 10,892 (75) | 1,369 (53) | 961 (70) | <.0001 |
| Baseline proxy interview status, $n$ (%) | 1,148 (6) | 805 (6) | 184 (7) | 159 (12) | <.0001 |
| Baseline self-rated health | 2.70 ± 1.15 | 2.59 ± 1.12 | 3.09 ± 1.14 | 3.17 ± 1.18 | <.0001 |
| Baseline diseases | 1.52 ± 1.22 | 1.48 ± 1.21 | 1.78 ± 1.24 | 1.42 ± 1.22 | <.0001 |
| Baseline depressive symptoms | 1.76 ± 1.97 | 1.61 ± 1.85 | 2.21 ± 2.17 | 2.51 ± 2.43 | <.0001 |
| Baseline ADL/IADL | 0.42 ± 1.36 | 0.34 ± 1.21 | 0.73 ± 1.80 | 0.69 ± 1.77 | <.0001 |

*Notes*: Statistics are reported as mean ± standard deviation or $n$ (%). Time-varying covariates are those associated with repeated observations within individuals. Data based on the 1995–2006 Health and Retirement Study. ADL = activities of daily living; IADL = instrumental activities of daily living.

\*$p < .05$; \*\*$p < .01$; \*\*\*$p < .001$.

As indicated in Equation 1, the distinct trajectories of disability were derived by modeling disability within each group as a function of time (i.e., number of years since the baseline) and other time-varying covariates. Within each group, disability was analyzed as an intercept only, a linear, or a polynomial model of time. We present Equation 1 as a linear function of time for simplicity of illustration. The time variable was centered at its mean to minimize multicollinearity when polynomial functions of time were evaluated. Through a process similar to that of latent class analysis, parameters were estimated to define the shape of the trajectories and the probability of group membership. The number of groups was chosen on the basis of the Bayesian information criterion (BIC) score and an examination of the 95% confidence interval of adjacent trajectories.

Because the disability measure can only vary between 0 and 11, we assumed a censored normal distribution for $Y_{iT}^g$ to account for possible floor and ceiling effects. In particular, $Y_{iT}^{*g}$ is a latent variable that is linked to its observed but censored counterpart, $Y_{iT}^g$ (i.e., functional status measure with a range of 0–11), as follows:

$$Y_{iT}^g = 0 \text{ if } Y_{iT}^{*g} < 0, \tag{2}$$

$$Y_{iT}^g = Y_{iT}^{*g} \text{ if } 0 \leq Y_{iT}^{*g} \leq 11, \tag{3} \text{ and}$$

$$Y_{iT}^g = 11 \text{ if } Y_{iT}^{*g} > 11. \tag{4}$$

It is important to note that the derived trajectories may vary significantly depending upon the inclusion of time-varying covariates ($X_{kiT}$) beyond the time-related parameters (Time$_{iT}$). Trajectories derived without time-varying covariates are not directly comparable with those identified by adjusting for time-varying covariates (Nagin, 2005, p. 124). This is because different variables are involved in identifying distinct latent classes or trajectory groups.

In the second component, trajectory group membership was treated as the dependent variable predicted by the person level time-constant covariates in a fashion similar to that for a multinomial logistic regression analysis. To examine ethnic differences in functional health trajectories, we evaluated the following specifications:

$$\pi_g(x_i) = e^{z_i\theta_g} / \sum_g e^{z_i\theta_g} \tag{5}$$

where $\theta_g$ represents the parameters of a multinomial logit model that capture the effects of time-constant covariates $z_i$ (e.g., age, gender, ethnicity, and education) on $\pi_g$, the probability of membership in group $g$ (Nagin, 2005, pp. 96–99). A SAS procedure, Proc Traj, was used to estimate Equation 5 simultaneously with Equation 1 (Jones et al., 2001).

To evaluate the hypotheses outlined previously, we undertook the following analyses. First, we derived the basic trajectory groups by estimating a model ($M_1$) in which disability is a function of time only, without any other covariates. Second, we identified trajectories while adjusting for

Table 2. Estimated Trajectory Groups and Group-Specific Growth Parameters, Before Adjusting for Time-Varying Covariates ($M_{1.0}$)

| | Excellent functional health | Good functional health with small increasing disability | High but stable disability | Accelerated increase in disability | Persistent severe disability |
|---|---|---|---|---|---|
| Growth parameter | | | | | |
| Intercept | −4.711*** | −0.432*** | 3.436*** | 3.247*** | 8.634*** |
| Linear slope | 0.100** | 0.459*** | −0.019 | 1.351*** | 0.230** |
| Quadratic slope | 0.009 | 0.005 | −0.045*** | 0.012 | −0.055*** |
| Cubic slope | 0.006** | −0.004* | 0.005 | −0.018*** | 0.002 |
| Group proportion (%) | 61.29 | 24.65 | 7.27 | 4.00 | 2.79 |
| Sigma | | | 2.534*** | | |
| Model fit statistics | | | | | |
| BIC ($N = 71,124$) | | | −61,656.46 | | |
| BIC ($N = 18,486$) | | | −61,639.62 | | |
| AIC fit index | | | −61,541.81 | | |
| Log likelihood | | | −61,516.81 | | |

*Notes*: Level 1, $N = 71,124$; Level 2, $N = 18,486$. Data reflect aggregate results from multiple imputation. BIC = Bayesian information criterion; AIC = Akaike's information criterion.

*$p < .05$; **$p < .01$; ***$p < .001$.

time-varying covariates (i.e., proxy interview, marital status, and health conditions; $M_2$).

For each set of trajectory groups, we assessed ethnic differences in the probability of group membership while controlling selection bias (resulting from mortality and attrition), age differences, and gender (i.e., $M_{1.1}$ and $M_{2.1}$). In addition, we examined how ethnic variations in the probability of group membership are mediated by education and baseline functional status (i.e., $M_{1.2}$ and $M_{2.2}$). To determine a mediation effect, we follow the classic approach outlined by Baron and Kenny (1986).

The HRS involves a national sample of households, augmented by oversamples of African Americans, Hispanics, and Floridians. We undertook separate analyses with and without weighting (i.e., Level 1 weights from the corresponding wave of interview and Level 2 weights from the 1998 interview) and obtained very similar results. Hence, we chose not to weight the data. To minimize the loss of subjects due to item missing, multiple imputation was undertaken (Schafer, 1997). In addition, we included measures of mortality, attrition, and proxy status in our model to control for selection bias associated with these factors. Finally, due to the massive sample (18,486 respondents with more than 71,000 observations), there is a concern about the overabundance of significant results. To offset this, only estimates with a *p* value less than .01 were considered as being statistically significant.

## RESULTS

### Trajectories of Disability

To identify the distinct trajectories of disability, we explored various models with alternative orders (e.g., intercept only, linear, quadratic, or cubic). Based on the statistical significance of their regression coefficients, a cubic specification was selected (see Table 2). The optimal number of trajectory

groups in each set of analyses was determined on the basis of (a) the BIC score and (b) whether there was an overlap in the 95% confidence interval of adjacent trajectories.

We chose five groups in charting disability over time (Table 2) because the BIC score leveled at five groups with the number of groups increasing from 2 to 10. In particular, the following trajectories were identified. First, accounting for 61.29% of the sample, "excellent functional health" (Trajectory 1) is characterized by a very low level of disability with positive but small linear and cubic slopes (Figure 1a; $M_{1.0}$ in Table 2). There is little disability throughout the period of 11 years. Hence, it mirrors "successful aging" as depicted by Rowe and Kahn (1987). As the second course, "good functional health with small increasing disability" (Trajectory 2) is distinguished by a slightly higher level of disability and a positive linear slope (24.65% of the sample). Individuals in this group experienced an increase of ADL/IADL from near zero to almost two during the 11-year period (Figure 1a). This seems to parallel what Rowe and Kahn (1987) described as usual or normal aging.

The remaining three trajectories all exhibit significantly greater disability that may reflect different types of pathological aging. First, the trajectory of "high but stable disability" (Trajectory 3) accounted for 7.27% of the sample. It was characterized by some three ADL/IADL difficulties with a slight decrease over the second half of the 11-year period. Second, the trajectory of "accelerated increase in disability" (Trajectory 4) fit 4.00% of the sample who experienced slightly less than one ADL/IADL difficulty at the beginning, which then increased to more than seven at the end of the 11-year period. Third, 2.79% of the sample experienced a course of "persistent severe disability" (Trajectory 5). Throughout the period of observation, individuals in this group consistently had seven or eight limitations in ADL/IADLs.

These findings offer some support for the existence of distinct disability trajectories particularly for those parallel
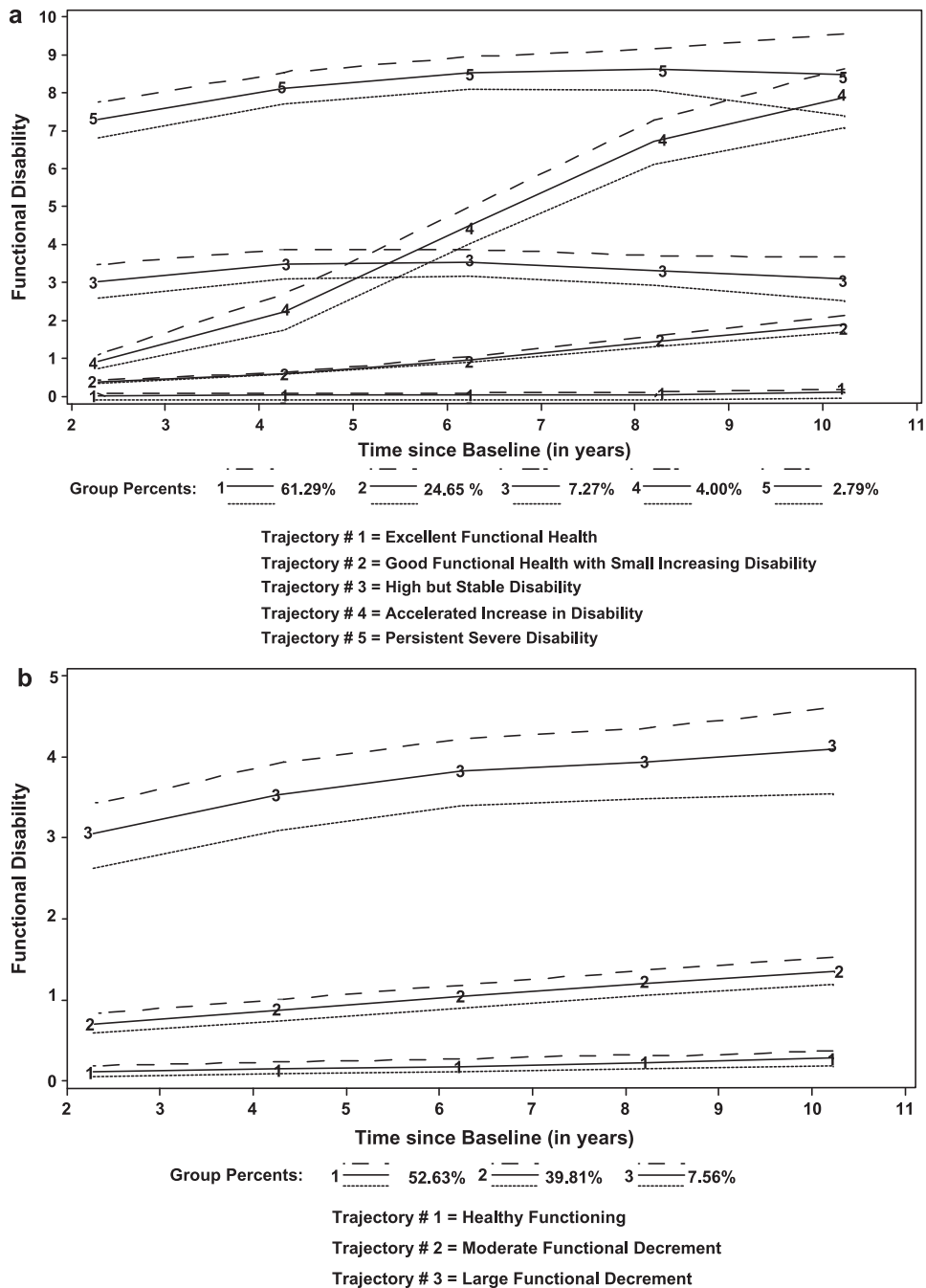
Figure 1. (a) Trajectory groups of functional disability over time without adjustment for time-varying covariates ($M_{1.0}$). (b) Trajectory groups of functional disability over time with adjustment for time-varying covariates ($M_{2.0}$). The dashed (---) lines represent the 95% confidence interval for each trajectory.

to successful aging and usual aging. The results are less clear about pathological aging in that three trajectories representing different subtypes emerged.

*Disability Trajectories With Time-Varying Covariates Adjusted*

Disability trajectory groups were also examined by adjusting for time-varying covariates including marital status, proxy interview status, and health status (Figure 1b; Table 3). On the basis of our analysis of 2–10 trajectory groups and their BIC scores, we chose three groups to characterize changes in disability. First, healthy functioning (Trajectory 1) is represented by individuals who had nearly no disability throughout the entire 11-year period, although there is a positive but small linear slope. Over half (52.63%) of the sample followed such a pathway. Second, moderate functional decrement (Trajectory 2) characterizes more than one

Table 3. Estimated Trajectory Groups and Group-Specific Growth Parameters, After Adjusting for Time-Varying Covariates (M$_{2.0}$)

|  | Healthy functioning | Moderate functional decrement | Large functional decrement |
|---|---|---|---|
| Growth parameter |  |  |  |
| Intercept | −11.383*** | −6.762*** | −3.060*** |
| Linear slope | 0.205*** | 0.242*** | 0.214*** |
| Quadratic slope | −0.007 | −0.004 | −0.021* |
| Cubic slope | 0.001 | −0.001 | 0.001 |
| Lagged proxy interview status | 1.783*** | 3.608*** | 4.851*** |
| Change in proxy interview status | 1.286*** | 2.890*** | 3.526*** |
| Lagged marital status | −0.740*** | −0.997*** | −0.997*** |
| Change in marital status | −0.138 | −0.286* | −0.378 |
| Lagged self-rated health | 1.698*** | 1.294*** | 1.452*** |
| Change in self-rated health status | 1.209*** | 0.883*** | 0.964*** |
| Lagged chronic disease | 0.472*** | 0.485*** | 0.343*** |
| Change in number of chronic disease | 0.461*** | 0.300*** | 0.309*** |
| Lagged CES-D score | 0.398*** | 0.554*** | 0.548*** |
| Change in CES-D score | 0.294*** | 0.418*** | 0.410*** |
| Group proportion (%) | 52.63 | 39.81 | 7.56 |
| Sigma |  | 2.561*** |  |
| Model fit statistics |  |  |  |
| BIC (*N* = 71,124) |  | −56,076.73 |  |
| BIC (*N* = 18,486) |  | −56,046.41 |  |
| AIC fit index |  | −55,870.35 |  |
| Log likelihood |  | −55,825.35 |  |

*Notes*: Level 1, *N* = 71,124; Level 2, *N* = 18,486. Data reflect aggregate results from multiple imputation. BIC = Bayesian information criterion; AIC = Akaike's information criterion; CES-D = *Center for Epidemiological Studies-Depression scale*.
*p < .05; **p < .01; ***p < .001.

third (39.81%) of the individuals in our sample who suffered from less than one functional limitation and a small increase in disability over the 11-year period. Third, large functional decrement (Trajectory 3) depicts a small proportion of individuals (7.56%) who had fairly substantial limitations in ADL/IADL. With three functional limitations on average at the baseline, they experienced a steady increase in disability over time.

These three trajectories appear fairly similar to three of the five derived without adjusting for time-varying covariates: excellent functional health (Trajectory 1, Figure 1a), good functional health with small increasing disability (Trajectory 2, Figure 1a), and high but stable disability (Trajectory 3, Figure 1a). When time-varying covariates were controlled, the two most disabled trajectory groups (i.e., accelerated increase in disability [Trajectory 4, Figure 1a] and persistent severe disability [Trajectory 5, Figure 1a]) identified initially could no longer be distinguished. These findings suggest that a significant portion of the variations in the disability trajectories are associated with changes in time-varying covariates including marital status and health conditions. In addition, the three resulting trajectories (Figure 1b) appear to offer a stronger support for the hypothesized trajectories: successful aging, usual aging, and pathological aging (H$_1$).

*Ethnic Differences in Disability Trajectories*

Table 4 presents the estimates derived from Proc Traj where coefficient estimates were reported as relative risk ratios (RRR = e$^b$, where $b$ is the logistic regression coefficient). In comparison with Whites, Blacks and Hispanics had significantly higher probabilities of experiencing trajectories of poorer functional health relative to the trajectory of excellent functional health (M$_{1.1}$ in Table 4). For instance, Blacks (RRR = 3.269, $p$ < .001) and Hispanics (RRR = 2.575, $p$ < .001) had approximately threefold risk than Whites in following a pathway of accelerated increase in disability (Trajectory 4). Blacks (RRR = 4.784, $p$ < .001) and Hispanics (RRR = 5.163, $p$ < .001) had even greater propensities than Whites in experiencing severe and persistent disability (Trajectory 5). This pattern of ethnic differences generally applied to the remaining functional health trajectories (M$_{1.1}$ in Table 4).

How do Blacks and Hispanics differ in their risk of experiencing various functional health trajectories? Further analysis using Blacks as the reference group in M$_{1.1}$ indicated no significant difference between Hispanics and Blacks in their likelihood of experiencing different trajectories. Hence, our findings yield some evidence supporting the hypothesis that Blacks and Hispanics are more likely to experience poorer trajectories of functional health, whereas there is insufficient evidence for the hypothesized differences in disability trajectories between Blacks and Hispanics (H$_2$).

How do ethnic differences in the trajectories of disability change when education and baseline functional health are taken into account? The Black–White differences in experiencing poorer trajectories of functional health attenuated

Table 4. Factors Associated With Trajectory Group Membership, Before Adjusting for Time-Varying Covariates ($M_1$)

| Trajectory | Parameter | $M_{1.1}$ | $M_{1.2}$ |
|---|---|---|---|
| Excellent functional health | Reference group | | |
| Good functional health with small increasing disability | Constant | 0.001*** | 0.004*** |
| | Dead | 5.415*** | 5.157*** |
| | Ever attrition | 1.118 | 1.196 |
| | Age in 1995 | 1.096*** | 1.090*** |
| | Female | 1.135* | 1.159* |
| | Black | 2.061*** | 1.797*** |
| | Hispanic | 1.701*** | 1.041 |
| | Education | | 0.901*** |
| | Baseline ADL/IADL | | 6.407*** |
| High but stable disability | Constant | 0.028*** | 0.024*** |
| | Dead | 3.613*** | 0.137 |
| | Ever attrition | 0.820 | 1.035 |
| | Age in 1995 | 1.009 | 1.035** |
| | Female | 1.555*** | 1.570** |
| | Black | 3.497*** | 2.406*** |
| | Hispanic | 2.911*** | 0.964 |
| | Education | | 0.832*** |
| | Baseline ADL/IADL | | 19.383*** |
| Accelerated increase in disability | Constant | 0.000*** | 0.000*** |
| | Dead | 21.444*** | 23.604*** |
| | Ever attrition | 1.381 | 1.051 |
| | Age in 1995 | 1.154*** | 1.138*** |
| | Female | 1.633*** | 1.657*** |
| | Black | 3.269*** | 2.382*** |
| | Hispanic | 2.575*** | 1.216 |
| | Education | | 0.857*** |
| | Baseline ADL/IADL | | 14.723*** |
| Persistent severe disability | Constant | 0.000*** | 0.000*** |
| | Dead | 31.572*** | 34.368*** |
| | Ever attrition | 0.892 | 0.684 |
| | Age in 1995 | 1.138*** | 1.129*** |
| | Female | 2.108*** | 1.968*** |
| | Black | 4.784*** | 2.460*** |
| | Hispanic | 5.163*** | 1.729* |
| | Education | | 0.834*** |
| | Baseline ADL/IADL | | 28.354*** |
| Model fit statistics | | | |
| BIC ($N = 71,124$) | | −59,483.88 | −57,263.55 |
| BIC ($N = 18,486$) | | −59,450.87 | −57,225.15 |
| AIC fit index | | −59,259.16 | −57,002.15 |
| Log likelihood | | −59,210.16 | −56,945.15 |

*Notes*: Level 1, $N = 71,124$; Level 2, $N = 18,486$. Data reflect aggregate results from multiple imputation. Estimates are reported as relative risk ratios. BIC = Bayesian information criterion; AIC = Akaike's information criterion; ADL = activities of daily living; IADL = instrumental activities of daily living.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5. Factors Associated With Trajectory Group Membership, After Adjusting for Time-Varying Covariates ($M_2$)

| Trajectory | Parameter | $M_{2.1}$ | $M_{2.2}$ |
|---|---|---|---|
| Healthy functioning | Reference group | | |
| Moderate functional decrement | Constant | 0.007*** | 0.002*** |
| | Dead | 2.170*** | 2.358*** |
| | Ever attrition | 0.948 | 0.970 |
| | Age in 1995 | 1.068*** | 1.086*** |
| | Female | 1.176** | 1.141* |
| | Black | 1.566*** | 1.513*** |
| | Hispanic | 1.045 | 0.887 |
| | Education | | 0.987 |
| | Baseline ADL/IADL | | 5.164*** |
| Large functional decrement | Constant | 0.000*** | 0.000*** |
| | Dead | 5.157*** | 5.117*** |
| | Ever attrition | 0.668 | 0.603 |
| | Age in 1995 | 1.116*** | 1.138*** |
| | Female | 1.603*** | 1.633*** |
| | Black | 2.389*** | 1.989*** |
| | Hispanic | 1.659*** | 1.322 |
| | Education | | 1.025 |
| | Baseline ADL/IADL | | 8.729*** |
| Model fit statistics | | | |
| BIC ($N = 71,124$) | | −55,114.78 | −54,060.57 |
| BIC ($N = 18,486$) | | −55,076.37 | −54,019.47 |
| AIC fit index | | −54,853.37 | −53,780.82 |
| Log likelihood | | −54,796.37 | −53,719.82 |

*Notes*: Level 1, $N = 71,124$; Level 2, $N = 18,486$. Data reflect aggregate results from multiple imputation. Estimates are reported as relative risk ratios. BIC = Bayesian information criterion; AIC = Akaike's information criterion; ADL = activities of daily living; IADL = instrumental activities of daily living.
*$p < .05$; **$p < .01$; ***$p < .001$.

explained by differences in education and baseline functional status. These findings offer some evidence for the hypothesis ($H_3$) that education and prior health account for more Hispanic–White differences than Black–White disparities in disability trajectories.

Based on our prior analyses of data derived from the HRS, ethnicity is significantly associated with diseases, self-rated health, and CES-D (e.g., Liang et al., 2008). In addition, there are significant ethnic variations in education and martial status (Table 1). According to the approach outlined by Baron and Kenny (1986), these results combined with those contained in Tables 3 and 5 enable us to make some inferences concerning the mediating effects of these variables on disability trajectories.

*Ethnic Variations in Disability Trajectories Adjusted for Time-Varying Covariates*

Even after controlling for changing marital status and health conditions, Blacks and Hispanics were still more likely than Whites to experience trajectories of poorer functional health ($M_{2.1}$ in Table 5). In particular, relative to Whites, Blacks (RRR = 2.389, $p < .001$) and Hispanics (RRR = 1.659, $p < .001$) had a nearly twofold risk of experiencing a large functional decrement (Trajectory 3 in

somewhat but remained significant ($M_{1.1} – M_{1.2}$ in Table 4). For instance, for Blacks, the RRR for following a course of persistent severe disability reduced from 4.784 ($M_{1.1}$) to 2.460 ($M_{1.2}$). In contrast, the Hispanics–White differences in experiencing poorer functional health trajectories were no longer statistically significant. Thus, only a proportion of the excess risk of Blacks over Whites could be explained by education and disability at the baseline. Meanwhile, the differences between Hispanics and Whites could be largely

Figure 1b). Blacks were also more likely than Whites to be in the moderate functional decrement group as opposed to the healthy functioning group (RRR = 1.566, $p$ < .001), whereas Hispanics did not differ from Whites in this regard. Additional analysis indicated that Hispanics had a lower risk in experiencing moderate functional decrement than Blacks (RRR = .667, $p$ < .001, table not shown). These results are consistent with the hypothesized ethnic variations in disability trajectories ($H_2$).

The observed ethnic variations in disability trajectories appear to be partially due to the heterogeneity in education and baseline functional status. Indeed, the results ($M_{2.2}$ in Table 5) were very similar to those based on trajectory groups without adjusting for time-varying covariates ($M_{1.2}$ in Table 4). For instance, Blacks' RRR of experiencing a large functional decrement reduced from 2.389 to 1.989 ($M_{2.2}$ in Table 5). The initially observed Hispanic–White difference in the risk of experiencing a large functional decrement was no longer significant when education and baseline disability were adjusted. These results lend some support for the differential mechanisms suggested in Hypothesis 3.

*Effects of Other Covariates*

In addition to ethnicity, older age and female gender were significantly associated with elevated probabilities of experiencing trajectories of poorer functional health ($M_{1.1}$ in Table 4). Age and gender variations remained unchanged, even after education and baseline functional status were controlled ($M_{1.2}$ in Table 4). Similar results concerning age and gender differences were obtained, when the disability trajectories were adjusted for time-varying covariates (Table 5).

To control for possible selection bias, mortality and attrition during the period of follow-up and proxy interviews were included in our analysis as covariates. Although they are generally considered confounding variables, they may also serve as surrogates for poor health. Mortality was substantially correlated with the relative risk of following a trajectory of poorer functional health, whereas attrition because of reasons other than death did not show a significant effect on the relative risks of belonging to various disability trajectories. This was the case for disability trajectories with or without adjusting for time-varying covariates (Tables 4 and 5). In addition, respondents, from whom proxy interviews were obtained, were significantly more likely to be more disabled in all trajectory groups ($M_{2.0}$ in Table 3). Accordingly, parameter estimates would be seriously biased if mortality and proxy interview were not controlled.

## DISCUSSION

The present research contributes to our understanding of ethnic variations in the multiple trajectories of disability on the basis of data derived from a national sample of Americans older than 50 years. In particular, it offers a quantitative depiction of the distinct trajectories of functional status, parallel to successful, usual, and pathological aging (Kane et al., 1999; Rowe & Kahn, 1987). After age 50, functional status evolves in five ways: (a) excellent functional health, (b) good functional health with small increasing disability, (c) accelerated increase in disability, (d) high but stable disability, and (e) persistent severe disability. These trajectories range from being a linear to cubic function of time. However, all of them exhibit a significant degree of stability, except that of accelerated increase in disability.

Our results are fairly comparable with those reported by Deeg (2005) who identified five trajectories of disability, including (a) stable not limited, (b) stable mild, (c) stable severe, (d) gradual increase, and (e) delayed increase, in addition to three trajectories specific to those deceased during the period of observation. Moreover, Nusselder, Looman, and Mackenbach (2006) identified 10 trajectories of disability among which 3 (i.e., entirely nondisabled, permanently mildly disabled, and mild but increasing disability) closely resemble those we have found. Of the remaining seven of their trajectories, six showed more fluctuations but only accounted for very small proportions of respondents (ranging from 0.4% to 2.4%), and one was reserved for those who died (5.8%) during the period of observation. To the extent that the findings from these studies converge, the validity of the five trajectories identified by us is reinforced.

Relative to conventional studies, our specifications are more dynamic in that trajectories of disability are included as a function of not only the lagged measures of marital status and health conditions but also their changes between two adjacent observations. When time-varying covariates such as marital status and health conditions are controlled, only three trajectory groups emerge: (a) healthy functioning, (b) moderate functional decrement, and (c) large functional decrement. As a close parallel to the notions of successful, usual, and pathological aging, these three trajectory groups show that heterogeneities in the changes in functional status are significantly associated with how martial status and other health conditions evolve over time.

Health trajectories are useful outcome measures, as they provide a dynamic depiction of the natural history of health and diseases. These trajectories are more informative than measures pertaining to health at one or more points in time because significant health difference at a given time may disappear or even reverse at a later time. In contrast, there may be distinct multiple courses of health changes associated with various diseases such as diabetes and heart disease (Chen et al., 2007; Lunney et al., 2003). Further research concerning how acute and chronic diseases are related to distinct health trajectories would facilitate disease management as well as the development of new initiatives for health promotion and disease prevention.

To the best of our knowledge, no prior study has focused on ethnic variations in person-centered disability trajectories in middle and late life, particularly among Black, Hispanic, and White Americans. We found that Black and Hispanic Americans have significantly higher probabilities relative to White Americans in experiencing poor functional health trajectories, with Blacks having an even greater risk than Hispanics. By analyzing functional health trajectories in conjunction with time-constant and time-varying covariates, we were able to examine ethnic differences in health in a more dynamic fashion. Indeed, it is remarkable that ethnic variations appeared to be relatively robust with or without controlling for time-varying covariates.

Prior research has revealed that many of the racial differences in health can be explained by SES factors (Robert & House, 2000). However, this may not apply to person-centered disability trajectories. Whereas the Hispanic–White differentiation in the probabilities of experiencing various disability trajectories is largely mediated by SES, Black–White disparities in this regard remain significant after these covariates are controlled. This finding provides some evidence that not all racial differences in health in the United States are explained by socioeconomic factors. In addition to SES, racism, neighborhood attributes, lifestyle, and social capital may have a bearing on ethnic variations in health (Crimmins et al., 2004; Smaje, 2000). There is also some evidence that ethnic variations exist in the ways how pathology, impairments, functional limitations, and disability are linked (Zsembik et al., 2000). The fact that immigrants constitute a significant proportion of Hispanic Americans may explain partially why Hispanics and Whites converged in disability trajectories when SES, marital status, and health conditions were adjusted (Williams & Lawler, 2001).

This study can be improved in several aspects. First, more ethnic groups may be included. For instance, Black immigrants from sub-Saharan Africa or Caribbean may be better educated than native-born Black Americans. Similarly, the health profile of Black immigrants varies by specific group and health outcome (Williams, 2005). Hispanics include Cubans, Puerto Ricans, Mexican Americans, and Central/South American-origin individuals. They are culturally diverse with different customs, values, migration patterns, and SES (Marger, 2003). In this regard, factors such as acculturation and age at immigration may have important implications for health in middle and later life (Angel & Angel, 2006; Markides & Black, 1996). In contrast, one may consider incorporating additional ethnic groups such as Japanese, Chinese, and Asian Indian Americans, which have shown substantial success in educational and occupational attainment in conjunction with better health (Williams). They could serve as useful benchmarks in understanding ethnic variations in health dynamics.

Second, ethnic variations in person-centered health trajectories can be further examined by analyzing each group separately. This will enable us to explore the unique patterns of trajectories within Blacks, Hispanics, and Whites. For instance, the number, configuration, and relative distribution of the courses of disability among Blacks could vary substantially from those among Hispanics and Whites. However, estimates from a given ethnic group (e.g., Blacks) so derived cannot be directly compared with those from other groups (e.g., Hispanics and Whites) because they are a function of covariances within a specific group (i.e., Blacks). Nevertheless, additional insights could be gained from such analyses.

Third, as respondents of HRS were sampled in mid- and late life, differential mortality had already altered the representativeness of the original birth cohorts before they were eligible for inclusion (George, 2005). This is often referred to as left truncation, which may lead to selection bias. In the present study, left truncation is likely to lead to a higher proportion of healthy respondents to be included in the sample. This might underestimate the rate of increase in disability over time. In contrast, survival may be more selective among Blacks and Hispanics than among Whites. If this were the case, more Whites with poor health than Blacks and Hispanics might be included in the HRS panel. This could lead to understated ethnic differences in health. However, it is unclear how large such biases are. More research on ways of adjusting for the biases due to left truncation is clearly warranted.

A more dynamic approach focusing on how person-centered health trajectories vary across Black, Hispanic, and White Americans would lead to an improved understanding of the linkages between ethnicity and health. Our research reveals that significant ethnic variations exist not only in the probabilities in experiencing various disability trajectories but also in the underlying mechanisms. Promising avenues for inquires include further explicating ethnic heterogeneities and implications of left truncation.

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