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Black–White Disparities in Adult Mortality: Implications of Differential Record Linkage for Understanding the Mortality Crossover

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Abstract Mortality rates among black individuals exceed those of white individuals throughout much of the life course. The black–white disparity in mortality rates is widest in young adulthood, and then rates converge with increasing age until a crossover occurs at about age 85 years, after which black older adults exhibit a lower mortality rate relative to white older adults. Data quality issues in survey-linked mortality studies may hinder accurate estimation of this disparity and may even be responsible for the observed black–white mortality crossover, especially if the linkage of surveys to death records during mortality follow-up is less accurate for black older adults. This study assesses black–white differences in the linkage of the 1986–2009 National Health Interview Survey to the National Death Index through 2011 and the implications of racial/ethnic differences in record linkage for mortality disparity estimates. Match class and match score (i.e., indicators of linkage quality) differ by race/ethnicity, with black adults exhibiting less certain matches than white adults in all age groups. The magnitude of the black–white mortality disparity varies with alternative linkage scenarios, but convergence and crossover continue to be observed in each case. Beyond black–white differences in linkage quality, this study also identifies declines over time in linkage quality and even eligibility for linkage among all adults. Although linkage quality is lower among black adults than white adults, differential record linkage does not account for the black–white mortality crossover.

Keywords Mortality · Race/ethnicity · Record linkage · Mortality crossover · National Health Interview Survey

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Introduction

The black–white disparity in US mortality rates is wide and enduring throughout much of the life course as a result of the socioeconomic disadvantages, barriers to quality healthcare, and institutional- and individual-level discrimination experienced by the black population (Elo et al. 2014; Jackson et al. 2011; Rogers et al. 2000; Williams and Sternthal 2010). In 2014, life expectancy at birth was 75.2 years among non-Hispanic black (hereafter "black") individuals and 78.8 years among non-Hispanic white (hereafter "white") individuals, a difference of 3.6 years (Kochanek et al. 2016). Despite mortality reduction among both groups throughout the twentieth century, the black–white life expectancy gap persists (Hummer 1996; Satcher et al. 2005). When age patterns of the black–white mortality rate disparity are considered, the black mortality disadvantage is largest in young adulthood, with black young adults exhibiting more than twice the mortality risk of white young adults. Then rates converge with increasing age until a crossover occurs at about age 85 years, after which black older adults exhibit a lower mortality rate relative to white older adults (Eberstein et al. 2008; Elo and Preston 1997; Manton and Stallard 1981; Nam 1995).

This apparent mortality convergence and crossover continues to capture the attention of population health researchers. The two leading explanations for the black–white mortality crossover are selective survival and data quality. The selective survival explanation suggests that the higher mortality among the black population in early life removes frail individuals, leaving a homogeneously robust black population at older ages. In contrast, the favorable socioeconomic conditions enjoyed by the white population in early life allow frail whites to survive to older ages. When the mortality experience of black older adults is compared with that of white older adults, who have more frail individuals surviving to advanced ages, black older adults will appear to have lower mortality rates than their white counterparts due to the selective survival of a particularly robust subset of black older adults (Manton and Stallard 1981; Otten et al. 1990). Recently, Masters (2012) expanded the heterogeneity explanation by examining disparate cohort patterns of mortality for the black and white populations. The robust/frail composition of black and white older adult cohorts was transformed throughout the twentieth century due in part to the social stratification by race of access to new health-enhancing resources, technologies, and information. This racial/ethnic change in population heterogeneity across cohorts led to the crossover being most evident among older cohorts, a trend concealed when researchers only examine age and period patterns. However, some researchers argue against the selective survival explanation by drawing upon evidence that populations that experience high mortality in early life tend to also experience high mortality in later life (Coale and Kisker 1986; Preston et al. 1998).

The data quality explanation for black–white mortality convergence and crossover posits that the quality of the data used to estimate mortality disparities is poorer among black adults than among white adults at older ages, thus biasing estimates of black–white mortality disparities. Much of this work has examined data quality issues in vital statistics data and identified age misreporting on the death certificates of black older adults as an important source of bias in mortality disparity estimates. That is, black adults who were born in the early twentieth century, before birth registration was mandated in all states, may claim (and subsequently have reported for them) an age that differs from their true age. Age misstatement generally biases mortality rate estimates downward (Preston et al. 1999). Preston and colleagues (1996) matched a sample of death certificates for black adults ages 65 years and older to their US census forms in 1900, 1910, and 1920 to show that the ages at death reported on death certificates are often incorrect. After adjusting for age misstatement, Preston and colleagues observed higher mortality rates among black older adults at all older adult ages such that the black–white mortality crossover was no longer observed. Most other studies have found that the black–white mortality crossover persists even with adjustments. Rosenberg et al. (1999) found that without adjustment, official death rates for black adults are only slightly biased due to age misstatement, as well as census undercount and racial/ethnic misclassification. Regarding the census-based population estimates that constitute the denominator of mortality rates, the US black population has historically been undercounted in US censuses (Anderson and Fienberg 1999; Robinson et al. 2002) including the 2010 census (Hogan et al. 2013). The census undercount reduces the denominator in the calculation of mortality rates for black adults.

Estimates of mortality risk using vital statistics data may also be problematic for US minority populations because racial and ethnic identity is self-reported on censuses (i.e., the denominator of death rate calculations) but reported by a funeral director on death certificates (i.e., the numerator of death rate calculations). Some adults who self-identify as black are recorded as white on their death certificate and vice versa (Rogers et al. 1997). However, agreement on race/ethnicity between survey records and death certificates is excellent among blacks and whites, but lower among other racial/ethnic groups (Arias et al. 2008; Sorlie et al. 1992). Race/ethnicity is accurately reported on death certificates to the extent that mortality estimates among black and white adults are not biased due to racial/ethnic misclassification.

The mortality crossover is also observed in data sources comprised social surveys prospectively linked to the National Death Index (NDI), such as the National Health Interview Survey-Linked Mortality Files (NHIS-LMF). These data sources avoid the issues of age misreporting and racial/ethnic misclassification found in vital statistics data, since the race/ethnicity self-reported or reported by a co-resident proxy on the survey is used to identify the race/ethnicity of the individual during mortality follow-up. Additionally, age is self-reported on the survey and then extrapolated to the time of death rather than relying on the age at death provided by a surviving family member or other informant. Survey-linked mortality data are a valuable tool in the study of racial/ethnic health disparities because they include measures of socioeconomic status and health behaviors (determinants linking race/ethnicity to health outcomes), whereas these variables are absent from vital statistics data (Eberstein et al. 2008; Elo and Preston 1997; Rogers et al. 2000). Given the popularity of these data, the quality of the linkage between surveys and death records and the extent to which these issues influence racial/ethnic mortality disparities must be evaluated.

Differential Record Linkage by Race/Ethnicity

Despite the strengths of survey-linked mortality data for estimating racial/ethnic disparities in mortality risk, they may be hampered by differential rates of record linkage for some population subgroups, such as racial/ethnic minority groups and older adults. Yet, the degree to which record linkage differs by race/ethnicity, age, and sex and the impact of such differences on mortality estimates remain uncertain. The overall NHIS-LMF data have been determined to be highly accurate in distinguishing true death matches (and survivor non-matches) and false death matches (and survivor non-matches). A calibration study found that the probabilistic linkage approach used to link NHIS and NDI records correctly ascertains the vital status of 98.5 % of respondents at the end of the follow-up period (National Center for Health Statistics [NCHS] 2009). However, few studies to date have assessed whether record linkage differs by race/ethnicity, and the few that do suggest that the magnitude and even the direction of racial/ethnic mortality disparities vary under alternative matching scenarios. For instance, Liao et al. (1998) used an earlier release of the NHIS-LMF dataset to examine the impact of using alternative matching scenarios relative to the NCHS-recommended match criteria on death rates and rate ratios by race/ethnicity. They found that mortality rates of non-Hispanic black and Hispanic adults relative to non-Hispanic white adults vary under alternative matching scenarios. In a more recent study using the 1989–2000 NHIS linked to NDI death records through 2002, Lariscy (2011) showed that linkage among Hispanic adults (especially those who are foreign-born) is less certain than among US-born non-Hispanic white adults. Lariscy further demonstrated that the hazard ratios of foreign-born Hispanic adults relative to non-Hispanic white adults are sensitive to alternative matching scenarios at ages 25–64 years but robust at ages 65 years and older.

Differences in record linkage between black and white adults could occur for a number of reasons. First, racial/ethnic differences in refusal or inability to accurately report the personally identifiable information (PII) used to link surveys and death records—such as Social Security number (SSN), name, and date of birth—could reduce linkage quality. Racial/ethnic differences in SSN reporting would be especially problematic since SSN is the most unique of the items used in the record matching algorithm and is best able to distinguish true matches from false matches. Miller and colleagues (2015) found lower SSN reporting among black adults relative to white adults on the NHIS. If PII is missing for a greater proportion of black adults than white adults, then their linkage quality will be poorer. Second, age misreporting among black older adults is pronounced on social surveys and administrative records (Kestenbaum 1992; Preston et al. 1996; Rogers et al. 1997). Although age misreporting is less of an issue in survey-linked data than in vital statistics data, age misreporting may negatively impact survey-linked data since date of birth is one of the items used to link records. If ages differ substantially between the survey and the death record, the likelihood of the two records being matched may be reduced. Third, race/ethnicity may be misreported on either record (most likely on the death certificate). Race/ethnicity is self-reported or reported by a co-resident proxy on social surveys, whereas race/ethnicity is reported on death certificates by a funeral director who may not record the same race/ethnicity with which the respondent self-identified. Previous studies have shown that race/ethnicity occasionally does not match between surveys and death records (Arias et al. 2008; Rogers et al. 1997; Sorlie et al. 1992). Since race/ethnicity is one of the items used to link the NHIS and the NDI, racial/ethnic discordance on the two records could lead to false ascertainment of a decedent as surviving, especially if other PII is missing or incorrect on either record.

Some researchers have suggested that the data quality issue among black older adults has improved over time since younger cohorts have better documentation of their date of birth and are therefore better able to accurately report their age. The oldest-old black adults in current mortality data sources were born in the late nineteenth and early twentieth century, when birth registration was incomplete in the United States and was particularly problematic for black births. Researchers point to the increase in the crossover age over time as evidence that age reporting among black adults may be improving (Kestenbaum 1992; Lynch et al. 2003; Masters 2012; Nam 1995). However, these improvements in age reporting among older black adults over time may be offset by reductions in survey participation and PII reporting by survey respondents (Brick and Williams 2013; Galea and Tracy 2007). NHIS nonresponse rates were 4.5 % in 1990 but rose to 17.8 % in 2009 (National Research Council 2013). Individuals' reasons for nonresponse include "too busy," "not interested/does not want to be bothered," "privacy concerns," and "interview takes too much time" (Bates et al. 2008). Among individuals who agree to participate in social surveys, willingness to provide PII has decreased over time. For example, among male NHIS respondents, SSN was missing for only 17 % of the 1986 sample but 72 % of respondents by 2004. The decline in SSN provision over time is similar among women (NCHS Office of Analysis and Epidemiology 2009). This decrease in SSN reporting is due in part to public concerns over identity theft (Dahlhamer and Cox 2007). Although increased accuracy in age reporting over time would likely improve estimates of mortality disparities (all else being equal), reductions in survey participation and PII reporting may diminish the quality of estimates.

Research Questions

This study assesses the presence of differential record linkage by race/ethnicity and the impact of racial/ethnic differences in linkage on estimates of mortality disparities. Analyses are guided by the following research questions:

1. Do indicators of record linkage quality (e.g., match class and match score) differ by race/ethnicity?
2. Do racial/ethnic differences in match score differ by age group?
3. Are estimates of black–white mortality disparities sensitive to alternative linkage scenarios?

4. Does the age at which black and white mortality rates cross over change when alternative linkage scenarios are used in place of the linkage criteria recommended by the NCHS?

Data and Methods

This study uses a special-request file of the 1986–2011 NHIS-LMF. The NHIS is a stratified, probabilistic survey of the US non-institutionalized civilian population. It has been conducted annually since 1957, allowing for multiple cross sections to be pooled to monitor health trends over time and to compile large samples of specific subpopulations, such as racial/ethnic minority groups. For years 1986 forward, NCHS has linked the NHIS to NDI death records to allow researchers to prospectively follow-up the vital status of NHIS respondents. The data used for the current study include respondents interviewed in years 1986–2009 and followed until 2011. NHIS records are probabilistically linked to NDI death records based on correspondence between thirteen items listed in both data sources: SSN, first name, middle initial, last name, birth month, birth day, birth year, father's surname, state of birth, state of residence, sex, race/ethnicity, and marital status.[1] NHIS records must meet one of three combinations of PII to be eligible for linkage. Potential matches are first identified based on seven criteria involving combinations of SSN, first and last name, middle initial, and date of birth. Then, an algorithm calculates match scores for each potential match to distinguish true matches from false matches. Match scores are the sum of weights assigned to each of the items on which records are matched. If the items agree for the potential match, the weight is positive; disagreement yields a negative weight. A higher match score indicates more items matching between the survey and death record.

Potential matches are then placed into one of five classes, based on the items on which they agree. Class 1 matches agree on at least eight digits of the SSN and first name, last name, middle initial, birth year (with an allowance of ± 3 years), birth month, sex, and state of birth. Class 2 matches agree on fewer items than class 1 matches; at least seven SSN digits and at least five additional items. Class 3 matches take two forms; either SSN is unknown but last name and at least seven items agree or SSN matches on six or fewer digits and at least eight other items agree. Potential matches classified as class 4 have unknown SSN on one of the records and fewer than eight of the items required for class 3 agree. Class 5 matches agree on fewer than seven SSN digits or agree on at least seven SSN digits but agree on fewer than five other items. The NDI linkage process may initially identify multiple potential death record matches for a survey, but only the single best match is included in the NHIS-LMF.

[1] The NCHS Office of Analysis and Epidemiology (2013) provides a detailed explanation of the NHIS-NDI linkage procedure. Harron et al. (2016) provide a more general discussion of record linkage methodologies.

All respondents placed into class 1 are considered deaths and all respondents placed into class 5 are considered survivors. For respondents in classes 2, 3, and 4, different cutoff match scores are used to ascertain vital status. The cutoff scores set by NCHS are 47 for class 2, 45 for class 3, and 40 for class 4. Respondents with a score greater than or equal to their class's cutoff score are considered deceased, and respondents with a score less than the cutoff score are considered survivors. These cutoff scores were chosen during the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study (NHEFS) to maximize correct identification of true matches while simultaneously minimizing false matches (NCHS 2009). However, such cutoff scores may not be most suitable among all subpopulations within the data. Ideally, all true survivors would have low match scores and be placed into class 5 and all true decedents would have high match scores and be placed into class 1. However, the entire score distribution and all five classes are populated with cases having varying degrees of match certainty. Analyses were conducted in Federal Statistical Research Data Centers because the variables match class and match score are restricted-use NHIS-LMF variables.

Race/ethnicity is measured as non-Hispanic black and non-Hispanic white. Respondents who identify as Hispanic or as a race other than black or white are excluded from the study. All analyses are stratified by sex due to sex differences in both linkage quality and mortality. Women experience a lower risk of mortality relative to men throughout the life course, and the female advantage in life expectancy at birth is larger among blacks relative to whites (Kochanek et al. 2016). A number of studies have documented more severe data quality issues in mortality data among women than men (Curb et al. 1985; Fenelon 2013; Preston et al. 1996). Unlike the public-use NHIS-LMF data, which top-code age at 85 years in recent survey years, the special-request file used for this study does not top-code age and thus allows observation of mortality among the oldest old, at the ages where black and white mortality rates purportedly cross over. Examination of match quality by age will reveal whether record linkage quality decreases with increasing age. The black–white mortality gap has been shown to be widest in early adulthood, to converge throughout midlife, and to cross over among the oldest-old (generally shown to occur at about age 85 years). If differential record linkage by race/ethnicity is problematic at select ages, it could bias estimates of black–white mortality disparities. Differential linkage may even account for black–white mortality convergence and crossover if linkage quality diminishes with age among black adults.

Analytic Approach

The first analytic stage involves estimating match class percentages, mean match class, and mean match score for black and white women and men, presented separately for the 243,984 decedents and 1,059,238 survivors identified by NCHS. In the second analytic stage, I predict mean score among decedents using ordinary least squares (OLS) regression. These OLS models adjust for race/ethnicity, age group (18–44, 45–64, 65–84, and 85+ years), and black-by-age group interactions to determine whether linkage quality decreases with age and whether the decrease is steeper among black adults relative to white adults. Models also adjust for survey year and a black-by-year interaction term to determine whether match quality patterns change over time and whether temporal changes differ by race/ethnicity, respectively. In these two analytic stages, I use survey procedures in SAS 9.2 software to estimate robust standard errors that account for the complex sampling design of the NHIS (SAS Institute 2011).

In the third analytic stage, I fit Poisson regression models with a log link function to estimate mortality rate ratios for black adults relative to white adults. I estimate sex-specific models for the four age groups and under three different linkage scenarios. Poisson models allow examination of whether individuals have survived or died during follow-up, as well as the timing of death. The quarter and year of interview, the quarter and year of death (if applicable), and the end date of follow-up are all known, so that models can accurately account for the duration of exposure until death or the end of the follow-up period. The individual-level data are transformed into a person-year file based on these dates of entry into the data and exit through death or end of follow-up. Respondents contribute half a person-year for the year of interview and year of death and one person-year for all intervening years and the final year of follow-up among respondents who survive through the end of 2011, resulting in 17,883,631 person-years of observation. The analyses with match score or match class as the dependent variable use individual-level data, and mortality analyses use person-year data.

I compare mortality rates and rate ratios for black adults relative to white adults using NCHS-recommended criteria (based on the NHEFS calibration study), a relaxed scenario (class-specific cutoff scores are decreased by five points), and a tightened scenario (class-specific cutoff scores are increased by five points) to demonstrate whether the black–white mortality disparity is sensitive or robust to changes in matching criteria.[2] Relaxing represents a more lenient scenario for determining a match and increases the total number of deaths since fewer items have to match between the survey and death record for a respondent to be considered a death during follow-up. Conversely, tightening represents a more stringent scenario for determining a match and reduces the total number of deaths since records have to match on more items to be considered a death. Coefficients are compared across models (Clogg et al. 1995) to test whether relaxing and tightening cutoff scores result in significantly different rate ratios.

In the final analytic step, I estimate coefficients for the effects of race/ethnicity and age on logged mortality rates using age in single years to determine whether the age of black–white mortality crossover for women and men changes when the class-specific cutoff scores are relaxed and tightened. A black-by-age interaction term allows age slopes to differ for black and white adults to identify the age at which black and white mortality rates cross under each linkage scenario. Because the crossover age is defined as the age at which black mortality rates equal white mortality rates, I estimate the crossover age by setting the black and white mortality functions equal to each other and solving for that precise age. In the mortality

[2] A five-point shift in class-specific cutoff scores is more subtle than the shifts by Liao et al. (1998) and is comparable to the four-point band used by NCHS staff in a sensitivity demonstration using the entire NHIS-LMF sample (NCHS Office of Analysis and Epidemiology 2009).

analyses, I use SUDAAN 11.0 software to account for the complex sampling design of the NHIS (Research Triangle Institute 2012).

All analyses are weighted using NHIS-LMF weights, which account for linkage ineligibility, to represent the non-institutionalized US adult population. Respondents who are ineligible for linkage are excluded from analyses. Figure 1 indicates that linkage eligibility remains reasonably high but decreased for a period of time, and a significantly greater proportion of black respondents than white respondents are ineligible for mortality follow-up from 1997 to 1999 and from 2002 to 2005. The rise in NHIS respondents' refusal to report SSN bears some responsibility for reduced linkage eligibility in the NHIS-LMF. This problem prompted NCHS to request fewer digits of respondents' SSN (e.g., the last four digits) when respondents refuse to provide their complete nine-digit SSN (Dahlhamer et al. 2006). This change is likely responsible for reversing the decline in linkage eligibility among NHIS respondents for years 2006 forward. NHIS-LMF data users should note this black–white difference in eligibility as an additional level of differential data quality since a higher proportion of ineligible black adults than white adults are excluded from vital status follow-up.

Results

Table 1 presents match class percentages, mean match class, and mean match score for black and white women and men, presented separately for NCHS-identified decedents and survivors. The top panel shows black–white differences in class and score among

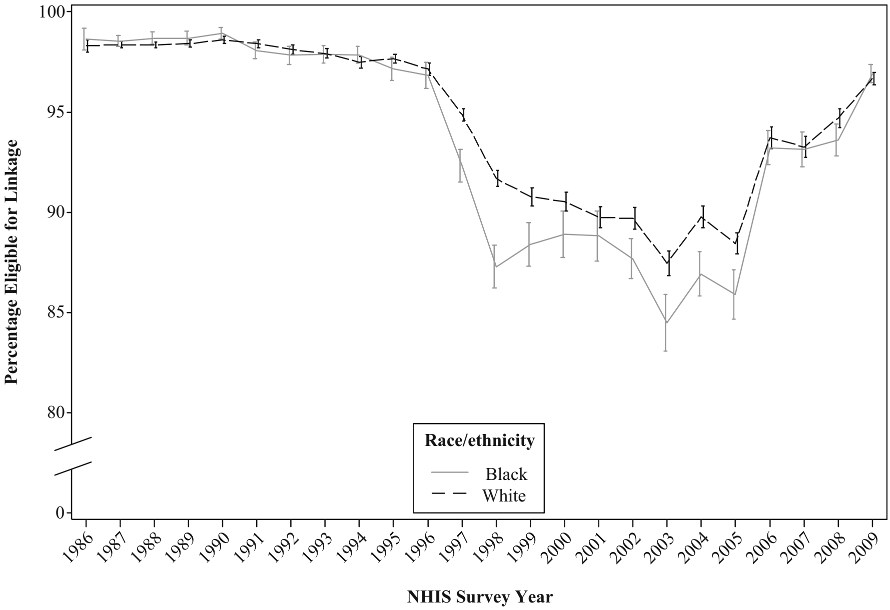

Fig. 1 Black–white differences in linkage eligibility (sex-combined data, with 95 % confidence intervals)

Table 1 Match class and match score distributions by race/ethnicity and sex, US adults ages 18+. Source 1986–2011 NHIS-LMF

	Female		Male	
	Black	White	Black	White
Decedents	20,198	104,240	17,738	101,808
Class (%)				
1	50.79 (49.74, 51.84)	59.35 (58.78, 59.93)	54.10 (52.83, 55.38)	65.79 (65.17, 66.40)
2	18.65 (17.90, 19.39)	15.35 (15.00, 15.70)	13.16 (12.57, 13.75)	8.94 (8.71, 9.16)
3	24.92 (23.93, 25.92)	21.95 (21.46, 22.44)	27.59 (26.53, 28.65)	22.43 (21.90, 22.96)
4	5.64 (5.25, 6.04)	3.34 (3.19, 3.49)	5.15 (4.73, 5.56)	2.84 (2.70, 2.98)
Mean class	1.85 (1.83, 1.88)	1.69 (1.68, 1.70)	1.84 (1.81, 1.86)	1.62 (1.61, 1.64)
Mean score	78.02 (77.62, 78.42)	79.16 (78.95, 79.37)	77.83 (77.38, 78.29)	80.94 (80.72, 81.16)
Survivors	103,040	470,210	70,227	415,761
Class (%)				
2	0.05 (0.03, 0.07)	0.07 (0.06, 0.07)	0.10 (0.07, 0.12)	0.07 (0.07, 0.08)
3	0.53 (0.48, 0.57)	0.42 (0.40, 0.44)	2.10 (1.97, 2.23)	1.34 (1.30, 1.39)
4	41.59 (41.03, 42.15)	31.12 (30.87, 31.38)	43.88 (43.31, 44.45)	32.36 (32.09, 32.63)
5	57.83 (57.27, 58.40)	68.39 (68.13, 68.65)	53.92 (53.34, 54.51)	66.23 (65.94, 66.51)
Mean class	4.57 (4.57, 4.58)	4.68 (4.68, 4.68)	4.52 (4.51, 4.52)	4.65 (4.64, 4.65)
Mean score	−1.58 (−1.87, −1.29)	−4.72 (−4.90, −4.54)	3.12 (2.84, 3.40)	−0.28 (−0.48, −0.09)

Percentages and means are weighted, and counts of deaths and survivors are unweighted. 95 % confidence intervals are listed in parentheses for percentages and means respondents identified as having died during follow-up. Recall that among decedents, a high score and placement into class 1 indicate better matches. For both women and men, white decedents have higher mean scores than black decedents. A greater proportion of white decedents than black decedents are placed into class 1 (characterized as more certain matches), and a greater proportion of black decedents than white decedents are placed into classes 2–4 (characterized as less certain matches).

The bottom panel of Table 1 shows mean score and class distribution among respondents identified as having survived the follow-up period. Recall that among survivors, the best non-matches have a low score and are placed into class 5. A significantly higher percentage of white survivors than black survivors are placed into class 5; the racial/ethnic difference is 10.56 % points among women and 12.31 % points among men. Black survivors have higher scores on average than their white counterparts, showing that, as among decedents, identification of black adults as surviving the follow-up period is generally less certain than white adults. Thus, for both decedents and survivors, match quality for black adults tends to be worse relative to white adults.

After establishing that linkages are less certain among black adults than among white adults in the overall sample, I examine age patterns of black–white differential record linkage. Table 2 presents coefficients from sex-specific

Table 2 OLS regression of match score on race/ethnicity and age among decedents, US adults ages 18+. Source 1986–2011 NHIS-LMF

	Female	Male
Intercept	83.56***	83.43***
	(0.28)	(0.26)
Black (ref: white)	−0.92*	−4.00***
	(0.46)	(0.50)
Age group (ref: 18–44)		
45–64	0.90***	2.31***
	(0.27)	(0.21)
65–84	−1.21***	3.32***
	(0.25)	(0.20)
85+	−3.54***	3.36***
	(0.28)	(0.31)
Black × age group		
Black × 45–64	−0.09	1.10*
	(0.50)	(0.47)
Black × 65–84	−1.01*	0.72
	(0.47)	(0.47)
Black × 85+	−1.75*	−0.80
	(0.68)	(0.96)
Year	−0.53***	−0.73***
	(0.02)	(0.02)
Black × year	0.02	0.10**
	(0.03)	(0.03)
N	124,438	119,546
R^2	0.0386	0.0612

* $p < .05$, ** $p < .01$, *** $p < .001$. Standard errors are listed in parentheses. *Year* is recoded as year of interview minus 1986. Match class is not included in the multivariate analysis given its high correlation with match score ($r = -0.94$)

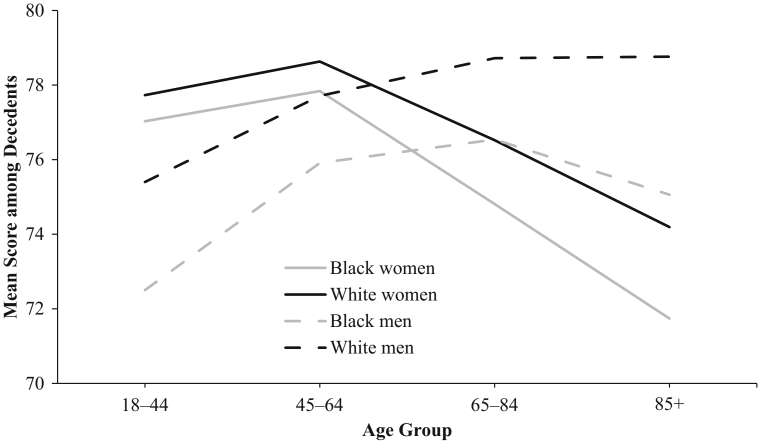

Fig. 2 Predicted mean match scores among decedents, by race/ethnicity, sex, and age group

multivariate OLS regression models predicting mean match score among decedents. As illustrated with predicted values in Fig. 2, mean score varies by age group among each sex and racial/ethnic subgroup.[3] Among women, mean score is lower among the 65–84 and 85+ year age groups than the 18–44 year old reference group. The black-by-age group interaction terms are negative and significant among women for the 65–84 and 85+ age groups, indicating that the age gradient is steeper among black women than white women at ages 65 and older, and the black–white match score gap increases with age. While match score decreases with age among women, match score increases with age among men; compared with the youngest male group, white male scores are 2.31, 3.32, and 3.36 points higher among the 45–64, 65–84, and 85+ age groups, respectively. Black and white mean scores among men converge somewhat for the 45–64 year age group, then black-by-age group interaction terms are not significant among men for the 65–84 and 85+ age groups. In other words, the black–white difference in match score among men is just as wide in early adulthood as in later adulthood, the stage of the life course for which data is assumed to be most problematic among black adults. As a result of the age-related declines in match score among women, mean match score is higher among women than men in the 18–44 year age group but lower among women than men in the 85+ age group.

Consistent with the finding that linkage eligibility decreases over time, the coefficients for survey year in Table 2 indicate that match score among decedents decreases over time. Among women, match score decreases by 0.53 points per year. Match score decreases by 0.73 points per year among white men, with a less steep decline among black men. These coefficients do not seem substantial on the surface,

[3] Mean match scores in Fig. 2 are predicted from the coefficients in Table 2. Since the variable *Year* in the model equals the year of interview minus 1986, *Year* is set to a value of 11 to correspond with 1997, the midpoint of the 1986–2009 NHIS period.

but they are concerning when one realizes that they represent the annual decrease in match score over a 24-year period.[4]

Since record linkage is more certain among white adults than among black adults, and many matches for both racial/ethnic groups have score and class values indicative of uncertain linkage quality, I investigate whether black–white mortality disparities are sensitive to modification of the cutoff scores. The top panel of Table 3 presents rate ratios of black mortality risk relative to white mortality risk in the four age groups using NCHS-recommended cutoff scores. Then, for black respondents whose matches are assigned to classes 2–4, the class-specific cutoff scores are relaxed (i.e., decreased by five points) and tightened (i.e., increased by five points) to determine whether the rate ratios increase, decrease, or remain constant under alternative linkage scenarios. Vital status of class 1 and class 5 respondents does not change in the sensitivity analyses since their classes do not have cutoff scores; all class 1 matches remain deaths and all class 5 matches remain survivors. However, vital status changes for some matches in classes 2–4. Cutoff scores are not relaxed or tightened for white adults since match quality is more certain among white adults.

Relative risk ratios using the NCHS linkage criteria echo racial/ethnic mortality disparities observed in previous studies; black mortality risk is more than twice as high as white mortality risk among young adults. Then rates converge with increasing age until mortality rates are significantly lower among black adults than among white adults at ages 85 years and older. Risk ratios of black mortality relative to white mortality increase somewhat when cutoff scores are relaxed but the difference is only significant for the 45–64 year age group among both men and women. Tightening leads to lower relative risk ratios than with NCHS cutoff scores, with significant differences among women ages 65 years and older and men ages 18–64 years. Although risk ratios vary when cutoff scores are relaxed and tightened, black adults are still characterized by a mortality disadvantage relative to white adults up to age 84 years and a mortality advantage for the 85+ age group.

Finally, in the bottom panel of Table 3, Poisson models predicting single-year age-specific mortality rates investigate whether the age at black–white mortality crossover is sensitive to relaxing and tightening of the cutoff scores. The positive black coefficients indicate a higher mortality rate among black adults relative to white adults at the baseline age of 18 years.[5] The negative black-by-age interaction term indicates a shallower age gradient of mortality risk among black adults than among white adults such that the racial/ethnic mortality rate gap narrows with increasing age. The age at crossover is 84.3 years among women and 86.9 years

[4] In supplemental analyses, I include a $Year^2$ term to determine whether match score decreases, reaches a minimum, and then increases over time, as is observed with linkage eligibility. The $Year^2$ term indicates a non-linear time trend, but with match score among decedents continuing to decline throughout the study period. Because the overall time trend does not change, I drop $Year^2$ from the model in favor of the more parsimonious model.

[5] I subtract 18 from age so that the black main effect represents the relative black–white mortality disparity at age 18 years. The black-by-age intercept term and age coefficients do not change with relaxing and tightening because the cutoff scores are adjusted for black adults only. Respondents with relaxed cutoff scores who switch from survivors to deaths during follow-up are assigned 2011 (the final year of mortality follow-up) as their year of death.

Table 3 Association between race/ethnicity and mortality using three linkage criteria, US adults ages 18+. Source 1986–2011 NHIS-LMF

	Female			Male		
	Relaxed	NCHS	Tightened	Relaxed	NCHS	Tightened
Black–white relative risk ratios (ref: white)						
Age group						
18–44	2.30	2.07	1.86	2.25	2.02	1.75†
	(0.0358)	(0.0372)	(0.0391)	(0.0342)	(0.0353)	(0.0357)
45–64	2.02†	1.77	1.66	2.04†	1.74	1.59†
	(0.0207)	(0.0215)	(0.0215)	(0.0194)	(0.0202)	(0.0203)
65–84	1.30	1.25	1.17†	1.37	1.30	1.22
	(0.0133)	(0.0134)	(0.0132)	(0.0145)	(0.0149)	(0.0152)
85+	0.88	0.85	0.72†	0.90	0.86	0.72
	(0.0196)	(0.0201)	(0.0209)	(0.0270)	(0.0282)	(0.0299)
Logged mortality rate coefficients						
Intercept	−10.7689	−10.7689	−10.7689	−10.1560	−10.1560	−10.1560
	(0.0207)	(0.0207)	(0.0207)	(0.0172)	(0.0172)	(0.0172)
Age	0.0916	0.0916	0.0916	0.0880	0.0880	0.0880
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Black (ref: white)	1.4192†	1.2470	1.2783	1.3602†	1.1719	1.1127
	(0.0341)	(0.0353)	(0.0357)	(0.0361)	(0.0381)	(0.0388)
Black × age	−0.0208†	−0.0188	−0.0211†	−0.0190	−0.0170	−0.0178
	(0.0006)	(0.0006)	(0.0007)	(0.0007)	(0.0008)	(0.0008)
Crossover age (years)	86.2	84.3	78.6	89.6	86.9	80.5
Deaths	125,719	124,438	123,281	121,105	119,546	118,466
Person-years	9,673,949	9,674,590	9,684,285	8,208,262	8,209,042	8,218,242

All risk ratios in the top panel are statistically different from 1.0 and all rate coefficients in the bottom panel are significantly different from zero at $p < .001$. Daggers indicate significant differences in coefficients across models, as determined using the Clogg et al. (1995) method († $p < .05$). "NCHS" indicates class-specific cutoff scores recommended by NCHS. "Relaxed" indicates class-specific cutoff scores are decreased by five points among black adults. "Tightened" indicates class-specific cutoff scores are increased by five points among black adults. Standard errors are listed below relative risk ratios and rate coefficients

among men when the NCHS-recommended cutoff scores are used, consistent with the crossover age estimated in prior studies. Relaxing the cutoff scores increases the crossover age to a later age by 1.9 years among women and 2.7 years among men. With tightened cutoff scores, the crossover occurs at an earlier age; 78.6 years among women and 80.5 years among men, about 6 years earlier than with the NCHS cutoff scores. Thus, the age at black–white mortality crossover is somewhat sensitive to adjustment of the cutoff scores, but the crossover continues to be observed under each linkage scenario.

Discussion

Research on racial/ethnic disparities in adult mortality has established greater mortality risk among black adults relative to white adults throughout much of the life course, and debate continues regarding the existence and explanations of the black–white mortality crossover. Yet the accuracy of estimates of racial/ethnic mortality disparities, particularly at older ages, is compromised by data quality issues. While biases in race/ethnicity-specific mortality estimates are well documented in official death rates comprised death certificate counts in the numerator and census estimates in the denominator, the issue of differential record linkage by race/ethnicity in survey-linked mortality data has received less attention to date. This study addresses whether record linkage is less certain among black adults relative to white adults and whether estimates of black–white mortality disparities are sensitive to alternative matching scenarios.

Results show that record linkage indeed differs by race/ethnicity. Black adults exhibit worse linkage quality than white adults among both women and men. Black decedents have lower mean match scores and are less likely to be classified in class 1 (i.e., near exact matches) relative to white decedents, indicating that record linkage is poorer among black decedents relative to their white counterparts. Similarly, black survivors have higher match scores and are less likely to be classified in class 5 relative to whites, indicating that record linkage is less certain among black survivors relative to white survivors as well. Although the magnitude of the black–white gap in match score among decedents varies by sex and age, lower match quality is exhibited among black adults for all age groups.

Next, I assess whether black–white mortality disparities are sensitive to relaxing and tightening of NCHS-recommended cutoff scores. Although relaxing and tightening cutoff scores lead to some instability in estimates of the black–white mortality disparity, the mortality crossover is observed under each matching scenario. In sum, estimates of black–white disparities in adult mortality risk calculated using NHIS-LMF data are robust to the issue of differential record linkage. The substantive interpretation of the black–white mortality crossover as reflecting selective survival and the subsequent different frailty compositions by race/ethnicity at older ages—as opposed to the data artifact interpretation—continues to receive empirical support. At the same time, linkage quality is worse among black adults than white adults and linkage quality overall is decreasing across time, as indicated by reductions in match score among decedents and a temporary decrease in eligibility for follow-up.

Sensitivity analyses show that the age of the black–white mortality crossover increases by about 2 years when cutoff match scores are relaxed (i.e., the lenient scenario) and decreases by about 6 years when cutoff scores are tightened (i.e., the stringent scenario), relative to the crossover age when using NCHS-recommended criteria. These results provide evidence that black–white mortality convergence and crossover is not a data artifact, as has been suggested by others. Most notably, Preston and colleagues (1996) suggested that adjusting for poorer data quality among black older adults relative to white older adults eliminates the crossover. Instead, results from the relaxed scenario resemble those of Hill et al. (2000) and

Lynch et al. (2003), who found that after adjusting for data quality issues, the crossover remains but occurs at a later age than found using unadjusted data. If the matching algorithm misses some deaths among black respondents, then the relaxed ratios and coefficients may provide a more accurate black mortality profile. This possibility does not bode well for black adults since the black adult mortality estimates under the relaxed scenario are generally worse than with the NCHS match criteria. The finding that tightening cutoff scores decreases the crossover age is similar to Masters' (2012) findings, in which the black–white mortality crossover age declines with the exclusion of NHIS-LMF respondents with characteristics believed to be associated with poorer linkage (e.g., missing birth date, missing educational attainment, proxy response, and age greater than 75 years at interview). Whereas Masters excluded these questionable cases, I include them but allow vital status to vary for some cases with match scores near the class-specific cutoff scores.

Missing and inaccurate PII have become serious issues that must be addressed in order for the NHIS-LMF to remain a leading data source for research on US mortality disparities. The rise in NHIS respondents' refusal to report SSN likely bears some responsibility for reduced match quality and linkage eligibility in the NHIS-LMF. One solution implemented by NCHS is to request fewer digits of respondents' SSN (e.g., the last four digits) when respondents refuse to provide their complete nine-digit SSN (Dahlhamer et al. 2006). This change has reversed the decline in SSN provision among NHIS respondents after 2006 (Miller 2012). Another potential strategy to improve record linkage between the NHIS and NDI among subpopulations could involve active follow-up (i.e., recontacting the respondent or contacting a surviving family member) of the matches with scores closest to their class's cutoff score rather than relying solely on passive follow-up through NDI record linkage. Although active follow-up of the entire NHIS-LMF sample would be prohibitively difficult given the large size of the dataset, active follow-up of the small subset of cases concentrated nearest to the class-specific cutoff scores may be reasonable. Another strategy could involve conducting a calibration study similar to the original NHEFS, but with an emphasis on racial/ethnic minority respondents who are characterized by poorer linkage quality. This exercise would determine whether the cutoff scores used to ascertain vital status are appropriate for all racial/ethnic, sex, and age groups. If it is found that the cutoff scores do not perform equally well for all groups, a set of best practice cutoff scores can be developed for population subgroups.

Limitations

Readers should be mindful of a few important limitations to this study. Although I find that surveys and death records match on less PII among black adults than among white adults, I cannot identify which items are responsible. The special-request file of the NHIS-LMF data used for this study includes match score and match class but not the personal identifiers reported on NHIS surveys and death records to maximize data access while protecting the confidentiality of NHIS respondents (Data Linkage Team 2015; Harron et al. 2012). Therefore, I do not examine the exact items responsible for yielding differential match score and match class distributions by race/ethnicity. Additionally, although this study examines adult mortality, black–white disparities are also substantial in infancy (Frisbie et al. 2010) and in childhood and adolescence (Kochanek et al. 2016). Finally, as a household-based survey, the NHIS is representative of the non-institutionalized civilian US population. Institutionalized individuals are not eligible for interview, but NHIS respondents who become institutionalized during follow-up can still be matched to their death record. This survey design leads to differences in sample inclusion by race/ethnicity due to disproportionate rates of incarceration (particularly among young men) and nursing home residence among older adults (Pettit 2012; Wang et al. 2014). Future research may identify adjustments for this data issue so that survey-based data can accurately estimate health disparities and identify the routes to eliminating such disparities among both institutionalized and non-institutionalized populations.

Conclusions

Survey-linked mortality data offer unique opportunities for studying black–white mortality disparities given their large samples of black and white respondents, self-reports of race and ethnicity, and detailed measurement of socioeconomic and behavioral characteristics that partially account for racial/ethnic health disparities. However, differential record linkage may bias mortality estimates in ways that are not yet well documented and understood. Therefore, researchers must investigate and acknowledge both the strengths and weaknesses of this form of data, exercise caution when interpreting mortality estimates for racial/ethnic minority groups characterized by data quality concerns, and pursue additional research that expands on this study’s findings to further document the extent to which racial/ethnic groups experience reduced data quality issues and how these issues impact estimates of mortality disparities.

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