Regional Differences in the Estimation of Influenza Burden in the Elderly: Does Choice of Population Denominator Matter?

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Abstract

Proper estimation of a population denominator is critical to many longitudinal epidemiological studies, though many researchers often overlook this. The objective of this study is to determine the sensitivity of age-specific influenza-related hospitalization rates in the elderly to the choice of four population denominators: Medicare denominator files, decennial census, linearly interpolated from decennial censuses, intercensal estimates, and the Centers for Medicare and Medicaid Services (CMS). We abstracted 14 million hospitalization claims from the Centers for Medicare and Medicaid Services for the period 1992-2004 by age and influenza season and applied each of the three denominators to the total hospitalizations by census region, state, and race. We found large discrepancies in the rates using the difference denominators, especially comparing Census 2000 to intercensal estimates. These discrepancies differed by region and race. Our findings underscore the need to account for population dynamics that may play a role in spatiotemporal disease distribution in longitudinal studies.

Introduction

Public health, epidemiology, and demography are inseparable disciplines. Disease processes are inherently linked to population dynamics that can play an important role in the magnitude and scope of disease distribution. The objective of many population-based public health studies is to estimate a disease incidence or prevalence, both of which consist of a numerator, a function of the number of cases in a given time frame and area, and a denominator, the population at risk of the disease or condition. Many epidemiological studies focus on the proper estimation of the numerator, and afford relatively less attention to the appropriateness and accuracy of the denominator.

Population dynamics should be taken into account to properly assess population-level disease trends over time and space. The potential for changes in population characteristics over time are not often assessed and included in the design of many population-level public health studies.[1] Assessing these dynamics becomes even more important when risk-factor based methods cannot fully explain disease trends and patterns.

In studies of the elderly, this issue is especially important, given the rapid changes occurring in this population subgroup as a result of population aging. The elderly population in many developed countries, such as the United States, is experiencing a number of changes resulting in rapid population change. The human life span and life expectancies have increased steadily over the past century, and are expected to continue increasing.[2] The result of this increase is that people are living longer, but not necessarily healthier. Since disease incidence increases rapidly with age in the elderly population, [3] the increase in life expectancy and life span intimates a greater number of elderly people living longer, but often with more disease, questioning the notion of the recent trend toward compression of morbidity at older ages.[4] Compressing morbidity ultimately depends upon the difference in the rates of increases between life expectancy and healthy life expectancy. Even if both overall and healthy life expectancy increase at the same rate over time, the difference between the two would result in a diseased population at the end of life that becomes older and older. As this occurs, simply by virtue of being older, this "unhealthy" population would be more prone to disease. Thus, the proper characterization of age-related disease patterns and populations is crucial for the timely and accurate targeting of economic and public health programs and policies designed to protect the elderly and extend life, particularly healthy life, for as long as possible.

Census data is used in a variety of forms to serve as the population denominator, some static, others dynamic. For example, in the literature related to influenza research, several longitudinal population-based studies have employed US Census estimates for individual intercensal years.[5,6] However, in some longitudinal influenza studies, researchers examined unadjusted numbers of influenza cases over time, which does not account for population change may have played a role in causing numbers of cases to increase or decrease over time.[7] This is analogous to using data from one census and applying that population longitudinally, as is done in some studies in other disciplines. Other influenza studies were performed involving population estimates mentioned the use of Census data, but did not specify which data was used, for example, decennial census data, intercensal estimates, linearly interpolated data, etc…[8,9]

The use of Medicare denominator files containing a wide range of demographic information in conjunction with Medicare claims and hospitalization records is somewhat common in epidemiological and public health studies. However, Medicare denominators have not been widely used in demographic studies of the elderly, despite its utility and coverage of the older US population.

An important issue to address in the comparison of population denominator data sources is the issue of race and ethnicity. Race or ethnicity is often a primary exposure of interest in many public health studies. For example, some public health research from 2008 has examined race as an independent risk factor in opioid prescription patterns,[10] obesity in children,[11] and depression,[12] among many others. Research on racial disparities in the medical and public health literature are common. Over the past 60 days, PubMed reported that 71 studies were published that have examined racial disparities on a variety of outcomes, including vaccination requirements for school entry[13] and kidney disease.[14] Racial and ethnic differences in fertility, mortality, and migration are also important in many population-based demographic studies. Recent demographic research has demonstrated key racial and ethnic differences in perinatal outcomes and pregnancy spacing,[15] infant mortality,[16] and premature mortality,[17] among others.

However, for a myriad of reasons, accurate and precise characterization of race and ethnicity is often difficult to achieve, particularly when using Census data. Collecting racial and ethnic data and its use in epidemiological and demographic studies has, in itself, been a subject of controversy.[18] Nonetheless, this data is still collected and used in a variety of settings. In order to obtain a more precise and comprehensive knowledge of the racial and ethnic makeup of individuals and the population, the US Census Bureau changed its methodology for assessing race between Census 1990 and Census 2000 and subsequent surveys. One such major change for the 2000 census was adding the instruction "Mark [X] one or more races to indicate what this person considers himself/herself to be." In comparison, the same question in the 1990 census form instructed respondents to "Fill ONE circle for the race that the person considers himself/herself to be." In addition, Asian and Pacific Islanders were split into two groups in the 2000 census forms, whereas Alaska Native and American Indian were combined to make one category in the 2000 census.[19] In the longitudinal study of disease trends, for example, this change in the manner in which racial and ethnic data was collected carries the potential for severe implications for public health and demographic research, especially those using Census-based population counts for studies of the US population.[20-21]

The history and development of race and ethnicity codes in CMS, formerly known as the Health Care Financing Administration (HCFA), is somewhat different than that of the US Census Bureau. Before 1994, HCFA coded Medicare enrollees by race using four race categories: White, Black, other, or unknown. The limitations and inconsistencies between this data and data from other federal and local agencies was apparent to HCFA and in 1994, three additional race codes were added: Asian (including Pacific Islander), Hispanic, and American Indian and Alaskan Native,[22] which were still not entirely consistent with the 1990 or 2000 US Census categorization of race. Coding of race in Medicare data, even with the expanded number of categories, was still not highly accurate for individual beneficiaries. A 2004 study compared Medicare categorization of race in the Medicare database to the results of the Medicare Current Beneficiary Survey and found that the accuracy of coding was high for Whites and Blacks, substantially lower for Asians, and extremely low for North American Natives.[23] A closer examination of trends and patterns of coding for race and ethnicity is essential for the proper estimation of racial and ethnic group disease rates and demographic patterns. Selection of the most appropriate denominator is critical to this understanding.

The objective of this descriptive study is to compare four different population-based denominators—Census 2000, Census intercensal estimates, linearly interpolated Census data, and Medicare denominator files—on the measurement of age-specific population size in the elderly population and apply these findings to estimate influenza and influenza-related hospitalization incidence in the United States elderly by region and race. Particular attention is paid to the relationships between Medicare denominator and Census-based data.

Methods

Data Sources

The total numbers of influenza-related hospitalizations were abstracted from the Centers for Medicare and Medicaid Services (CMS) from the US Department of Health and Human Services. Approximately 14 million hospitalization records were used in the analysis. Data were available for the population age 65 through 84 for the influenza seasons 1992-93 through 2003-04. Total numbers of cases were obtained by state, single year of age, and influenza season, defined as July 1 through June 30 of the following year, since influenza tends to peak in the winter months.[24]

The four denominators of study—population counts by single year of age and year—were obtained from the US Census Bureau and CMS. The first denominator was taken directly from Census 2000 and applied to all years of the study (1991 through 2003). The second denominator consisted of single-year of age and influenza season population counts that were interpolated or extrapolated from two US censuses, 1990 and 2000, and applied to all years in the study period. The third denominator file was obtained from the Population Estimates Program (PEP) of the US Census Bureau. PEP produces population estimates for individual years and single years of age for individuals age 65 and above. According to the US Census Bureau, some of the applications of these estimates include federal funding allocations, denominators for per capita time series, as survey controls, in monitoring recent demographic changes, and, as in the case of this study, as denominators for vital rates.[25] Because they are not based on a population-level census, they may be subject to error and bias.

The fourth and final denominator utilized in this study was derived from Medicare beneficiaries denominator files for twelve of the thirteen years of study—1991 through 2002. This file contains data on all Medicare beneficiaries enrolled and/or entitled in a given year and is an abbreviated version of the Enrollment Data Base. However, the Denominator File does not contain data on all beneficiaries ever entitled to Medicare. The file contains data only for beneficiaries who were entitled during the year of the data.[26]

From these four denominator files, the total number of cases in each region, year, age, and race, where appropriate, was divided by the corresponding population to obtain influenza-related hospitalization incidence for each denominator. The population age 98 and above was excluded from the analysis of Medicare data because, for most years, those above age 98 and above were categorized as 98 exactly, resulting in an overestimate of those age 98, and underestimating the population above age 98.

Data Analysis

This study was designed as a descriptive assessment of these four data sources to look at discrepancies among them overall, and with respect to age, year, region, and race/ethnicity. These rates were then applied on the national level to determine how different population denominators produce discrepancies in national estimates of influenza and pneumonia disease in the vulnerable elderly population. All data analysis was performed using SAS v. 9.0 (Cary, NC) and SPSS v. 15.0 (Chicago, IL). Graphics were produced in SPSS v. 15.0 and Microsoft Excel.

National Data

On the national level, population counts in the population age 65 to 97 were estimated from each of the four data sources for the years 1991 through 2003, where available by single year of age for each individual year of study. Next, percent differences between each of the four measures were calculated for each age- and year-specific population. In all, five comparisons were calculated: Census 2000-CMS, Census 2000-PEP, PEP-CMS, CMS-Linear Interpolation, and PEP-Linear Interpolation (Table 1). The sixth comparison, Census 2000-Linear Interpolation, was omitted from this analysis because the linearly interpolated data is simply a function of the population sizes between Census 1990 and Census 2000. Percent differences between each of the comparisons were summarized and graphed for the national population on the whole.

Table 1: Specific comparisons of data sources by age and year performed on the national level

	Census 2000	Linear Interpolation	Intercensal Estimates (PEP)
Intercensal Estimates (PEP)	X	X	
Medicare (CMS)	X	X	X

Regional Comparisons

The above technique was repeated for the five comparisons of interest for each of the four Census regions of the contiguous United States- Midwest, Northeast, South, and West. Population counts were tabulated on the regional level overall and by single year of age and year of study. Percent differences between each of the data sources were also calculated, both overall and for single years of age. These percentage differences were likewise summarized and graphed to illustrate differences among these data sources for population counts by region.

Racial and Ethnic Comparisons

Racial and ethnic discrepancies in age-specific population size were assessed at the national level. The comparison of interest was between CMS and Census 2000, which is commonly used in longitudinal studies of disease, as described above. Medicare data was graphed for each race/ethnic group for the national population age 65 to 97 for the time period 1991 through 2002 by single year of age and calendar year. The percent differences between these and analogous population counts abstracted from Census 2000 were calculated, summarized, and graphed only for those races for which data from both sources was available.

Results

Annual population counts for the US population age 65 and above from each of the four data sources are displayed in Table 2. In general, the population increased from 1991 to 2003, irrespective of data source. The largest relative increase occurred in the 85+ population, which increased from 1991 to 2003 46% using linear interpolation and 48%

Table 2: Annual population counts from four data sources, Census 2000, linearly interpolated data, intercensal estimates (PEP), and Medicare (CMS), by age and Census region

		1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
Overall	Census 2000										35027211			
	Linear Interpolation	31586762	31969034	32351306	32733578	33115850	33498123	33880395	34262667	34644939	35027211	35409483	35791755	36174027
	Pop. Estimates	31740782	32256088	32772814	33168046	33575397	33911898	34138796	34337032	34490337	35027211	35280111	35540164	35901742
	CMS	30541971	31035899	31548633	31925398	32235086	32559935	32789628	33003817	33137319	33367101	33565322	33755865	
65-74	Census 2000										18369819			
	Linear Interpolation	18126557	18153586	18180615	18207644	18234674	18261703	18288732	18315761	18342790	18369819	18396848	18423877	18450906
	Pop. Estimates	18270480	18442615	18629548	18702982	18756523	18690093	18527687	18389968	18218248	18369819	18324208	18286189	18355282
	CMS	17464330	17645982	17842501	17922771	17981590	17953609	17798769	17694961	17530637	17479790	17438377	17412571	
75-84	Census 2000										12422268			
	Linear Interpolation	10315943	10549979	10784015	11018051	11252088	11486124	11720160	11954196	12188232	12422268	12656304	12890340	13124376
	Pop. Estimates	10319218	10538090	10738119	10945025	11178192	11466603	11744353	11946246	12146695	12422268	12590807	12761114	12886772
	CMS	9873986	10073109	10262283	10459005	10614770	10874310	11168579	11375777	11579088	11772374	11938738	12087522	
85+	Census 2000										4171270			
	Linear Interpolation	3096648	3216050	3335453	3454855	3574258	3693660	3813063	3932465	4051868	4171270	4290672	4410075	4529477
	Pop. Estimates	3103366	3225808	3353638	3466824	3585667	3698483	3808374	3940435	4063155	4171270	4299311	4425180	4589522
	CMS	3085225	3188042	3305965	3401521	3487845	3574757	3658528	3759911	3845242	3928066	3994663	4059011	
Midwest	Census 2000										8223852			
	Linear Interpolation	7771087	7821394	7871701	7922008	7972316	8223853	8072930	8123237	8173545	8223852	8274159	8324467	8374774
	Pop. Estimates	7818616	7913799	8001597	8055086	8115325	8223854	8151165	8157340	8152089	8223852	8239090	8250517	8292859
	CMS	7634839	7725896	7818459	7871278	7910442	8223855	7960510	7972326	7961929	7972911	7981013	7992276	
Northeast	Census 2000										7343774			
	Linear Interpolation	6985604	7025400	7065197	7104994	7144791	7184587	7224384	7264181	7303977	7343774	7383571	7423367	7463164
	Pop. Estimates	7023267	7098323	7169224	7207741	7251905	7274304	7272541	7278106	7275713	7343774	7346701	7354470	7370535
	CMS	6790862	6861193	6929407	6967694	6993966	7013900	7017545	7020689	7014334	7021351	7013770	7007660	
South	Census 2000										12419945			
	Linear Interpolation	10865167	11037920	11210673	11383426	11556179	11728933	11901686	12074439	12247192	12419945	12592698	12765451	12938204
	Pop. Estimates	10905222	11105111	11311006	11484148	11647796	11803016	11926601	12019314	12098010	12419945	12545742	12675866	12847989
	CMS	10344454	10537368	10747857	10918453	11050657	11201414	11316539	11423302	11498070	11610473	11717181	11816898	
West	Census 2000										6922366			
	Linear Interpolation	5877474	5993573	6109673	6225772	6341871	6457970	6574069	6690168	6806267	6922366	7038465	7154564	7270663
	Pop. Estimates	5906055	6047820	6196397	6323346	6459341	6584100	6681273	6771381	6850223	6922366	7027753	7135003	7261491
	CMS	5611234	5737953	5867985	5976605	6080569	6194328	6282873	6360151	6429346	6521006	6608032	6690601	

using intercensal population estimates. The population age 85+ increased approximately 32% between 1991 and 2002 in Medicare enrollees. The West and South regions also experienced the greatest increases in elderly population size over this period. The Medicare population counts were consistently lower than both the linearly interpolated and the intercensal population estimates for all ages and regions.

The single year of age-specific counts for Census 2000, and single year of age-specific counts by calendar year for Medicare and intercensal estimates population counts are shown in Figure 1. These data illustrate some of the overarching trends and patterns in the elderly population. Overall increases in population size with time across most age groups can be observed by looking at each horizontal region of the graph, with slight decreases in the youngest elderly in the intercensal estimates. Figure 2 shows the same data by region.

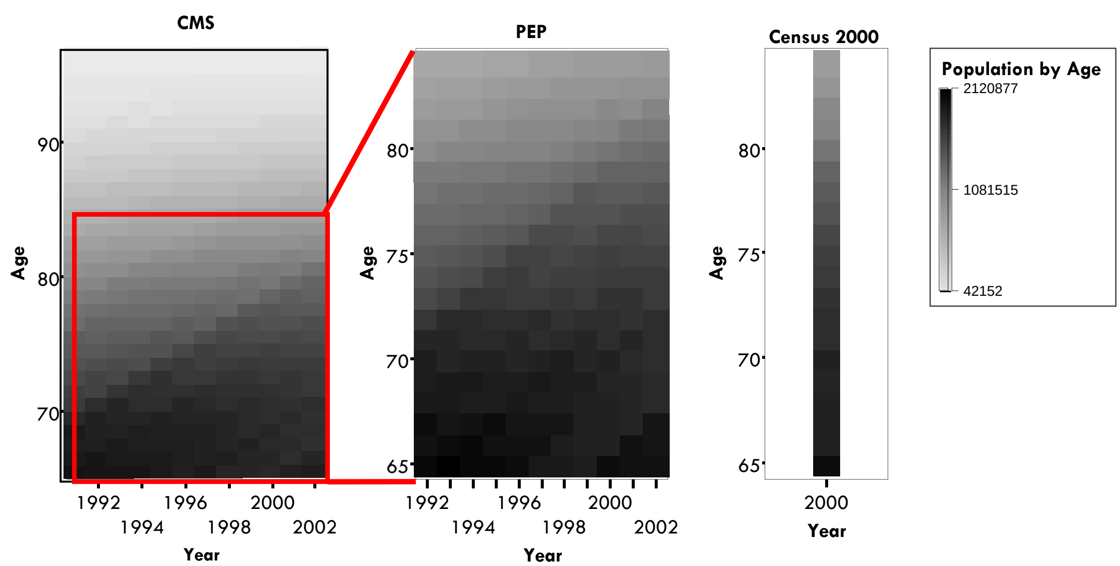

Figure 1: National age- and year-specific population counts for CMS (ages 65 to 97), intercensal estimates (PEP, ages 65 to 84), and Census 2000 (1991-2002)

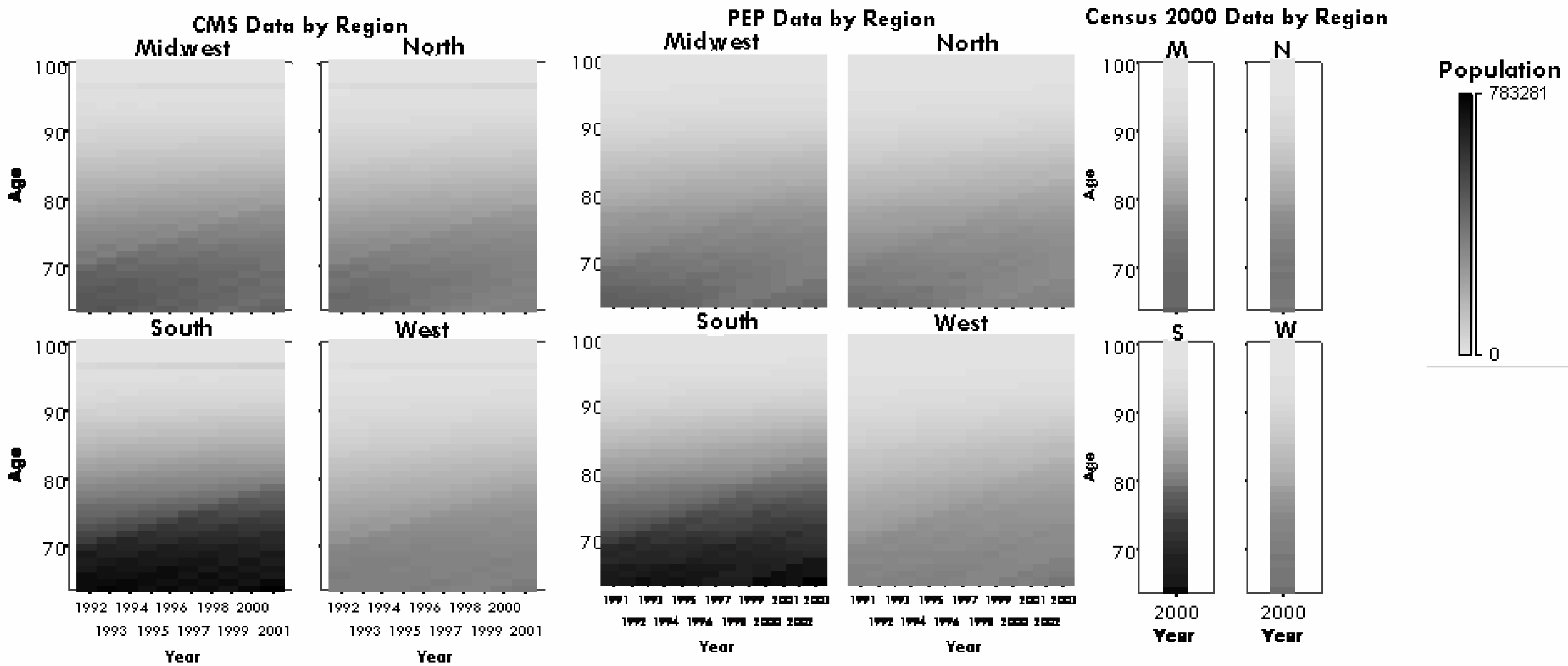

Figure 2: Regional population estimates by age and year for three denominator files: CMS, intercensal estimates, and Census 2000 (1991-2003)

This data reflects the patterns observed above in the summary table (Table 1) of regional differences in population size and trends. The above figure shows that not only are there distinct regional differences in the size of the elderly population, there are also regional patterns in the distribution of the elderly population by year and age. As described above, the South region has the highest overall numbers of elderly population. Looking horizontally across the charts, it appears as if the size of the younger elderly population remains almost constant using both the intercensal estimates and Medicare beneficiaries in the Northeast and Midwest regions, whereas the population size increases noticeably with time in the South and West regions. There are also notable cohort effects for all regions examined. The cohort effects are represented by the diagonal lines and regions.

There are several notable anomalies observable from these data. Intercensal estimates from the Population Estimates Program of the US Census Bureau are available by single year of age only for the population age 84 and below. The population age 85 years and above are grouped into an 85+ category. Thus, in the population age 85 and older, the proportional distributions of single year of age populations from Census 2000 was applied to each year of intercensal population estimate data. The result of which suggests that the relative decrease in population size above at and above age 85 is artificially held constant by this approach, and may mask the true patterns that exist in this population. Another anomaly is the relatively intense horizontal band of population counts in the Medicare beneficiary data at age 98. It appears as if, in this Medicare denominator file, the population of Medicare beneficiaries age 98 and above is artificially grouped into this category. However, there were a few beneficiaries above age 98 who were represented by their single year of age in the data set.

A closer examination of the population counts for the Medicare beneficiaries and intercensal estimates is shown in Figure 3. These data represent the full population age 65 and above, including those above age 97 in the Medicare data. In each age group, the gap between the intercensal estimates and Medicare beneficiary counts widened slightly over time, although population counts were consistently lower in each age group compared to population counts obtained through the intercensal estimates.

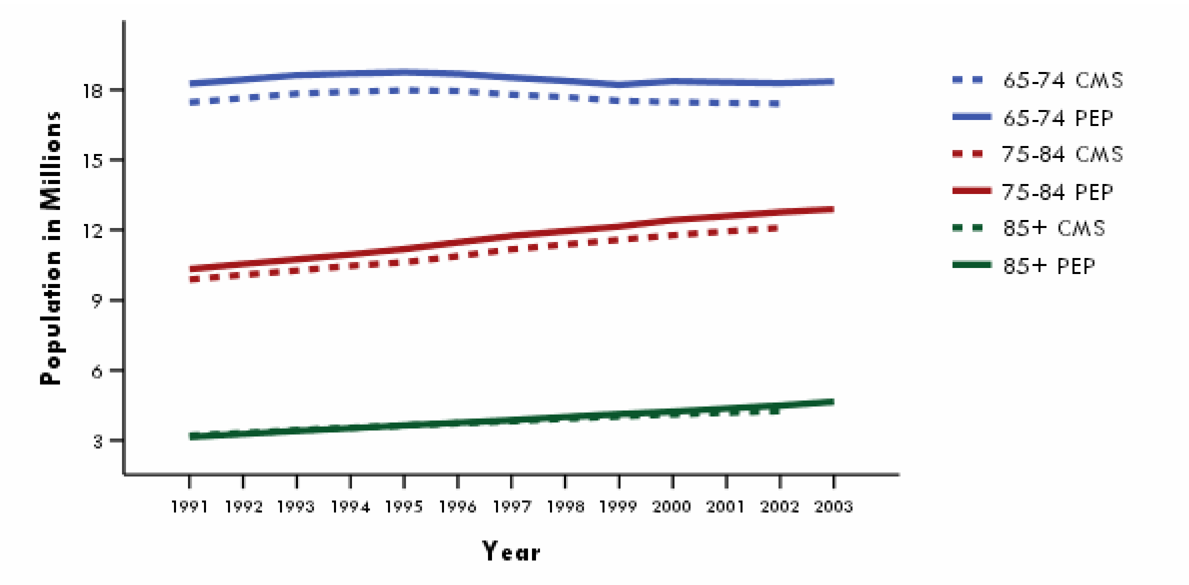

Figure 3: Annual population estimates in the Medicare (CMS) beneficiary and intercensal estimates (PEP) data sets by age group

Race data was compiled for Census 2000 and for Medicare beneficiaries. Racial patterns of Medicare beneficiaries with respect to time and age are shown in Figure 4. Whites and Blacks comprise the majority of the Medicare population. It is important to note again that prior to 1994, all other racial and ethnic groups were coded as “other” or “unknown” in CMS (formerly HCFA) databases. The unknown category of Medicare

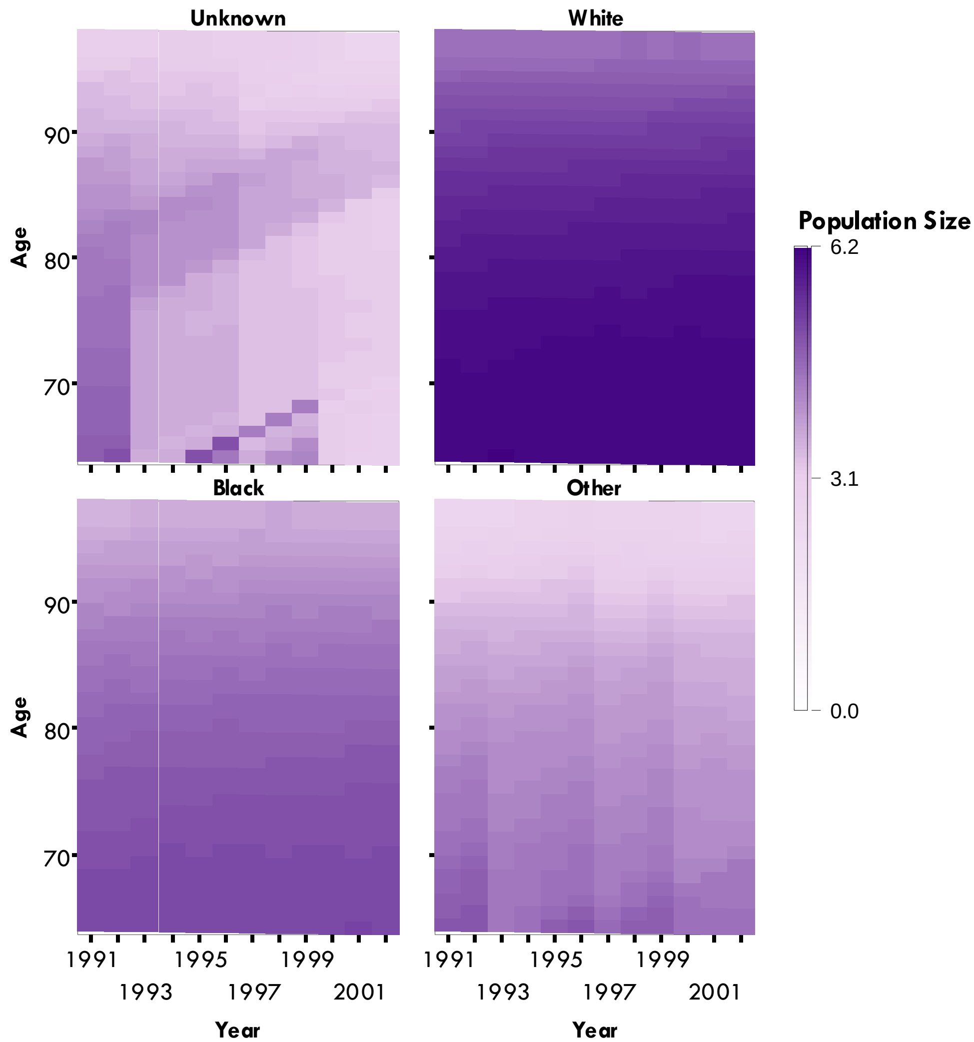

Figure 4: Composition of Medicare beneficiary population by race, age, and year (1991-2002)

beneficiaries showed tremendous variation and unusual age patterns. Beginning in 1995 and lasting for approximately 5 years, the size cohort of beneficiaries age 65 was much larger than in previous cohorts. Subsequent cohorts (i.e. those age 65 in 1996-1999) also had unusually high counts of Medicare beneficiaries of "unknown" race and ethnicity, but those sizes were smaller than that initial cohort. There was also a diagonal band of higher-than-expected numbers of population in the unknown category starting in 1991 for those ages 75 to 82 and lasting throughout the study period. In general, however, the numbers of Medicare beneficiaries of unknown race/ethnicity decreased in stepwise fashion throughout the period of study. The first such step-down occurred between 1992 and 1993, the next four years later, and the next between 1999 and 2000. Similar stepwise patterns were observed in the “other” category, although the overall population levels did not decrease substantially at those jumps.

Comparison of Data Sources for Influenza and Pneumonia (P&I)

Each of the four data sources was compared to the others to determine the magnitude and patterns of discrepancies in the data. Influenza and pneumonia (P&I) cases were collected from CMS and rates were calculated for single year of age and influenza season (July-June). Figure 5 displays the percent differences between each pair of data sources for P&I with respect to age and year. The Medicare beneficiary data from CMS generally represented underestimates of population, which resulted in overestimates of P&I rates, compared to those produced using intercensal estimates, Census 2000 or linear interpolation. The largest discrepancies occurred comparing Census 2000 to Medicare data. There were also notable cohort effects that were apparent from the graphs. The cohort of 71-year-olds in 1991 had overall larger discrepancies in estimated P&I rates comparing CMS to PEP, Census 2000, and linearly interpolated population denominators in comparison to other ages. The apparent overestimates of population size using Census 2000 were greatest in the early years at the oldest age groups.

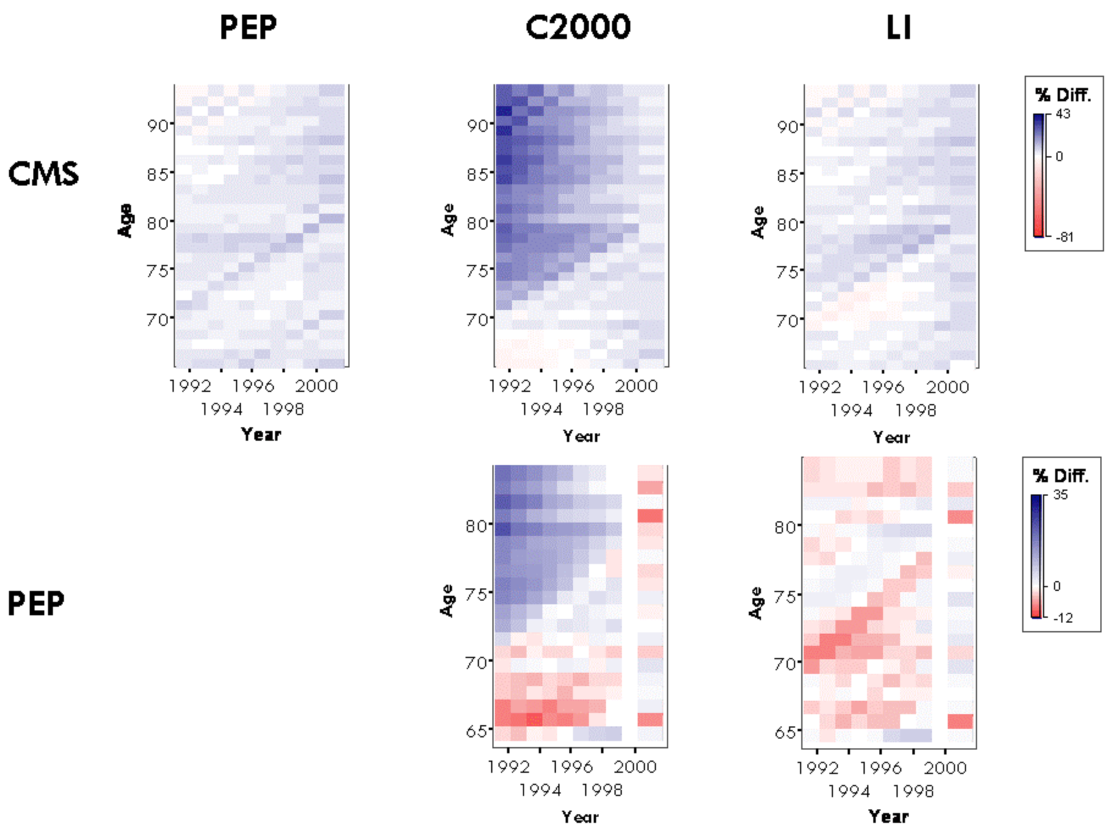

Figure 5: Percent differences among data sources for influenza and pneumonia rates. In each case, rates were assessed using the data source in each row as the denominator, then using the data source in each column as the denominator. Red regions indicate that P&I rates were higher using the row-based population data, and blue regions represent regions where the numerator is larger than the denominator. The intensity of the color represents the magnitude of the discrepancy.

It should be noted that the comparisons between PEP intercensal estimates and Census 2000 and linearly interpolated data are represented on a different color scale for the magnitude of the association than those comparisons for CMS. Overall, PEP intercensal estimates had smaller discrepancies in the estimation of P&I rates compared to Census 2000 and linear interpolation, but there are still notable patterns, similar to those described above. The cohort of 71-year olds in 1991, for example, showed anomalous patterns in the estimation of P&I rates comparing these data sources. Differences in the estimation of P&I rates by region are displayed in Figure 6.

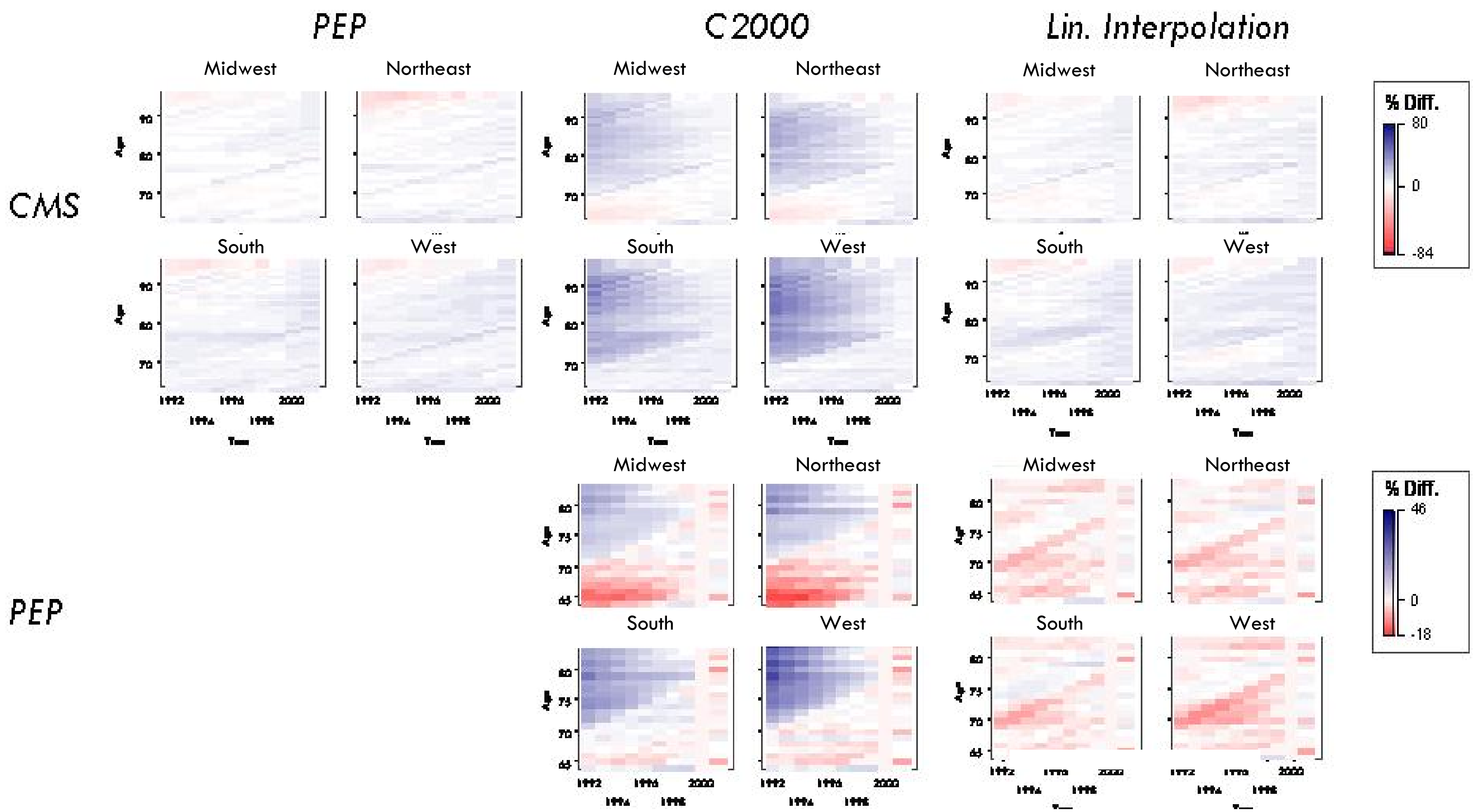

Figure 6: Percent differences among data sources for influenza and pneumonia rates by region. M = Midwest, N = North, S = South, W = West

These graphs demonstrate that the estimation of P&I rates is sensitive to the selected population denominator. It should be noted again that the scales are different for the CMS and PEP comparison rows. Regional patterns appear strongest when comparing Census 2000 estimates to either CMS or PEP estimates. In general, Census 2000 provides overestimates of population size relative to the other population sources, which results in underestimation of P&I rates. This is especially pronounced in the oldest age groups in the South and West regions comparing Census 2000 to Medicare and intercensal estimates. The red region in the Northeast and Midwest regions comparing Census 2000 to intercensal estimates suggests that Census 2000 underestimates the population, and therefore overestimates the P&I rate in those age groups.

Lastly, the overall discrepancies in P&I rates were examined for each of the five comparisons of interest with respect to age alone for all years combined. The distribution of mean absolute percent errors (MAPEs) is shown in Figure 7. These graphs show that the largest absolute discrepancies exist between the Medicare beneficiary data from CMS and Census 2000. The magnitude of these discrepancies increased with age then declined above age 90. The South and West regions had the largest discrepancies overall. Comparatively, there were only small overall mean discrepancies between the P&I rates using Medicare denominators to either linearly interpolated population or intercensal estimates. However, the discrepancies tend to spike at age 65. This may be an artifact of the way in which Medicare beneficiaries are enrolled, given that eligibility for Medicare generally begins at that age. MAPEs for the comparison of rates using Census 2000 and intercensal estimates increased with age, while there were comparative little differences between P&I estimates using linearly interpolated and intercensal population estimates.

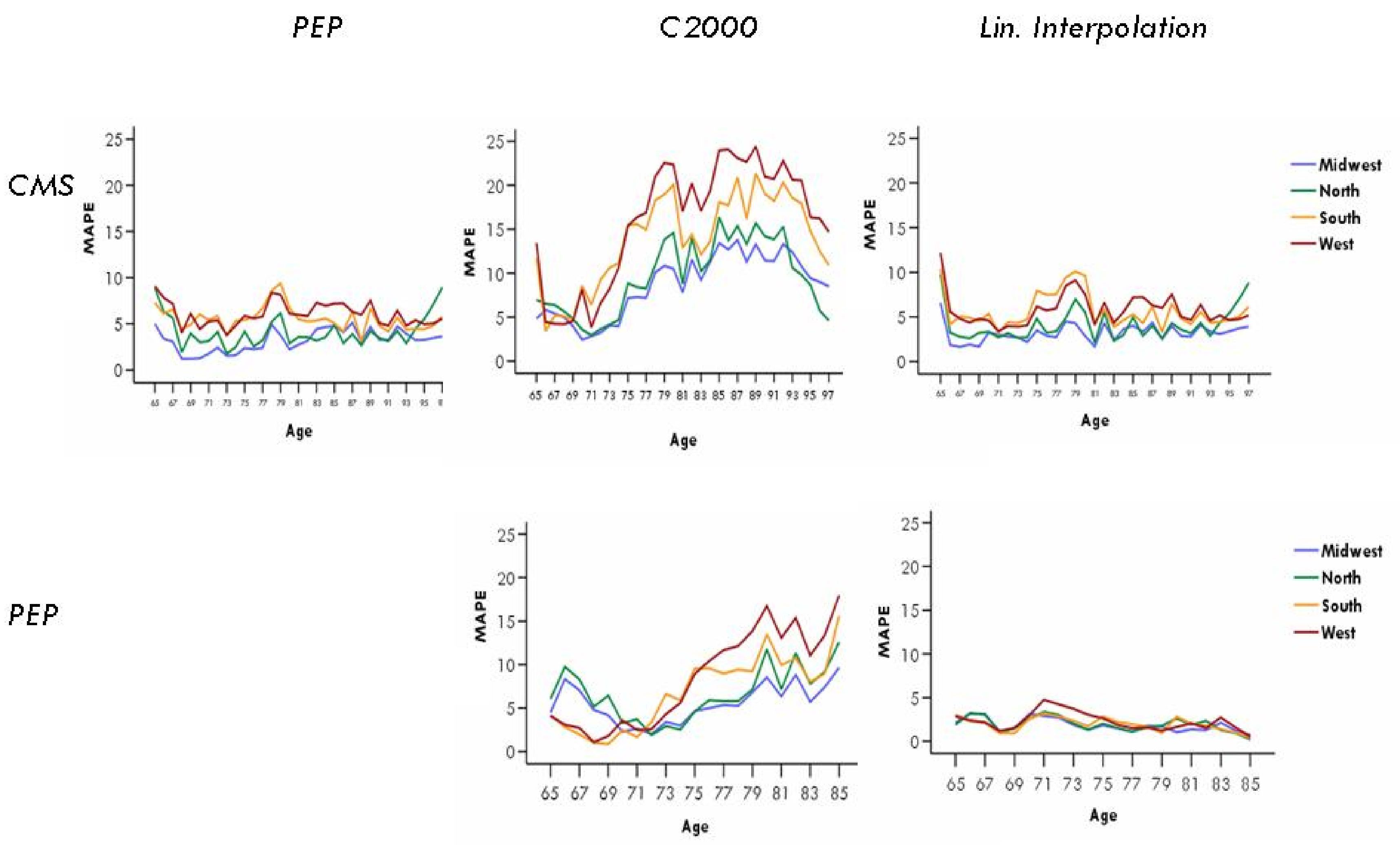

Figure 7: Regional and age patterns in mean absolute percent errors in the estimation of P&I rates comparing data sources

Discussion

For the purposes of this study, it can be assumed that the PEP intercensal population estimates, though subject to error, are the most accurate measures of population counts during intercensal years. These estimates are obtained through administrative records and are estimated and updated annually for the past year in order to get the most accurate estimates.[27] Although possibly more labor intensive, this study suggests that, where possible, PEP estimates should be used in longitudinal epidemiological population-based studies of rates instead of data from once census. Linearly interpolated data is also a comparatively precise source of data that reflects population change in a denominator, when single year estimates are not available. This study shows that even seemingly small absolute differences in population counts can make a substantial difference in the estimation of age-specific rates, and that proper estimation of the denominator is critical in public health literature.

Using Medicare-based denominator files of enrollees may be useful when studying diseases abstracted from Medicare claims data. There are several important caveats to this approach, however, as demonstrated in this study. First, data on race and ethnicity are not consistent with the prevailing approaches used in most other government agencies, such as the Census Bureau. To that end, race and ethnicity have been incrementally refined in the Medicare database since 1993 to better reflect a clearer picture of Medicare beneficiaries by race and ethnicity. Second, although most residents age 65 and above are eligible for Medicare benefits, not all are actively enrolled. Medicare coverage in the US elderly is approximately 96-98%, which indicates that there will almost always be discrepancies between population counts abstracted from Medicare data and other data sources.

These results emphasize the need to account for population change in longitudinal public health research. Those longitudinal studies that use data from one census and apply it to many years, that ignore the issue of the denominator altogether and simply use case counts over time, or do not standardize their data to reflect population dynamics could be improved to more accurately represent population change as a potential cause of changing disease distributions. This is a particularly important issue in the elderly, a population subgroup whose structure changes rapidly, and is projected to experience some of the most substantial changes in the coming years.

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