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The Dynamic Contribution of Chronic Conditions to Temporal Trends in Disability among U.S. Adults

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Abstract

Background—Although evidence has shown that U.S. late-life disability has been declining, studies have also suggested that there has been an increase in chronic diseases between 1984 and 2007.

Objectives—To further illuminate these potentially contradictory trends, we explicate how the contribution of chronic conditions changes across four common types of disability (ADL, IADL, mobility disability, and functional limitations) by age (A), period (P), and birth cohorts (C) among adults aged 20 and above.

Methods—Our data came from seven cross-sectional waves of the National Health and Nutrition Examination Survey (NHANES). We utilize a cross-classified random effect model (CCREM) to simultaneously estimate age, period, and cohort trends for each disability. Each chronic condition was sequentially then simultaneously added to our base models (socio-demographics only).

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Author Contributions

S. Lin, A.N. Beck, and B.K. Finch conceptualized the study. S. Lin performed the statistical analysis and led the writing. All authors contributed to results interpretation and manuscript writing and revisions.

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Reductions in predicted probability from the base model were then calculated for each chronic condition by each temporal dimension (A/P/C) to assess the contribution of each chronic condition.

Results—There was increasing age-based contribution of chronic conditions to all disabilities. The period-based contribution remained quite stagnant across years while cohort-based contributions showed a continual decline for recent cohorts. Arthritis showed the greatest contribution to disability of all types which was followed by obesity. Cancer was the least important contributor to disabilities.

Conclusion—Although chronic conditions are becoming less disabling across recent cohorts, other competing risk factors might suggest prevailing causes of disability.

Keywords

Disability; Age-Period-Cohort; Chronic condition

Introduction

It is well documented that the prevalence of U.S. late-life disability has been declining in the past few decades;^{1, 2} in particular, the decline was most pronounced for instrumental activities of daily living (IADL). Similar declines in disability were also found in a previous study which adjusted for sociodemographics and other temporal dimensions (age and cohort effects).³ Despite the fact that disability is declining, studies have shown that there has been an increase in chronic diseases between 1984 and 2007.^{4, 5} These two seemingly contradictory trends were not only found in the U.S. but also in European countries such as the Netherlands.⁶ Several studies have offered explanations for these trends. First, increased use of assistive devices promotes greater independence among individuals who are afflicted by chronic diseases.^{7, 8} Second, improved screening and advanced medical treatments might mitigate the severity of chronic conditions and possibly halt the progression from morbidity to disability.⁸ Third, environmental changes such as safer and improved sidewalks can help people with mobility issues to better ambulate around their environments.⁷ All of the above evidence suggests that the potentially disabling impacts of chronic disease can be reduced over time. Further confirmation comes from previous studies^{6, 9} that link disability trends with chronic conditions and demonstrate a divergent trend between certain types of disability and some major chronic conditions.

While the aforementioned studies focused on the older population, Martin and colleagues¹⁰ assessed relationships between disability trends and chronic conditions among a group of individuals who were between the ages of 50 and 64. Unlike the older population, a significant increase in needing help for activities of daily living (ADL) was uncovered and the proportion of individuals needing help with IADLs and having difficulty with physical functioning remained stable from 1997 to 2007. Martin et al.¹⁰ also reported that the contribution of specific chronic condition to disabilities was inconsistent across years—some had a growing role and others had a declining role. As demonstrated above, there are disparate trends in the contribution of chronic conditions to disability that are dependent on age differences. Obviously, the relationship between chronic conditions and disability

requires further disentangling. As a result, we aggregated the entire adult population aged 20-80 and attempted to explicate how age relates to the impact of chronic conditions on four different types of disability: ADL disability, IADL disability, mobility disability, and functional limitations. In addition, we explored how the contribution of chronic conditions changes across survey years (period) and birth cohorts. We estimated an age-period-cohort model developed by Yang and Land¹¹ and we describe below why simultaneously examining these three temporal dimensions (age, period, and cohort) is important.

Three Temporal Dimensions: Age, Period, and Cohort

Demographically speaking, time can be captured by three temporal dimensions: age, period, and cohort (A-P-C). Age (A) is a proxy of the biological aging process which brings about internal physiological change due to an accumulation of exposure, genetic manifestation of disease, and/or the natural breakdown of the human body.¹² Period effects and cohort effects are external to individuals but still play substantial roles in determining an individual's health. Period effects (P) reflect technological, environmental, economic, and socio-cultural changes over time that affect the entire population simultaneously, but perhaps not equally. For example, as a result of drought, there might be an increase in food price which affects a higher proportion of low income residents than those who are financially well-off. Birth cohort (C) is defined as a group of individuals who were born in similar years and experience formative social events throughout the life-course.¹¹ Although individuals in the same cohort experience similar historical and social events, successive cohorts experience different historical and social conditions which will result in differential exposures to socioeconomic, behavioral, and environmental risk factors. While each temporal dimension has a unique contribution to population health—including disability—neglect of one of them could produce biased estimates of health trends.^{11, 13, 14} In this study, we were able to consider the effects of age, period, and cohort simultaneously and explicate the contribution of chronic conditions to four common types of disability by age, period, and cohort which is not currently available in the disability literature.

Methods

Target Population

This study utilized seven waves of the National Health Nutrition and Examination Survey (NHANES): III (1988-1994), 99-00, 01-02, 03-04, 05-06, 07-08, and 09-10. The NHANES is a successive, cross-sectional, and nationally representative survey which is administered by the National Center for Health Statistics (NCHS). It is designed to assess the health and nutritional status of U.S. adults and children. Due to changes in survey administration, there was a small measurement gap between 1995 and 1999. The exact year (period) of interview/examination is not available in the public release data; consequently, we developed a coding scheme to best estimate the respondent's year of interview. Based on available information of the public dataset, we created a lower estimate (interviewed in the earliest possible interview date) and an upper estimate (interviewed in the latest possible interview date) for each individual (website link to be provided after blinding process ends). The concordance rate was quite high between upper and lower estimates. It is important to note that because the data collection period within NH3 has a larger gap (varying from 2-3 years period) than

NH4-NH9 (2 year period), the concordance rate for NH3 is substantially lower ($K=0.54$) than NH4-NH9 ($K=0.90$). Although both estimates produced similar results, we selected the lower estimate for both periods and cohorts. We excluded respondents below age 20, women who were pregnant, respondents who belong to the oldest (1900) and youngest (1990) cohort band or were missing birth year (cohort) information. We dropped these respondents because we cannot determine the obesity status for pregnant women prior to the pregnancy and the small sample sizes in the two cohorts precluded reliable estimates. Finally, the amount of missing data for each disability outcome is different; Table 1 depicts the sample sizes for each outcome and set of predictors for disability.

Measurements

Dependent variables—Disability was assessed consistently across the seven survey waves; however, some verbiage changed between NHANES III and NHANES 99-00 onward. In NHANES III, respondents were asked if they have “no difficulty,” “some difficulty,” “much difficulty,” or are “unable” to do a variety of activities by themselves and without the use of aids. From NHANES 99-00 onward, respondent were asked, “By yourself and without using any special equipment, how much difficulty do you have... (doing a variety of activities)?” From NHANES 03-04 onward, an additional response category (do not do at all) was added. Respondents who indicated “do not do at all” were treated as missing. We replicated four disability outcomes by Seeman et al.¹⁵: (1) activities of daily living (ADL) disability, (2) instrumental activities of daily living (IADL) disability, (3) mobility disability, and (4) functional limitations. If the respondents indicated having some difficulty, much difficulty, or were unable to do any of the activities belonging to a particular disability category, they were considered having that particular disability. For example, if a respondent is unable to walk from one room to another in the same floor and has some difficulty managing money, he or she is considered having an ADL disability as well as an IADL disability. It is also important to note that the disability type categories were not mutually exclusive. A substantial amount of respondents (38.1%) indicated having multiple disabilities. For example, among those who had a mobility disability, 44.8% also had an ADL disability. For those who had functional limitations, about half of them (51.7%) also had an IADL disability.

Independent variables—Age was modeled directly as a linear term. We did not calculate the predicted probability of disability for ages (80+) that are beyond the lowest top-coded age (NHANES 09/10) across waves. Period and cohort were not modeled directly but obtained through a post-estimation strategy. Period represents the year that the respondent was interviewed (1988-2010). Cohort measures the respondent's birth year. Cohorts were calculated by decrementing respondents' age from period measures. These cohorts were then grouped into 5-year cohort bands to prevent a perfect linear relationship (cohort = period – age), known as the “identification problem” in demographic research¹¹. The mid-year of the 5-year cohort band was used to label respondents born in that 5-year range. The finalized cohort bands range from 1905 to 1985 cohorts. Our models control for several sociodemographic variables; including gender, marital status, employment status, years of education, income to poverty ratio, and household size. The following six chronic conditions were also adjusted for in our models: cancer, diabetes, arthritis, lung problems (including

asthma, bronchitis, and emphysema), obesity and cardiovascular diseases (including congestive heart failure, heart attack, and stroke).

Analysis

We utilize a cross-classified random effect model (CCREM) developed by Yang and Land¹¹ to overcome the identification problem and simultaneously estimate the age, period, and cohort trends of four types of disabilities. As detailed in Yang and Land,¹⁶ CCREM has the ability to adjust for the multi-level structure of repeated cross-sectional data. More specifically, the model can account for non-independence of individuals cross-classified within cohorts/periods who may share similar experiences unique to their birth cohorts or shared across time-periods (survey year). The cross-classified model is appropriate for our study because respondents are not strictly nested within periods and cohorts in a hierarchical fashion. Further, the CCREM model does not directly estimate period and cohort effects in order to avoid perfect collinearity with respect to all three temporal components that we consider. These effects can be recovered through post-estimation strategies, however, which will allow for the graphical/ statistical presentation of temporal trends for age, period, and cohort. Subsequently, we determine how chronic conditions' contributions to disability change across age, periods, and cohorts. To determine the percent reduction of predicted probability for disabilities across A-P-C for each chronic condition considered, we first specified our A-P-C models. A total of nine logistic CCREMs were estimated for each disability outcome. In Model 1 (base model, hereafter), age was entered as a linear term in the fixed effect portion of the model and the periods and 5-year cohort bands were included as random effects. See the equation for Model 1 below. **Equation:**

$$\text{logit} \{Pr(Y_{ijk}=1|A_{ijk})\} = \beta_{0jk} + \beta_1 A_{ijk} \quad \text{Model 1 Level 1 (\#1)}$$

where Y_{ijk} is the presence or absence of a given disability for $i=1, 2, \dots, n_{jk}$ individuals within cohort j and period k . Age is represented by A_{ijk} ; we cohort-median centered this term to reduce bias.

$$\beta_{0jk} = \gamma_0 + u_{0j} + v_{0k}, \quad u_{0j} \sim N(0, \tau_u), \quad v_{0k} \sim N(0, \tau_v) \quad \text{Model 1 Level 2 (\#2)}$$

At level 2, β_{0jk} is the outcome, which in this model, represents the cell mean of individuals who belong to birth cohort j and surveyed in year k . γ_0 is the model intercept, or expected mean at zero values for all level 1 covariates averaged across all periods and cohorts; u_{0j} is the residual random effect of cohort j (i.e., the contribution of cohort j averaged over all periods on β_{0jk}) and is assumed to be normally distributed with mean 0 and a within-cell variance τ_u ; and v_{0k} is the residual random effect of period k (i.e., the contribution of period k averaged over all cohorts) and is assumed to be normally distributed with mean 0 and a within-cell variance τ_v .

For Model 2, we added all sociodemographic variables (represented by βX_{ijk}) to the fixed effect portion of the base model (See equation #3). For Models 3-8, each of the six chronic condition domains was added separately to Model 2. Below, we provided an equation for adding arthritis to Model 2 as a demonstration (See equation #4).

$$\text{logit} \{Pr(Y_{ijk}=1|A_{ijk})\} = \beta_{0jk} + \beta_1 A_{ijk} + \beta' X_{ijk} \quad \text{Model 2 (\#3)}$$

$$\text{logit} \{Pr(Y_{ijk}=1|A_{ijk})\} = \beta_{0jk} + \beta_1 A_{ijk} + \beta' X_{ijk} + \beta_3 \text{Arthritis}_{ijk} \quad \text{Model 3 (\#4)}$$

$$\text{logit} \{Pr(Y_{ijk}=1|A_{ijk})\} = \beta_{0jk} + \beta_1 A_{ijk} + \beta' X_{ijk} + \beta_3 \text{Arthritis}_{ijk} + \dots \beta_n \text{Cancer}_{ijk} \quad \text{Model 9 (\#5)}$$

For Model 9, all chronic conditions were added simultaneously (See equation #5). We consequently estimate the predicted probability of disability for each A-P-C dimensions and for each model specified. Only the full model (Model 9) regression estimates (See table 2) are shown in this paper.

Models 3-8 estimates, however, were used to determine the reduction in the predicted probabilities after separately adjusting for each chronic condition, we calculate the ratio of predicted probability between Model 2 (A-P-C + Sociodemographics) and each of Models 3-8 (e.g. Model 3: A-P-C + Sociodemographics + Arthritis) as well as Model 9 (i.e. A-P-C + Sociodemographics + all chronic conditions). If the ratio was below 1, we decremented the ratio from one and multiplied by 100 to derive the percent reduction of predicted probability of disability from Model 2. If the ratio was above one, we decremented one from the ratio to derive the percent increase of predicted probability of disability from Model 2. The percent reductions in the predicted probability for each type of disability (i.e. percent contribution to disability) from each chronic condition entered separately, as well as all chronic conditions, as captured in the full model, were calculated. The percent contribution of each chronic condition separately will be discussed but not presented in tabular format. Only the graphs including all chronic conditions (Model 9) are shown in the paper. Stata 12.1 xtlogit command was used to estimate our CCREM models (Models 1-9) and a commonly used post-estimation command (i.e., predict command with reffects option) were also performed to recover the random coefficients for periods and cohorts using “Best Linear Unbiased Prediction – BLUP.”¹⁷

Results

Respondents' Characteristics

Table 1 presents the available sample size for each disability outcome and describes the sociodemographic and chronic condition distributions among respondents. Since the distributions of sociodemographics and chronic conditions were similar across the four disability outcomes, we only report results using the ADL disability outcome. About half of the respondents were women (52.3%). The majority of the respondents were Non-Hispanic White and married. There was an equal number of respondents who were employed or retired at the time the survey was conducted. The mean age was about 59 years and the mean household size was about 3 people per household. The mean income to poverty ratio was about 2.3 and the respondents had, on average, 11 years of education. The top three chronic conditions among respondents were arthritis (37.2%), obesity (30%) and diabetes

(15%), whereas, emphysema (3.5%), congestive heart failure (5.6%) and stroke (5.8%) were the three least prevalent chronic conditions among respondents.

Table 2 shows the regression estimates and variance components from our fully adjusted model (Model 9). Increasing age was associated with greater likelihood of all types of disability. Women were significantly more likely to have all types of disability except ADL disability. Additional analyses demonstrated that the pattern of disability reduction with the introduction of chronic conditions was similar for men and women and therefore, we do not present gender-stratified results. Respondents who were widowed, divorced, or separated were more likely to have a disability than those who were married. Retired or unemployed respondents were more likely to be disabled than an employed respondent. Those who had more years of education or higher income to poverty ratio were less likely to be disabled. Finally, those with any type of chronic condition, except cancer, were more likely to have a disability. Across four different types of disability, arthritis, stroke, emphysema, and congestive heart failure were consistently shown as the top three strongest association with disabilities. For example, the top three chronic conditions associated with ADL disability are arthritis (OR=2.7), stroke (OR=2.3), and congestive heart failure (OR=1.6); whereas the top three chronic conditions for mobility were emphysema (OR=2.7), stroke (OR=2.4) and arthritis (OR=2.2). In addition, both random effects (period and cohort) were significantly different from zero.

As A-P-C trends of these four types of disability have been reported in our earlier findings (blinded citation), we will only examine the percent contribution of each chronic condition across age, period, and cohorts here. Figure 1a depicts the age-based percent reduction in predicted probability for all types of disability after adjusting for all chronic conditions simultaneously. In other words, this figure shows the percent contribution of chronic conditions towards the predicted probability of ADL disability as well as IADL disability, mobility disability, and functional limitations. These trends were estimated across period (Figure 1b) and cohort (Figure 1c) as well.

All chronic conditions taken together (Figure 1a), as well as arthritis, and cardiovascular diseases considered separately increasingly contributed to ADL disability with age, while obesity was slowly declining with respect to its contribution to ADL disability with age. The remaining conditions seemed to contribute evenly across age. These patterns were very similar to those found for IADL disability. For mobility disability and functional limitations, the same patterns also held; however, the increasing contribution of all chronic conditions taken together (as shown in Figure 1a), arthritis, and cardiovascular diseases (results not shown) were much attenuated. For example, for ADL disability, the percent contribution of all chronic diseases increased about 14 % from age 20 (34.4%) to age 80 (48.4%); whereas, the percent contribution for mobility disability increased only about 7% (40.8% at age 20; 47.9% at age 80). The declining contribution of obesity across age, on the other hand, was most salient for functional limitations. Finally, cancer contributed very minimally across age and this is consistent for all four types of disability.

For chronic conditions taken together (Figure 1b), there was an obvious decline in the contribution from 1988 to 2003 then a continual increase followed from 2003 to 2010;

however when examined separately each condition appeared to contribute equally across periods suggesting that it is multiple condition profiles that are driving these patterns. For example, cardiovascular diseases, lung problems, and diabetes had similar contributions across periods. In addition, cancer contributed minimally across periods. All of these patterns were very similar to those found for IADL disability, mobility disability and functional limitations. For cohort-based ADL disability trends, all chronic conditions taken together and arthritis, considered separately, showed an increased contribution to ADL disability (Figure 1c) from the 1905 cohort to the 1935 cohort which was followed by a continual decreased contribution other than a small uptick between 1980 and 1985. Obesity, however, showed a slow and continual increased contribution to ADL disability across cohorts; the percent contribution increased from 2.1% in the 1905 cohort to 11.9% by the 1985 cohort. Cardiovascular diseases showed a slow decline as a contributor to disability from 1905 to 1965 before plateauing for the most recent cohort. For lung problems and diabetes, the contributions to ADL disability remained at the same level across cohorts. Finally, cancer made virtually no contribution to ADL disability across cohorts. Similar contribution patterns found in ADL disability were also observed for IADL disability, mobility disability, and functional limitations; however, there were some discrepancies across disability outcomes. The increasing contribution by obesity was more salient for mobility disability and functional limitation than ADL disability and IADL disability. For example, the contribution increased by 17.2% between the 1905-1985 cohorts for mobility disability and 11.9% for functional limitations; however, the increase was only 9.8% and 4.1% for ADL and IADL disabilities, respectively. In addition, for IADL disability, mobility disability and functional limitation, a noticeable crossover between arthritis and obesity occurred. For most of the earlier cohorts, arthritis had a greater contribution to disability than obesity; however, the contribution flipped after the crossover. The crossover occurred in the 1975 cohort for IADL disability; the 1950 cohort for mobility disability and the 1970 cohort for functional limitation.

From our results, we were also able to determine the ranking of disability contributions by various chronic conditions. Although the ranking of chronic conditions differs across A-P-C dimensions and disability outcomes, a distinctive ranking pattern can still be identified. After all chronic conditions taken together (#1), the top contributor to disability was arthritis (#2), followed by obesity (#3). Lung problems, cardiovascular diseases, and diabetes all appeared to contribute similarly to disability. Finally, cancer contributed the least to all disabilities for all temporal trend dimensions.

Discussion

For the age-based contributions to ADL and IADL disabilities, we noticed a remarkable increase in the contribution across age for all chronic conditions as well as for arthritis and cardiovascular disease, considered separately. Although this pattern was also found for mobility disability and functional limitations, the increase across age was attenuated (as evident in the example provided in the result section). This suggests that arthritis, cardiovascular diseases, and all chronic conditions taken together are becoming more important contributors to ADL and IADL disability as individuals age. In contrast, the

contribution of obesity slowly declined across ages for all types of disabilities. It is possible that as individuals grow older, they are more likely to become less obese and more fragile.

When examining the period-based contributions to disability, we observed that the contribution of each chronic condition was stagnant across periods except for the contribution of all chronic conditions taken together which shows a V-shape with the nadir occurring in 2002/2003. Our finding on a stagnant period-based contribution, when examined each condition separately, was consistent with a recent study in the Netherlands which showed that the association between chronic diseases (diabetes, heart disease, peripheral arterial disease, stroke, lung disease, joint disease, back problems and cancer) and activity limitations was stable between 1990 and 2008 among adults aged 55 to 84.⁶ On the other hand, Martin et al.¹⁰ reported variation in chronic condition contributions by survey periods which is consistent with our pattern of results when we considered all conditions together. They found that arthritis and rheumatism was increasingly cited by NHIS respondents aged 50-64 as the cause for difficulty in physical functioning between the two periods (1997-1999 vs. 2005-2007); however, the number of individuals that cited arthritis and rheumatism as causes of ADL and IADL disabilities declined between these two periods. Other increasingly cited causes of disability included diabetes; depression, anxiety, and emotional problems; and nervous system conditions. The use of different age groups [20-80 in our study vs. 40-64 & 65+ in Martin et al.¹⁰] might suggest an explanation for the discrepancy between our results and those reported by Martin et al.¹⁰

The cohort-based chronic disease contribution from all chronic diseases taken together, and arthritis and cardiovascular diseases by themselves, showed a distinct pattern. For all four types of disability, the contribution of these chronic conditions increased from the 1905 cohort to the 1930-1940 cohort which was followed by a continual decline through the most recent cohort. This suggests that although chronic conditions still contribute substantially to disability, their salience has declined across cohorts. This declining contribution from chronic conditions among more recent cohorts aligns with earlier evidence that chronic conditions are becoming less disabling.⁶⁻⁹ Coupling this fact with the increasing IADL disability across newer cohorts,¹⁸ it is puzzling as to what, if not increasing chronic conditions, might be causing the IADL disability increase among recent cohorts. It is plausible that other competing risk factors are contributing to IADL disability. As reported by Martin et al.,¹⁰ the newly emerging and increasing role of depression/anxiety/emotion problems and nervous system conditions may become more salient factors for ADL disability, IADL disability, and functional limitations. In addition, Thorpe et al.¹⁹ also reported that African American women and men with major depressive symptoms had nearly three times or slightly over three times the odds for mobility disability, respectively. They further explained that apathy might play the mediating role between depressive symptoms and disability. The lack of psychological well-being among depressed individuals may further interfere with their motivation to engage in certain activities.

In addition to the recent declining role of cardiovascular diseases and arthritis, we also observed an increasing contribution of obesity to disability prevalence. As discussed in the results section, the increased salience of obesity was more obvious for mobility disability and functional limitation than for ADL and IADL disabilities. Several studies have also

shown the important contributing role of obesity. Bhattacharya, Choudhry, and Lakdawalla²⁰ reported in their study that the rising prevalence of obesity was an important source of increasing disability in the working-age population. Vincent, Vincent, and Lamb²¹ also demonstrated that mobility related activities such as walking, stair climbing and chair rise were associated with obesity, especially for those whose BMI exceeded 35 kg/m². Although Martin et al.¹⁰ only found a small role for obesity, they indicated that obesity is related to arthritis, rheumatism, back or neck problems, diabetes, and other musculoskeletal conditions that have greater salience for disability. In addition, we noticed a crossover demonstrating that the contribution of obesity outweighs arthritis between the 1950 and 1975 cohorts, although this varies by disability outcome. This crossover was most dramatic for mobility disability. This suggests that ameliorating the risk of obesity should become a top priority for curtailing mobility disability among more recent U.S. cohorts.

We found that women had significantly higher levels of disability for all outcomes with the exception of ADLs; supplemental analyses also demonstrated that the overall A-P-C trends were very similar for men and women. The overall pattern of the contribution across temporal dimensions as described above were also very similar to trends observed from men and women separately; however, we found that chronic conditions contributed more in an absolute sense among women. We were also unable to compare these findings to previous studies as none of the previous investigations, to our knowledge, reported the contribution of chronic conditions by gender.

Finally, we also identified the ranking of chronic disease contributions for disability. Other than all chronic conditions considered simultaneously, arthritis had the largest contribution to all types of disability, followed by obesity. The ranks for other conditions such as lung problems, cardiovascular diseases, and diabetes were inconsistent across the three A-P-C dimensions and the four disability outcomes. Cancer, however, made the smallest contribution to all types of disabilities regardless of gender and A-P-C dimensions. Our ranking of chronic condition contribution is consistent with two recent investigations^{10, 22} that also showed arthritis being the most common contributor to disability. Arthritis/rheumatism was reported as the top cause of physical functional limitation among NHIS respondent aged 40-60 and those who were 65 and over. For ADL and IADL disabilities, arthritis/rheumatism still ranked the most common contributor among respondents aged 65 and above; however, it was ranked second among respondents aged 40-60, only after back/neck problems. Similar to our ranking, Martin et al.¹⁰ found that heart problems, lung problems, and diabetes were closer to the bottom of the ranking for respondents aged 40-64; however, heart problems were ranked #3 in 1997-2003 and #4 in 2004-2010 among respondents aged 65 and above. It is plausible that our ranking is slightly different than those reported by Martin et al.¹⁰ given the differences in our age ranges.

There are several caveats of our study. First, our period and cohort estimates were not exact as the exact birth year (cohort) and interview year (period) were not available in public NHANES data, however, we were able to estimate the upper and lower estimates of period using a previously established protocol (citation blinded; will be available after the blinding process) that showed nominal inconsistencies. In addition, we had some discontinuities in interview years between 1988 and 2010 due to a small survey gap between NHANES III

(1988–1994) and NHANES 99–00 data collection periods. Second, selectivity with respect to undiagnosed illness may bias our overall prevalence, but more than likely would have had no effect on our temporal trends. Third, NHANES is a cross-sectional survey, precluding us from making causal links between chronic condition variables and disability status. Although the NHIS survey is also a cross-sectional survey, the NHIS directly asks respondents whether a host of chronic conditions caused their disability. Despite this advantage, our results using NHANES data show a chronic condition contribution ranking that is comparable to previous investigations^{10, 22} utilizing the NHIS data.

Our study, however, offers several new findings that go beyond previous investigations. We are able to present the contribution of chronic conditions for the full range of ages, periods, and birth cohorts while simultaneously controlling these three temporal dimensions in the same model. Previous studies were only able to compare disease contribution by examining aggregated periods.^{10, 22} In addition, our results on declining chronic condition contribution in the more recent U.S. cohorts confirm the hypothesis that chronic conditions are becoming less important for disability. On the other hand, recent evidence suggests that other health conditions such as mental health and nervous system conditions may emerge as new causes of disability. Finally, our study covers adults in a much broader age range (20+) than previous studies.^{5, 6, 10}

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Figure 1.

Percent reductions of predicted probability for ADL, IADL, mobility disability and functional limitation by age, period, and cohort.

Table 1Respondents' characteristics by four disability outcomes^{*}

	ADL Disability (N=24,835)	IADL Disability (N=24,733)	Mobility Disability (N= 22,728)	Functional Limitations (N= 24,825)
Sociodemographics				
<i>Gender</i>				
Men	47.7	47.6	47.8	47.7
Women	52.3	52.5	52.2	52.4
<i>Race/Ethnicity (%)</i>				
Non-Hispanic White	49.4	49.4	49.5	49.4
Non-Hispanic Black	23.5	23.6	23.3	23.5
Mexican American	20.5	20.5	20.8	20.5
Other	6.5	6.5	6.4	6.5
<i>Marital Status (%)</i>				
Married	56.2	56.2	57.2	56.2
Never married	14.9	14.9	15.0	14.9
Other	28.9	28.9	27.8	28.9
<i>Employment Status (%)</i>				
Unemployed	24.1	24.0	22.4	24.0
Employed	37.1	37.3	39.4	37.2
Retired	38.8	38.7	38.2	38.8
<i>Age (Mean) [□]</i>				
	58.6	58.5	58.2	58.6
<i>Household size (mean)</i>				
	2.8	2.8	2.8	2.8
<i>Poverty to income ratio (mean)</i>				
	2.3	2.3	2.4	2.3
<i>Years of education (mean) [□]</i>				
	11.0	11.0	11.0	11.0
Chronic Conditions				
Arthritis (%)	37.2	37.2	34.5	37.2
Asthma (%)	10.3	10.3	9.4	10.4
Congestive Heart Failure (%)	5.6	5.6	4.9	5.6
Heart Attack (%)	7.5	7.5	6.8	7.5
Stroke (%)	5.8	5.7	4.8	5.8
Chronic Bronchitis (%)	7.7	7.7	7.0	7.7
Emphysema (%)	3.5	3.5	3.1	3.5
Obesity (%)	30.7	30.7	29.3	30.7
Diabetes (%)	15.0	14.9	13.4	15.0
Cancer (%)	8.5	8.5	8.0	8.5

* Figures presented in this table were not accounted for survey weights.

[□] Overall means were reported here; however, cohort-median-centered variables were used in our models.

Table 2

Regression coefficients for the full model (Model 9) by disability types.

	ADL		IADL		Mobility Disability		Functional Limitation	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Age (cmc) [Ⓢ]	.033 **	.016 .049	.023 **	.006 .040	.035 ***	.022 .048	.049 ***	.035 .064
Female	-.51 ***	-.123 .020	.361 ***	.292 .429	.309 ***	.239 .380	.306 ***	.245 .368
Marital Status								
Married	-	-	-	-	-	-	-	-
Never married	.032	-.082 .146	.162 **	.055 .269	-.022	-.136 .092	-.104 *	-.202 -.006
Other (widowed, divorced, & separated)	.149 ***	.068 .229	.228 ***	.151 .304	.140 **	.061 .219	.082 *	.010 .153
Years of education (cmc) [Ⓢ]	-.038 ***	-.048 -.029	-.037 ***	-.046 -.027	-.043 ***	-.053 -.034	-.034 ***	-.042 -.024
Income to poverty ratio (cmc) [Ⓢ]	-.126 ***	-.155 -.097	-.122 ***	-.149 -.095	-.177 ***	-.205 -.149	-.095 ***	-.119 -.071
Household size (mc) [Ⓢ]	.027 *	.004 .051	-.002	-.024 .021	-.006	-.029 .018	-.007	-.028 .014
Employment Status								
Employed	-	-	-	-	-	-	-	-
Unemployed	.821 ***	.725 .917	.940 ***	.849 1.030	.728 ***	.635 .821	.606 ***	.526 .685
Retired	.386 ***	.265 .507	.537 ***	.419 .655	.287 ***	.174 .400	.219 ***	.122 .316
Arthritis	.997 ***	.926 1.069	.798 ***	.729 .866	.807 ***	.738 .877	1.102 ***	1.039 1.164
Lung Conditions								
Asthma	.177 **	.071 .283	.245 ***	.142 .348	.274 ***	.162 .387	.224 ***	.121 .327
Bronchitis	.376 ***	.258 .493	.459 ***	.344 .574	.587 ***	.463 .712	.457 ***	.336 .578
Emphysema	.358 ***	.197 .519	.656 ***	.496 .816	.993 ***	.814 1.172	.558 ***	.383 .732
Heart Conditions								
Congestive heart failure	.465 ***	.332 .598	.618 ***	.484 .752	.753 ***	.601 .905	.577 ***	.426 .727
Heart attack	.265 ***	.143 .387	.264 ***	.143 .386	.426 ***	.296 .557	.343 ***	.218 .469

	ADL		IADL		Mobility Disability		Functional Limitation	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Stroke	.831***	.709 .953	.942***	.818 1.065	.890***	.748 1.032	.771***	.632 .911
Diabetes	.399***	.313 .485	.330***	.244 .415	.401***	.310 .492	.446***	.361 .531
Cancer	.021	-.093 .135	.172**	.064 .281	.173**	.059 .288	.208***	.103 .313
Obesity	.358***	.284 .431	.262***	.191 .332	.640***	.568 .713	.601***	.536 .666
Intercept	-2.490***	-2.727 -2.253	-2.297***	-2.612 -1.982	-2.301***	-2.570 -2.03	-1.241***	-1.488 -.995
Variance component								
SD (period)	.272***	.178 .415	.349***	.236 .515	.197***	.130 .298	.235***	.155 .356
SD (cohort)	.347***	.241 .498	.514***	.361 .732	.483***	.336 .695	.421***	.292 .607

mc = cohort-median centered; mc=mean centered.

*** p<.001

** p<.01

* p<.05