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Education, income, and functional limitation transitions among American adults: contrasting onset and progression

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Background Although a robust association between socioeconomic status and health has been shown in past research, the processes that explain the connection are not well understood. This paper seeks to advance such understanding in two ways, first by attending to the distinction between onset of a functional health problem and its progression, and second by addressing whether and how education and income relate differently to the onset versus progression of functional health problems.

Methods Data come from the Americans' Changing Lives survey (n = 3617). The baseline was conducted in 1986 and outcome status measured in 1994. Activity limitations are categorized into none, mild, moderate, severe. Onset is defined as having no limitation at origin and a limitation at outcome. Progression is defined as limitation of a particular severity at origin and improving, staying the same, or getting worse with respect to the severity. Multinomial regressions determine transition probabilities related to onset and progression.

Results Those with higher income and education are less likely to experience an onset. Only income associates with progression. Those with the highest income are most likely to improve and least likely to get worse in comparison to those with the lowest income.

Conclusions Education, being determined early in life and influencing psychosocial mechanisms throughout life, may have a greater impact on prevention of activity and functional disorders. Income's role may be both as a prevention factor and as a mechanism for management of health problems.

Keywords Social class, activities of daily living, limitation of activity, adults, ageing

A large and rapidly growing body of research indicates that socioeconomic position is predictive of mortality and morbidity, and declines in functional status at various ages in various societies.[1–24] The association has been found to be robust across populations, methodologies, and measures. Yet, the processes through which this association occurs are still not well understood. This paper seeks to advance such understanding in two ways: (1) by attending to the distinction between the onset of health problems and their course or progression; (2) by addressing whether and how education and income differentially affect indicators of health.

Although it is well known that characteristics such as age, gender, and socioeconomic status influence the probability of having functional disorders, surprisingly little attention has been paid to the degree to which these attributes relate to functional problems as process. This is due in part to the relative lack of panel data on representative population samples that span sufficient years to allow for analyses of changes in capacity. Further, although education and income are both valued resources that are distributed differentially, and causally connected over the life course, rather than just being indicators of a single underlying dimension of 'status', each is distinctive, having unique causes and consequences as well as common ones.

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We expect that education is more strongly predictive of onset, while income is more predictive of course or progression. This expectation begins from the recognition that most health problems of adulthood are chronic in both aetiology and course, and are the outcome of a long process of development as a function of exposure to a wide range of social, psychological, behavioural, and biomedical risk factors.[25] Education indexes both the socioeconomic position of individuals early in adulthood and a stock of human capital available to them from that time on, both of which influence long-term patterns of exposure to and experience of major psychosocial and biomedical risk factors, including: (1) preventive and therapeutic medical care; (2) deleterious health behaviours such as smoking and lack of exercise; (3) chronic and acute stress; (4) lack of social relationships and supports; (5) exposure to physical hazards in home, neighbourhood, and work environment, such as pollution and dangerous work conditions; and (6) psychological orientations or dispositions inimical to health such as anger/hostility or lack of efficacy/control.[26]

In contrast, income, as usually measured in terms of the past year, reflects socioeconomic position and resources closer to the time of assessment of a health problem, thus being not only a more proximate influence on the onset of a health problem but, also a determinant of the course of that problem. That is, income influences not only the exposure to or experience of aetiological risk factors for health, but also, and probably more strongly than education, the resources available for the treatment or management of disease or for modifying life circumstances to reduce the factors (e.g. stress) producing or maintaining the disease.

Past studies have shown both shared influences and notable differences in education and income influences on health.[27,28] Non-US evidence suggests that education more strongly relates to the existence of a functional health problem while income more relates to the severity of the problem.[29] Other research has distinguished between prevention and management of a health disorder,[30] and shown education to differentially predict incidence, recovery, severity, and mortality. Where onset and progression have been examined, the focus has been on older adults,[31–33] and these studies showed that most sociodemographic characteristics influence both onset and progression, but education influences onset only. These past studies are beginning to suggest that the psychosocial and biomedical mechanisms through which socioeconomic factors influence health could differ depending upon the stage of disorder. Mediating factors such as exercise and avoidance of risky behaviour may act upon prevention, while the availability of medical and rehabilitative programmes, which itself is differentially determined across socioeconomic characteristics, may better relate to management after an onset.

Prior prospective analyses on the US national sample considered here have found that income is a stronger predictor of mortality than education, while education has little effect on mortality net of income.[34] However, education is as strong or a stronger predictor of changes in health.[7] This research has failed to carefully distinguish between the onset of health problems among those free of such problems, and the course among those with such pre-existing problems. In the present study, we focus on how education and income differentially associate with the probability that a functionally healthy person at one point in time contracts a functional health problem over time, and the probability that a person who has functional limitations improves or gets worse over time. Specifically, using a sample of American adults aged ⩾25, we ask the question, is it the case that education is more related to onset and income to progression of functional limitation?

Methods

Data

The study uses 1986 and 1994 waves of the Americans' Changing Lives survey (ACL), a longitudinal probability sample of 3617 non-institutionalized adults aged ⩾25 living in the contiguous US. Respondents were first interviewed in 1986, and re-interviewed in 1989 and 1994. By 1994 there were 542 deaths, and 513 were lost to follow-up. Blacks and those aged ⩾60 were over-sampled, and weights are used to adjust for this and non-response. More detail on the study can be found in several other publications resulting from these data.[7,34–36]

Measures

Activity limitation is defined as an individual's reported belief that their health hampers their ability to conduct basic daily activities. The ACL study did not include a extensive battery of Activities of Daily Living[37] and Instrumental Activities of Daily Living.[38] It did include individual items on ability walking, climbing stairs, and getting in/out of a chair, and also asked, '(H)ow much are your daily activities limited in any way by your health or health-related problems?' This study uses the latter question, which may be thought of as a one-question substitute for a battery of items. Responses allowed were not at all, a little, some, quite a bit, and a great deal. A little and some are combined into one category called mild activity limitation. Quite a bit is considered as a moderate limitation and a great deal is considered as severe level activity limitation.

Respondents initially reported education as years of formal schooling. Although we tested for single years, and measured discretely in various schemes, we found the most parsimonious and useful coding to be a three-category measure, with categories for less than high school, completed high school, and more than high school education. It should be noted that other coding schemes do not alter substantive findings. For income, a question asked respondents to list combined self and spouse yearly income from all sources before taxes. Those not responding were led through income brackets. This allows those not responding to the open-ended question to be categorized into broad groups. The remaining refusals were given income levels imputed on the basis of regression procedures including income in other waves of the ACL as predictors. A four-category income response variable is constructed (<US$10 000; US$10 000–19 999; US$20 000–39 999; ⩾US$40 000).

Multivariate models adjust for several covariates that are important determinants of health outcomes. These are age, sex (male or female) race (white, black and other), and marital status (married and unmarried). All covariates are measured at baseline. Table 1 provides the number of cases and per cent distribution for the originating and outcome status, and all explanatory measures. For ease of presentation in this Table, age is categorized here into five categories, but is treated as a continuous variable in multivariate models.

Table 1 Descriptive information on study variables (weighted sample, N = 3617)

	No. of cases	Per cent
Originating status		
No limitations	2598	71.8
Mild	716	19.8
Moderate	148	4.1
Severe	155	4.3
Outcome status		
No limitations	1621	47.5
Mild	799	23.1
Moderate	109	3.2
Severe	105	3.0
Did not survive	349	10.1
Did not respond	451	13.1
Explanatory variables		
Less than high school education	925	25.6
Completed high school	1134	31.4
More than high school	1558	43.1
Income		
<US$10 000	694	19.2
US$10 000–19 999	748	20.6
US$20 000–39 999	1271	35.1
US$40 000+	904	25.0
Age (years)		
<40	1530	42.3
40–49	676	18.7
50–59	485	13.4
60–69	479	13.2
⩾70	445	12.3
Gender		
Male	1703	47.1
Female	1914	52.9
Race		
White	2698	83.1
Black	389	10.9
Other race	215	6.0
Marital status		
Married	2649	73.2
Not married	968	26.8

Conceptualization and modelling

The originating status is activity limitation measured in 1986 and the outcome status is measured in 1994. *Onset* refers to having no limitation at origin and having a limitation of any severity at outcome. Progression refers to the movement from a particular severity of limitation at origin (mild, moderate, or severe) to a particular status at outcome. Progression can refer to staying the same as well as changing status. A transition probability is the probability that an individual with a particular limitation status at origin has a particular outcome status. The sum of transition probabilities from any originating status is 1.0. The aim of the analysis is to determine whether education and income are associated with these activity limitation transition probabilities.

It is understood that any one individual who reports no limitations at origin and outcome may have experienced limitations during the inter-survey period. It is also understood that an individual who has a particular severity at origin may have gone through several different transitions over the inter-survey period. Although this is true, we can also assume that the characteristics that relate to onset and progression will relate to the chance of experiencing limitations or limitations of a particular severity at any point in time. For instance, if older adults are more likely than are younger adults to have functional limitations, then the probability that an individual who does not have a limitation at origin will subsequently report a limitation at outcome will be related to age. In this way, we assume that onset and progression, defined by using two stationary points in time, relates to onset and progression measures using continuous time.

If onset and progression are a function of different sets of determinants, then transitions need to consider two discrete groups. Those reporting no limitation at origin are within the first group. For this group, we monitor the probability of an onset. The second consists of those who report limitations at time of origin. For these individuals we determine probabilities related to progression. We categorize progression as remaining the same severity, improving, or getting worse.

We consider two additional transitions for each group. First, we consider not surviving the inter-survey period. Second, we consider not responding to the follow-up. About 13% of the original sample were non-respondents at outcome and it is possible that they have different education, income, and other characteristics than those who do respond to the follow-up. These additional two outcomes need to be considered in order to assure that our models are not biased due to selectivity.

Although we are mostly interested in education and income, onset and progression are also considered to be a function of age, sex, marital status, and race. In addition, progression may be a function of severity of limitations at time of origin. Grudy and Glaser[27] for instance, showed that improvement in status is more likely for those with higher levels of severity. Survival should also be related to severity of activity limitation at origin.

Since the outcomes for both onset and progression are non-ordered categorical responses, we utilize multinomial logistic regression equations procedures to estimate probabilities. The model estimates a set of coefficients that correspond to each possible outcome category. For example, given four outcomes, the probability of outcome 1 is:

$$\Pr(Y = 1) = (\exp \beta x^{(1)})/(\exp \beta x^{(1)} + \exp \beta x^{(2)} + \exp \beta x^{(3)} + \exp \beta x^{(4)})$$

where βx represent a vector of coefficients and set of characteristics. To identify this model, it is necessary to set one $\beta x = 0$. Thus, if $\beta x^{(1)} = 0$, the remaining coefficients measure the change in probability relative to $\beta x^{(1)}$. Setting a different contrast category changes coefficients, but predicted probabilities for groups remain the same. Unless the contrast category chosen is the one of ultimate interest, it is often more intuitive to examine predicted probabilities with multinomial response categories than coefficients estimated from the model. We examine both coefficients and predicted probabilities.

Our models presented below include both education and income. Analyses entering education and income separately differ little from those shown below. All procedures were conducted using the Stata Version 7.0 statistical software. Weighting for multivariable procedures is conducted using sampling or 'probability' weights, as they are called in Stata, meaning that

weights are treated as the inverse of the probability that the observation is included due to the sampling design.[39]

Results

Originating and outcome status

Table 2 shows survival to be strongly dependent upon originating status. The proportion not surviving the inter-survey period is about 5% for those originating without any activity limitation, 16% for those with mild, 33% for those with moderate, and 44% for those with severe limitation. In contrast, non-response varies only modestly and non-monotonically by originating status, with a tendency for non-response to be highest among those without limitations. This suggests that the selection in terms of non-response is not substantially determined by functioning.

For those who do survive, outcomes are dependent upon originating status. About 58% of those without limitations at time of origin are limitation free at outcome compared with 25%, 9%, and 7% of those with mild, moderate, and severe limitations. There is also a fair amount of movement in and out of states of limitation and around levels of severity. Complete recovery is least likely for those originating with severe limitation and most likely for those originating with mild limitation, but the chance of some improvement is substantial for all.

Determinants of onset

Table 3 presents the model predicting transition probabilities for the group originating without limitations (n = 2556). Results presented are odds ratios (OR). Remaining without limitation is the contrast and outcomes of onset, not surviving, and not responding, are viewed relative to remaining without. OR of greater than 1.00 indicate a higher probability of an onset, dying, or not responding, while OR of less than 1.00 indicate a greater probability of remaining without limitation. The 95% CI around the OR are shown in parentheses.

Both education and income are significant determinants of onset. Those completing high school or with more than high school education are less likely to experience an onset, and the same can be said for those with higher levels of income. Education and income relate strongly to survival as well, with those with high school or more education and those with higher levels of income being less likely to die relative to remaining without limitations. (Further analyses not shown here suggest small but insignificant additional gains after high school and >US$40 000.) Those with higher education, and those with higher income, are

Table 2 Outcome activity limitation status by originating status

	Originating status			
Outcome status	No limitations	Mild limitations	Moderate limitations	Severe limitations
Activity				
No limitations	57.9%	24.7%	8.7%	7.0%
Mild	19.0	40.7	26.8	10.6
Moderate	1.7	5.4	13.0	9.2
Severe	1.9	3.7	7.2	16.2
Does not survive	5.4	16.0	32.6	44.4
Does not respond	14.2	9.4	11.6	12.7
n	2,556	680	138	142
χ^2		861.3 $P < 0.000$		

Table 3 Multinomial regression odds ratios (OR) for onset of functional limitations (95% CI in parentheses)

	Has an onset versus Remains without limitations	**Does not survive versus Remains without limitations**	**Does not respond versus Remains without limitations**
Less than high school education	–	–	–
Completed high school	0.56** (0.41, 0.75)	0.53* (0.31, 0.89)	0.68* (0.47, 0.98)
More than high school	0.56** (0.42, 0.77)	0.61 (0.35, 1.06)	0.49** (0.33, 0.71)
Income <US$10 000 (comparison)	–	–	–
Income US$10 000–19 999	0.83 (0.57, 1.21)	0.59 (0.33, 1.06)	0.90 (0.59, 1.37)
Income US$20 000–39 999	0.72 (0.50, 1.03)	0.31** (0.16, 0.59)	0.64* (0.42, 0.97)
Income US$40 000+	0.59** (0.40, 0.89)	0.19** (0.08, 0.41)	0.55* (0.35, 0.88)
Age	1.03* (1.02, 1.04)	1.10** (1.09, 1.12)	1.00 (0.99, 1.00)
Gender (Female = 1)	1.05 (0.85, 1.29)	0.30** (0.19, 0.46)	0.91 (0.71, 1.17)
White (comparison)	–	–	–
Black	1.51* (1.08, 2.11)	2.88** (1.64, 5.07)	2.51** (1.79, 3.53)
Other race	2.85** (1.95, 4.18)	1.58 (0.51, 4.88)	2.22** (1.37, 3.59)
Marital status (Married = 1)	1.06 (0.82, 1.39)	0.86 (0.53, 1.39)	0.68** (0.50, 0.91)
LL		–2418.2	
LR χ^2 (model)		561.0**	

**$P < 0.01$, *$0.01 < P < 0.05$, $0.05 < P < 0.10$.

less likely to respond to the follow-up relative to remaining without limitations. Associations with other covariates are generally as would be expected. For instance, higher age is associated with a greater probability of having an onset and not surviving.

Determinants of progression

Table 4 displays results for those originating with limitations. Since these are individuals who have limitation, staying the same is not necessarily a favourable outcome, although it is more favourable than getting worse. Improvement of status is the comparison. OR greater than 1.00 indicate a higher probability of remaining the same, getting worse, not surviving, or not responding. Ratios less than 1.00 indicate a higher probability of improving. Those beginning with severe limitations cannot get worse, and this coefficient is omitted (it is statistically zero). Again, 95% CI are shown in parentheses.

The principal difference between this model and the previous one is that education generally ceases to be predictive with the only significant coefficient indicating, contrary to expectations, that people in the highest educational category are more likely to stay the same relative to improving. (We find this also in models considering education without income, therefore the result is not a function of shared variance.) In contrast, those in the highest income category, when compared with the lowest category, are less likely to stay the same relative to improve, and less likely to get worse relative to improve. In other words, those in the highest income category are more likely to improve in status. Those in the highest two income brackets are less likely to die relative to improving. The relationship between education and survival is also not generally significant, though any relationship that does exist is in the opposite direction of expectations. As for the other covariates, it appears as if only age continues to have a strong influence on transition probabilities. Results also show strong associations with the originating status. Those who originate with moderate or severe activity limitations are more likely to improve than are those who originate with mild limitations. For both Tables 3 and 4, interactions between education and income on the one hand and functional status at origin on the other were tested (results not shown) but they did not significantly improve the models.

Predicted probabilities

Given that multinomial regression must, by definition, define a contrast outcome, the direction and magnitude of relationships that do not involve the contrast are difficult to determine just by looking at the coefficients. Figure 1 presents a series of predicted probability plots to clarify associations. The plots show transition probabilities derived by using coefficients from the previous

Table 4 Multinomial regressions odds ratios (OR) for progression of functional limitations (95% CI in parentheses)

	Stays the same versus Improves	Gets worse versus Improves	Does not survive versus Improves	Does not respond versus Improves
Functioning difficulties				
at start of period mild (comparison)	–	–	–	–
Moderate	0.16**	0.31**	0.56	0.44*
	(0.09, 0.30)	(0.14, 0.68)	(0.31, 1.01)	(0.21, 0.90)
Severe	0.27**	–	1.65	0.77
	(0.15, 0.48)		(0.92, 2.95)	(0.39, 1.54)
Less than high school education	–	–	–	–
Completed high school	0.99	0.54	1.18	0.58
	(0.61, 1.61)	(0.24, 1.15)	(0.66, 2.09)	(0.30, 1.12)
More than high school	1.55	1.03	1.03	0.63
	(0.94, 2.56)	(0.49, 2.15)	(0.55, 1.92)	(0.31, 1.28)
Income <US$10 000 (comparison)	–	–	–	–
Income US$10 000–19 999	0.77	0.98	0.62	1.22
	(0.45, 1.31)	(0.46, 2.09)	(0.34, 1.15)	(0.63, 2.37)
Income US$20 000–39 999	0.70	0.52	0.44*	0.51
	(0.40, 1.22)	(0.22, 1.21)	(0.22, 0.88)	(0.23, 1.14)
Income US$40 000+	0.38**	0.23*	0.24**	0.14**
	(0.20, 0.74)	(0.07, 0.72)	(0.09, 0.62)	(0.03, 0.55)
Age	1.03**	1.04**	1.12**	1.03**
	(1.02, 1.04)	(1.02, 1.06)	(1.10, 1.14)	(1.01, 1.05)
Gender (Female = 1)	0.82	0.68	0.30**	1.01
	(0.57, 1.19)	(0.38, 1.22)	(0.19, 0.48)	(0.58, 1.76)
White (comparison)	–	–	–	–
Black	1.16	1.55	1.73	1.85
	(0.61, 2.23)	(0.61, 3.90)	(0.80, 3.74)	(0.85, 4.00)
Other race	0.87	1.74	1.35	1.34
	(0.41, 1.87)	(0.64, 4.75)	(0.50, 3.61)	(0.49, 3.66)
Marital status (Married = 1)	1.05	1.09	0.75	0.83
	(0.67,1.65)	(0.56, 2.15)	(0.44, 1.29)	(0.46, 1.49)
LL		–1159.4		
LR χ^2 (model)		462.8**		

**$P < 0.01$, *$0.01 < P < 0.05$, $0.05 < P < 0.10$.

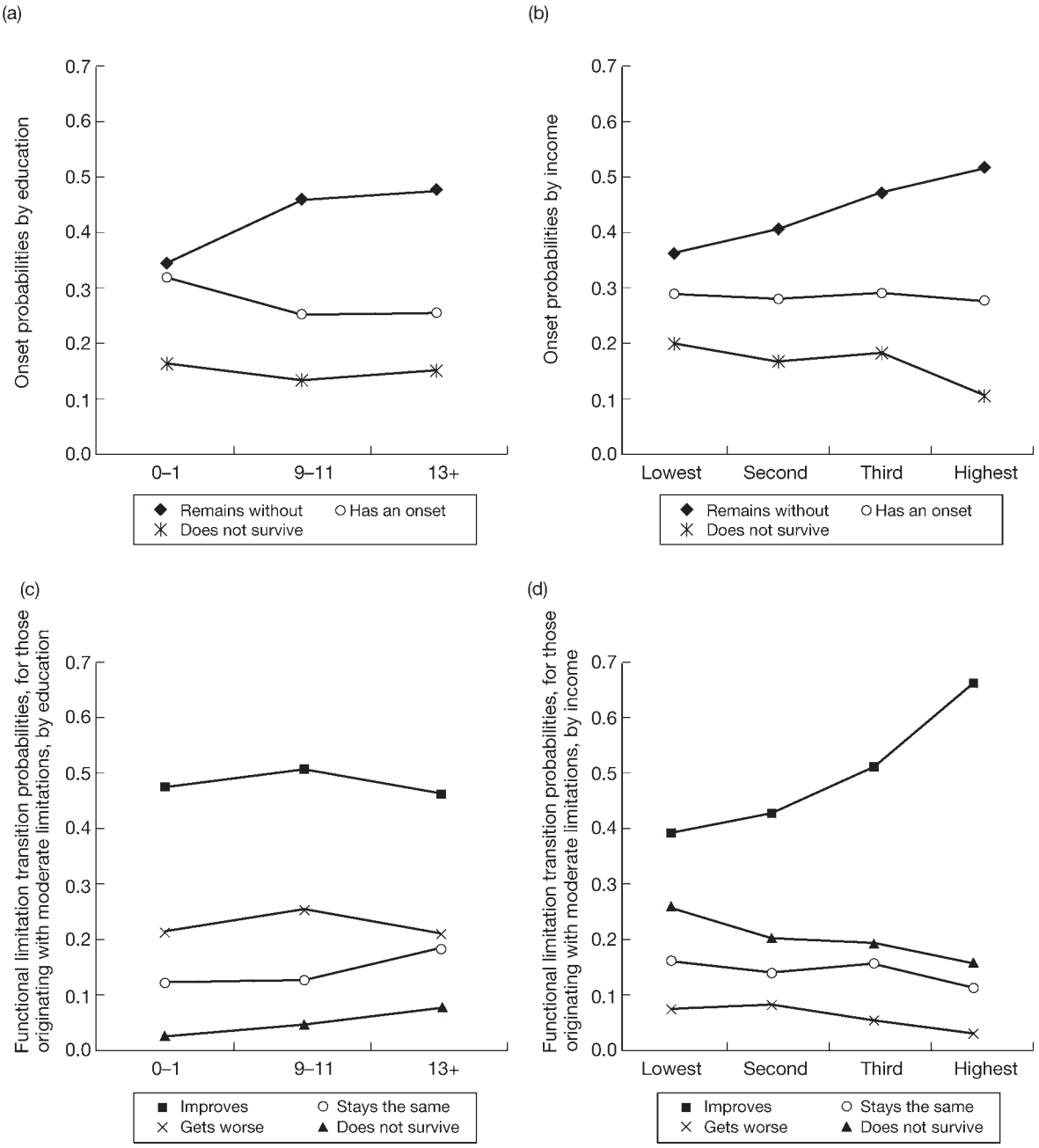

Figure 1 Estimated probabilities of selected transitions by education and income

models. Non-response is omitted as an outcome, so the sum of probabilities is not 1.0. The probabilities hold other variables constant such that they are averages for the sample.

Figure 1(a and b) shows probabilities associated with onset; (a) shows these probabilities for the three categories of education and (b) by the four income categories. Figure 1(a) shows education to be strongly associated with onset of activity limitation. The probability that someone without a limitation at time of origin remains limitation free by outcome increases from about 0.35 for those with without completed high school, to about 0.45 for those completing high school, and then levels off for those with more than high school education. At the same time, the probability of having an onset decreases from about 0.32 to about 0.25. The probability of dying remains fairly flat. The probability of remaining without limitations also increases with increasing income. The chances of dying decrease with increasing income from about 0.20 for those in the lowest income category to about 0.08 for those in the highest.

Figure 1(c and d) shows probabilities associated with progression. We examine probabilities only for those originating with moderate limitations, so 'improves' means having an outcome of no or mild limitations and 'gets worse' means having an outcome of severe limitations. Associations between education and progression are flat. For instance, the probability of

improving is about 0.50 regardless of level of education. The probability of improving, however, increases substantially with income from about 0.39 to about 0.66 between the lowest and highest income levels. There is also a decrease in the probability of not surviving by income.

Further tests

In order to further test the robustness of our findings, we conducted other procedures and sensitivity tests. Already mentioned were tests for associations considering education and income separately, tests for education measured continuously and using various categorizations, and various interactions. We noted some additional beneficial effect of education on onset at the very upper levels, for instance, among those with ⩾17 years of formal schooling, although the additional benefit is generally not significant. We also examined various measures of functional status using different survey items, and results did not differ substantially from those reported here.

Since most 'events', for instance deaths, will occur to those at older ages, we examined equations that stratified by age and interactions of socioeconomic status by age. Also, because of potential differences in effects across gender, we examined our results for men and women separately. At times these results are not very meaningful because of small cell sizes resulting from dividing the sample further, particularly when examining progression, since fewer originate with limitations. Nonetheless, the results are worth reporting since they not only serve to affix some additional perspective to the analyses but suggest direction for further research. For the most part, results were consistent across ages and sex. Interactions showed that income effects were a little less important as age increased, which makes some sense since current income should be a less distinguishing indicator of status once people begin to retire. Education had a somewhat greater influence on the chances of improving status among those originating with limitations at younger ages. Although this was not consistent across the transitions, it is a reasonable finding if it is assumed that limitations at younger ages tend to be more acute and subject to fluctuation rather than the chronic types of limitations that are more characteristic at older ages.

Finally, disadvantages inherent in separating the sample into smaller sizes include making estimates less stable and not allowing for determination of whether differences in effects are statistically significant. We addressed this by pooling samples and examining equations that predicted outcomes (no limitations, mild, moderate, severe, did not survive, did not respond) using interaction terms for education and income by originating status. The results are consistent with those shown above. There are significant interactions between education and originating status. These interaction effects serve to lessen the effect of education on outcome status for those who originate with limitations. There are no significant interactions with income, suggesting that income operates more consistently across originating statuses.

Conclusion

In order to advance our understanding of the mechanisms through which socioeconomic status factors relate to health, the current study examined transition models for onset and progression of functional limitation. Education was strongly associated with onset, while income was found to have associations with both onset and progression. We conclude that education and income have varying effects and that onset and progression are a function of different sets of predictors. This is generally consistent with our expectations, suggesting the necessity of attending increasingly to the different ways in which socioeconomic variables relate to health outcomes. Education, which is largely completed and fixed by early adulthood, exerts a pervasive effect on trajectories of experience in early and middle adulthood, has strong effects on the onset of functional health problems (or the avoidance thereof), but little or no effect on the progression of such problems among those who already manifest them at baseline. Income affects the onset of functional health problems, and equally affects the course of such problems, especially the chances of improvement and avoidance of further decline.

We also saw that mortality is differentially influenced by education and income. Both appear to improve survival chances among those who originate healthy. Education has less influence among those who originate with limitations. This finding is in contrast to earlier studies that do not examine survival separately among those originating in different states of health. It may be that those with higher education are better able to ward off health disorders that threaten survival. But, when problems do arise to those with high levels of education, they may be of equal or greater seriousness in comparison to the health problems that arise for those with lower levels of education.

Some of the current findings are consistent with the results of other recent studies, some of which also use the ACL data. Lantz *et al.*[34] find that income is better able to predict mortality, which is normally the outcome of the progression of disease. In contrast, Lantz *et al.*[7] find that education is as or more predictive than income of changes in functional self-rated health, these changes reflecting not only the course of existing health problems but also the onset of new problems, with the present study isolating this onset. Education is more predictive of risky health behaviours which contribute to onset of health problems with a long latency (i.e. smoking, drinking, and eating patterns), while income is more predictive of a health behaviour (physical exercise) with more immediate effects on health, even among those with disease.[34] Examining physical functioning among older adults, Zimmer *et al.*[24] in Taiwan, and Grundy and Glaser[33] in Britain, find education to be predictive of the incidence or onset of a functional problem among those beginning an observation period in a healthy state, but not predictive of changes in function among those originating with problems. Together, these studies are beginning to suggest the need to separate out socioeconomic influences according to specific stages of the disease and disability to further understand the processes involved.

There are limitations to the current study. First, loss to follow-up tends to be a problem in most panel research. To the extent that the predictors operate the same way in the non-respondent group as in the respondent group, modelling the loss to follow-up as a transition adjusted for some of this in the current analysis. Those lost to follow-up tend to have higher levels of education and income than respondents, and they are more likely white and married (Tables 3 and 4). Individuals with these types of characteristics tend to be in the functionally healthier group. If their transitions follow the patterns

found, then participation of those that were lost would have strengthened significance of associations. However, there is also the possibility that those lost are a unique group. Since we cannot be certain about their health transitions, loss to follow-up remains a limitation.

Second, our outcome measure of functional limitation is somewhat limited, being based on responses from a single item. The ACL questionnaire included other functional items, like ability walking, climbing stairs, and getting out of a chair. We examined these individually and together as an index, and the results do not vary substantially from those reported herein. Other analyses of this data show that the single item measure we used behaves similarly to other indices of self-assessed and chronic health conditions[7,35] However, it would be informative if the current methodology were expanded to analyses of the onset and progression of other types of health problems, including clinical measures of health.

Third, the number of cases does not allow us to confidently stratify to assess whether associations are similar across age and sex groups. This is particularly true for the group that originates with limitations. However, as noted above, initial indications are that there may be at least some moderate differences in effects for the younger versus older groups, while the effects of income may be stronger for men than for women. We suggest future study would do well to examine interactions more carefully.

Despite these limitations, the results have implications for our understanding of functional health and socioeconomic disparities therein, and for the potential application of such understanding. Education is an early life experience, but has implications for later life health. We interpret our results to suggest that education is associated with the prevention of functional health disorder. This works through better understanding of the nature of disease and how to avoid illness, for instance, a history of not smoking, healthy diet, and other factors that have long-term impact on prevention. Hence, those with higher education will witness a delay or compression of morbidity. Income is also important with respect to prevention, likely for similar reasons, but income is even more important in terms of facilitating improvement and recovery from problems once they arise. We suggest that this may be a function of the greater ability to treat and manage disease among those with higher income. Higher current income, for instance, may allow individuals to purchase quality health care and other amenities that can assist in recovery. A reverse causal connection with income is also possible since those who become ill are more likely to reduce their employment as a result, leading to declining income. Yet, the current study did examine effects of baseline income on changes in health over time, enhancing the confidence of the causal connection. Further research that uncovers the distinct pathways through which education and income influence the onset and progression of health disorders would assist in further elucidating the distinct processes involved.

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