Data Appendix – For Online Publication

In this appendix, we provide more information on the data employed in the analysis.

National Health Information Survey (NHIS)

The National Health Interview Survey (NHIS) and National Health and Nutrition Examination Survey (NHANES) are sponsored by the National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Maryland. We utilize NHIS data from 2009-2016. Questions on pain, functional limitations, and disability insurance receipt were similar during this time period.

The joint pain questions begin with the question: "The next questions refer to your joints. Please do NOT include the back or neck. DURING THE PAST 30 DAYS, have you had any symptoms of pain, aching, or stiffness in or around a joint?" For people who answer yes, they are asked to identify the specific joints. A final question is: "Did your joint symptoms FIRST begin more than 3 months ago?". We consider chronic knee pain to be joint pain in the knee that began more than 3 months ago. The NHIS data asks about current occupation in all years and longest occupation in 2010 and 2015.

Figure 2 in the paper shows the education gradient in musculoskeletal impairments and chronic knee pain. One concern with these analyses is that the set of people who received more years of education is increasingly selected at older ages, since years of education have increased over time. To address this, we re-estimated the education gradient in these variables using a simulated education measure, as in Meara et al. (2008).[1] We randomly reassign people across adjacent education groups so that the share of people in each five year age-sex cell is equal to the average for that sex among people aged 55-59. Figure A1 shows the alternative measure of the percent of the population with chronic knee pain using this alternative measure of education. The results are very similar to those in Figure 2.

National Health and Nutrition Examination Survey (NHANES)

The NHANES were conducted periodically from the 1970s through the early 1990s and have been continuous since 1999. Questions about knee pain were asked in NHANES I (1971-74), NHANES II (1976-80), NHANES III (1988-94), and the continuous NHANES (1999-04). Our primary regression analysis uses data from the continuous NHANES. Table A1 shows summary statistics for the NHANES data by education.

In the text, we note that estimating the model for the impact of job characteristics on knee pain in the population aged 25-34 shows no relationship between jobs of young adults and knee pain. Those results are shown in Table A2. We also note in the text that the results are generally similar if we include indicators for other conditions in our primary specification. Table A3 shows the impact of including other conditions. These conditions include respiratory disease (asthma,

[1] Meara, Ellen R. Seth Richards, and David M. Cutler, "The Gap Gets Bigger: Changes in Mortality and Life Expectancy By Education, 1981-2000, *Health Affairs*, 2008, 27(2): 350-60.

emphysema, or chronic bronchitis), heart disease (coronary heart disease, angina, heart attack), congestive heart failure, stroke, cancer (divided into skin and other cancer), thyroid disease, liver disease, diabetes, and osteoporosis. All of the conditions are positively related to knee pain, even those that should have no physiological basis for such a relation. Including these variables reduces the size of the education gradient without appreciably changing the impact of physical demands and obesity. Thus, it results in a larger share of the education gradient being attributed to physical demands and obesity.

OsteoArthritis Initiative (OAI)

The OsteoArthritis Initiative (OAI) is a collaborative informatics system created by the National Institute of Mental Health and the National Institute of Arthritis, Musculoskeletal and Skin Diseases (NIAMS) to provide a worldwide resource to quicken the pace of biomarker identification, scientific investigation and OA drug development. Dataset identifier(s): [NIMH Data Archive Collection ID(s) or NIMH Data Archive Digital Object Identifier (DOI)]. We utilized the controlled access datasets distributed from the Osteoarthritis Initiative (OAI), a data repository housed within the NIMH Data Archive (NDA).

The OAI is a longitudinal sample of people at five sites with severe arthritis and pain, or people at risk for severe arthritis and pain. The survey is divided into three cohorts: a progression cohort (N=1,504) with established arthritis and pain, an incidence cohort at risk for arthritis and pain (N=3,504), and a healthy sample (N=123). The sample is not nationally representative, and no weights are reported. The enrollment wave is termed wave "00". All other waves were at annual frequency with the exception of waves 2 and 4, which were at 18 and 30 months. We do not analyze these data. We generally identify the data by the wave in which the observations were recorded.

OAI asks about many dimensions of knee functioning. The primary metric we utilize is the pain subcomponent of the Knee Injury and Osteoarthritis Outcomes Score (KOOS).[2] The pain subcomponent consists of 10 questions. The first question is "How often do you experience knee pain?" with possible answers of never, monthly, weekly, daily, and always. The subsequent 9 questions ask "What amount of knee pain have you experienced in the last week during the following activities? Twisting/pivoting on your knee; Straightening knee fully; Bending knee fully; Walking on flat surface; Going up or down stairs; At night while in bed; Sitting or lying; Standing upright". In each case, possible answers are none, mild, moderate, severe, and extreme. The values to the 9 pain questions are coded from 0-4. The average across the 9 questions is multiplied by 25 and that total is subtracted from 100. Thus, extreme pain in all activities would be scored as 0, while no pain would be scored as 100. For ease in comparing knee pain results with other surveys, we recode the data by not subtracting the total from 100.

There is clear evidence of selection into the OAI. Figure A2 shows that pain is highest in the enrollment wave. Mean reversion happens quickly, however; there is no evidence of a large change in knee pain between the "01" and "03" waves.

[2] https://www.orthopaedicscore.com/scorepages/knee_injury_osteopaedic_outcome_score.html

Section IV of the paper discusses the impact of knee pain on leaving the labor force. This is shown empirically in Figure A3. The sample in the figure is people aged 45-64 who are working for pay or in a family business in the base year. The three figures show the probability of working in the next year, the probability of being not in the labor force due to health, and the probability of being not in the labor force for other reasons. Greater knee pain increases the probability of a transition from work to not in the labor force for other reasons among people with a high school degree or less but not among people who are college graduates.

Midlife Development in the US (MIDUS)

The Midlife in the United States (MIDUS) study has been funded since 1995 by the following: John D. and Catherine T. MacArthur Foundation Research Network, National Institute on Aging (P01-AG020166), and National institute on Aging (U19-AG051426),

The MIDUS survey was first fielded in 1995-96. Sample responders were aged 25-74. There were four samples in the MIDUS: a national sample; oversamples from 5 metropolitan areas; siblings of people in the national sample; and a sample of twin pairs. Table A4 has the sample sizes in the different groups. Because not all of the samples were national, there are no survey weights.

The original MIDUS sample was resampled in 2004-06 (MIDUS 2) and again in 2013-14 (MIDUS 3). The survey added questions about joint pain in these later waves. People are first asked a question: "Do you have chronic pain, that is do you have pain that persists beyond the time of normal healing and has lasted from anywhere from a few months to many years?" People who answer yes are then given a set of choices for where the pain is located. One choice is knees.

Information about jobs is available in a series of questions. We utilized a question asked of people who worked in the past 10 years: "How often does your job require a lot of physical effort?"

Our regression sample is people aged 45-74 in MIDUS 3 who have data on education and chronic knee pain. Table A5 shows summary statistics for the sample. There is a clear difference in physical requirements on the job and in obesity rates by education.

MIDUS asks a number of psychological questions, with many of the scales developed by the researchers. We utilize several of the scales, as discussed in the paper. Table A6 shows the specific variables that go into each scale and the scoring methodology and Table A7 shows the means by education.

Health and Retirement Study (HRS)

The Health and Retirement Study (HRS) is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and conducted by the University of Michigan. HRS is an ongoing longitudinal survey of the population aged 51 and older. Consistent data on whether the person has been limited by arthritis are available from 1995. We sample people aged 45-74 to minimize the importance of selective mortality by education in the older population. Table A8

shows the regression discontinuity estimates of the impact of reaching age 65 on arthritis treatment, along with the difference-in-difference estimates between the less and more educated populations.

Coronary Artery Risk Development in Young Adults (CARDIA)

The Coronary Artery Risk Development in Young Adults (CARDIA) study is supported by contracts HHSN268201800003I, HHSN268201800004I, HHSN268201800005I, HHSN268201800006I, and HHSN268201800007I from the National Heart, Lung, and Blood Institute (NHLBI). The study enrolled 5,115 people aged 18-30 at four sites in 1985-86. The data on blood pressure response to stressors are from the second wave of the study. Education is based on completed information as assessed in later waves of the survey. Because the data are from particular sites, no weights are provided.

Job Characteristics Data

Our data on job characteristics come from England and Kilbourne.[3] The original sources are as follows. The National Academy of Sciences assembled a file linking information from the 1977 Dictionary of Occupation Titles (DOT) to 1970 Census occupation and industry codes.[4] This was averaged across individuals within an occupation to form a single measure of occupation information using 1970 occupation codes. This latter file was merged to a dataset from Treiman,[5] which had information on both 1970 and 1980 occupation codes for a sample of people in the 1970 Census. The result is a file with 1977 DOT information for 1980 Census occupation codes. We modified the file in two ways. First, the original file from England and Kilbourne had information on education requirements but not the components of education requirements (reasoning, math, and language). To follow the definitions of Autor and Dorn (2013), we repeated the process to add in the math education level. Second, we used data from the Census bureau to crosswalk 1980 occupation codes to 1990 occupation codes[6] (which are in the NHANES) and 2000 occupation codes[7] (which are in NHIS).

Abstract work is defined as the average of the level of math in the occupation and the extent to which the job requires adaptability to accepting responsibly for the direction, control, and planning of an activity. Routine work is the average of a five-point finger dexterity measure and the percent of workers requiring adaptability to situations requiring the precise attainment of set limits, tolerances, or standards. Manual work is defined as the share of workers whose job requires

[3] England, Paula, and Kilbourne, Barbara. Occupational Measures from the Dictionary of Occupational Titles for 1980 Census Detailed Occupations. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2013-06-20. https://doi.org/10.3886/ICPSR08942.v2

[4] National Academy of Sciences. Committee on Occupational Classification and Analysis. Dictionary of Occupational Titles (DOT): Part I - Current Population Survey, April 1971, Augmented With DOT Characteristics and Dictionary of Occupational Titles (DOT): Part II - Fourth Edition Dictionary of DOT Scores for 1970 Census Categories. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2006-09-06. https://doi.org/10.3886/ICPSR07845.v2

[5] U.S. Bureau of the Census, 2016, "Census of Population and Housing, 1970 Public Use Sample: 15%, One-in-One-Hundred [With 1980 Imputations Prepared by Donald Treiman (1% sample from the SMSA/County Group 15% questionnaire)] (M298V1)", https://doi.org/10.7910/DVN/F8EQSZ, Harvard Dataverse, V1.

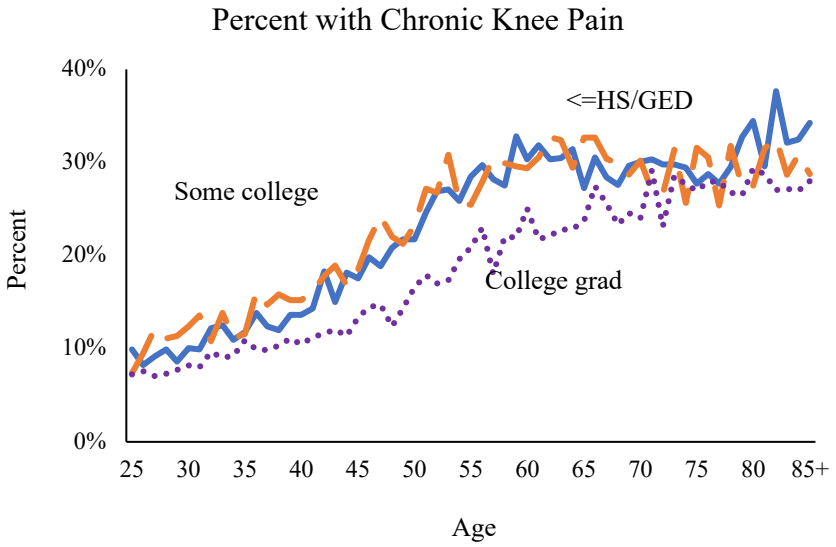
[6] http://unionstats.gsu.edu/IndOcc_80-90.htm

[7] https://www.cdc.gov/niosh/topics/coding/docs/Occ_Census1990_to_Census2000.xls

eye-hand-foot coordination. All variables are standardized prior to averaging, so the resulting indices are standard normal.

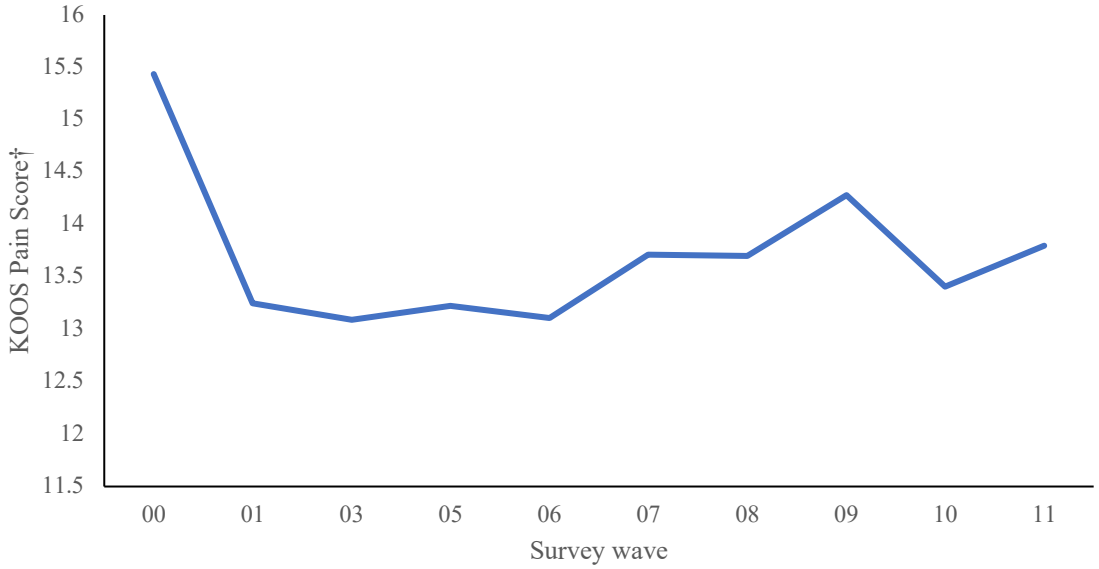
We use factor analysis to group the four measures of physical performance into a physical demands score and the six environmental measures into an environmental factor score. The four physical measures are: (1) a five point strength scale (sedentary, light, medium, heavy, very heavy); (2) the percent of workers engaged in climbing and/or balancing; (3) the percent engaged in stooping, kneeling, crouching, and or crawling; and (4) the percent engaged in reaching, handling, fingering, and/or feeling. The six environmental exposure variables are the percent of workers subjected to: (1) extreme cold with or without temperature changes; (2) extreme heat with or without temperature changes; (3) wet and/or humid conditions; (4) noise and/or vibrations; (5) hazards; and (6) atmospheric conditions. The first eigenvalue is 2.28, and the second eigenvalue is 0.18. Thus, the data are fit well with a single factor.

Figure A1: NHIS results with simulated education



The figure is similar to figure 2 in the paper, with the exception that the share of people by education in each five-year age group is standardized to equal that for the population aged 55-59.

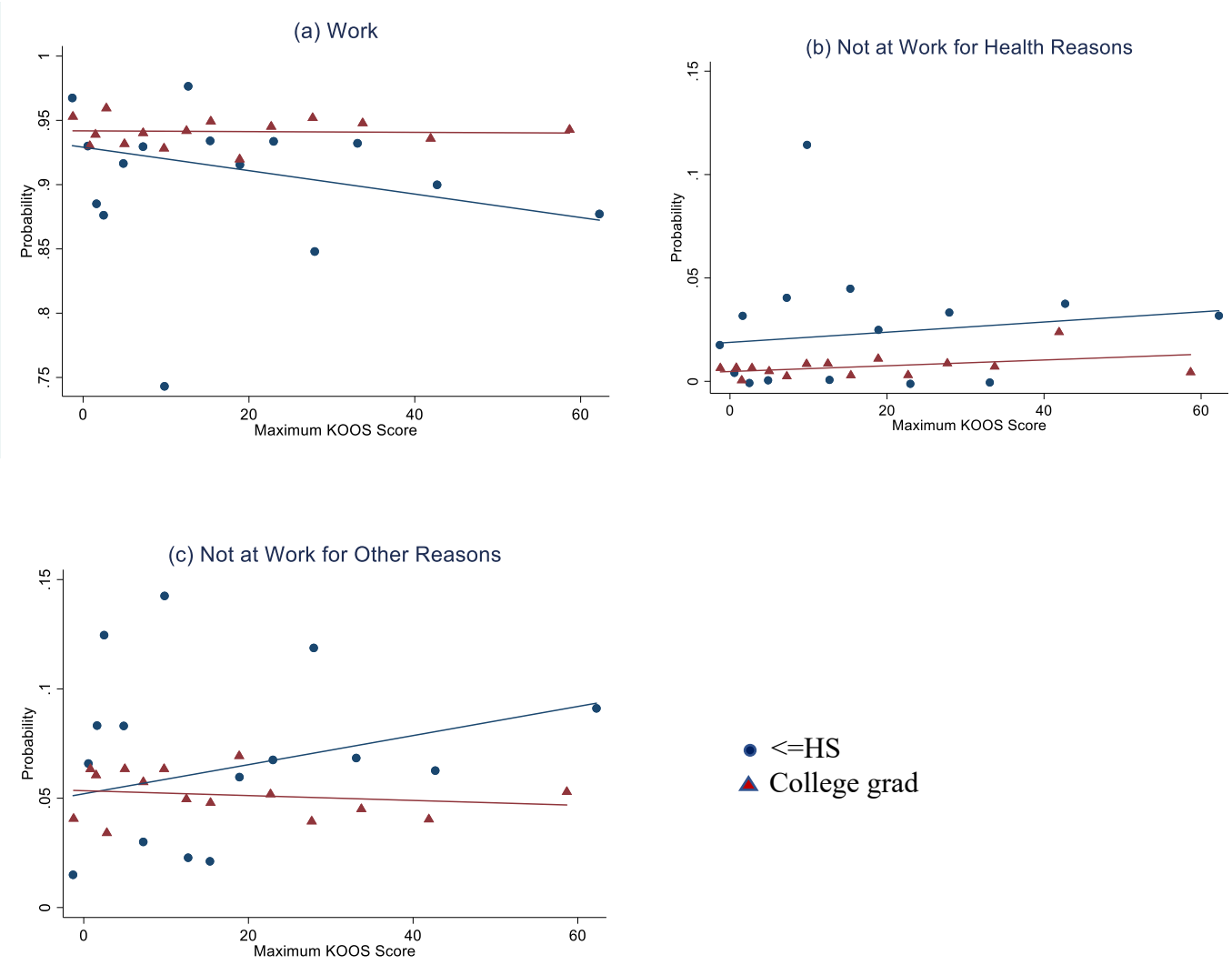
Figure A2: Evidence of Selection in OAI Data



Note: The survey waves are as identified in the survey, where "00" is the first interview wave. Waves 2 and 4 were at 18 and 36 months and are not presented. Thus, the time interval between consecutive waves along the x-axis is one calendar year.

† The KOOS pain score is defined as 100 minus the calculated score, so that a higher number indicates more pain.

Figure A3: Impact of Knee Pain on Work Transitions



Note: Data are from the OAI. The sample is people who are ages 45-64 and are employed in the base year. In each panel, the dependent variable is labor force status in the next wave, one year apart. The knee pain score is the maximum knee pain for both knees. Regressions include individual fixed effects and five-year age-sex dummy variables.

Table A1: Summary Statistics for Continuous NHANES, 1999-2004

Measure	<=High School (47%)	Some college (28%)	College grad (24%)
Demographics			
Average age	57.8	55.2	55.7
Male	46%	46%	55%
Race/Ethnicity			
Non-Hispanic white	69%	81%	85%
Non-Hispanic black	13%	9%	5%
Mexican-American	7%	3%	1%
Other race	4%	4%	6%
Other Hispanic	7%	4%	3%
US born	84%	91%	88%
Veteran	18%	23%	23%
Weight			
Current BMI			
<18.5	1%	1%	1%
18.5-25	27%	30%	35%
25-30	37%	36%	38%
30-35	21%	20%	17%
35+	12%	12%	8%
Missing	2%	2%	1%
Maximum BMI			
<18.5	1%	0%	1%
18.5-25	16%	17%	22%
25-30	33%	35%	40%
30-35	29%	26%	23%
35+	19%	20%	13%
Missing	2%	2%	1%
Job information			
Physical effort factor	0.22	-0.21	-0.62
Abstract work	-0.27	0.04	0.62
Routine work	0.01	0.12	-0.33
Manual work	0.11	-0.16	-0.22
Armed force / Missing occupation / Never work	6%	2%	2%

Note: The sample is people aged 45-74. Data are weighted using survey weights. The total sample size is 6,371 people.

Table A2: Impact of Job Characteristics on Knee Pain in People Aged 25-34, NHANES, 1999-2004

	Dependent Variable: Pain in Either Knee	
Independent Variable	**(1)**	
Education		
Some college	0.004	(0.013)
College graduate	-0.023	(0.015)
Job attributes on current job		
Physical demands	-0.004	(0.012)
Abstract work	-0.005	(0.010)
Routine work	0.021**	(0.018)
Manual work	0.003	(0.011)
Current BMI		
Underweight	-0.049	(0.034)
Overweight	0.010	(0.013)
Obese	0.040**	(0.016)
Morbidly obese	0.071**	(0.020)
N	2,669	
R^2	.033	

Note: All regressions control for five-year age-sex cells, race and ethnicity dummy variables, a dummy variable for veteran status, and a dummy variable for being US born.
**(*) indicates statistically significant at the 5% (10%) level.

Table A3: Robustness of Knee Pain Results to Including Other Conditions

	Dependent variable: Pain in either knee			
Independent Variable	**(1)**		**(2)**	
Education				
Some college	-0.003	(0.012)	0.005	(0.012)
College graduate	-0.032**	(0.012)	-0.006	(0.014)
Job attributes on longest job				
Physical demands	---		0.022**	(0.009)
Abstract work	---		0.016*	(0.008)
Routine work	---		0.015**	(0.006)
Manual work	---		0.010	(0.008)
Current BMI				
Underweight	---		0.072	(0.055)
Overweight	---		0.008	(0.016)
Obese	---		0.049**	(0.022)
Morbidly obese	---		0.162**	(0.029)
Maximum BMI				
Underweight	---		-0.107	(0.082)
Overweight	---		0.047**	(0.018)
Obese	---		0.093**	(0.022)
Morbidly obese	---		0.047*	(0.028)
Other conditions				
Respiratory	0.069**	(0.013)	0.063**	(0.013)
Ischemic heart disease	0.094**	(0.018)	0.088**	(0.017)
Congestive heart failure	0.013	(0.029)	0.001	(0.029)
Stroke	0.107**	(0.027)	0.099**	(0.027)
Skin cancer	0.019	(0.027)	0.020	(0.026)
Other cancer	0.029*	(0.017)	0.034**	(0.017)
Thyroid	0.077**	(0.015)	0.069**	(0.015)
Liver	0.045**	(0.022)	0.051**	(0.022)
Diabetes	0.069**	(0.016)	0.031**	(0.016)
Osteoporosis	0.134**	(0.020)	0.138**	(0.020)
N	6,366		6,366	
R^2	.053		.081	
Change in coefficient on college grad	**---**		**82%**	
From physical demands	**---**		**59%**	
From obesity	**---**		**44%**	

Note: Data are from the NHANES, 1999-2004. The sample is people aged 45-74. Data are weighted to national totals. All regressions control for five-year age-sex cells, race and ethnicity dummy variables, a dummy variable for veteran status, and a dummy variable for being US born. In column 2, dummy variables are included for whether the person's longest job was in the armed forces, was missing, and whether the person never worked and for missing current BMI and maximum BMI. **(*) indicates statistically significant at the 5% (10%) level.

Table A4: Sample Size in the MIDUS Survey

Sample group	MIDUS 1 (1995-96)	MIDUS 2 (2004-06)	MIDUS 3 (2013-14)
Main sample	3,487	2,257	2,423
City oversamples	757	489	---
Siblings of main sample	950	733	677
Twin pairs	1,914	1,484	1,360
Total	7,108	4,963	4,460

Table A5: Sample Means in the MIDUS Survey

Sample group	<= High School	Some College	College Grad
N	452	494	838
Average age	65.8	63.5	62.2
Job requires physical effort (MIDUS 2)			
All of the time	11%	6%	2%
Most of the time	19%	11%	7%
Some of the time	23%	27%	17%
Little of the time	21%	30%	38%
Never	12%	17%	31%
Refused	6%	6%	4%
No work in 10 years	7%	2%	1%
BMI (MIDUS 3)			
Underweight / Normal weight	24%	29%	33%
Overweight	34%	36%	38%
Obese	23%	20%	17%
Morbidly obese	16%	13%	9%
Missing	4%	3%	3%

Note: The sample is people aged 45-74 in MIDUS 3.

Table A6: Psychological Questions in the MIDUS

Area	Specific Questions	Scoring
Life Satisfaction	Using a scale from 0 to 10 where 0 means "the worst possible life overall" and 10 means "the best possible life overall," how would you rate your life overall these days?	---
Affect	During the past 30 days, how much of the time did you feel… Answers: 1 All of the time; 2 Most of the time; 3 Some of the time; 4 A little of the time; 5 None of the time	Mean across set of items, scaled so that higher scores reflect higher levels of positive, negative affect
Positive	(a) cheerful? (b) in good spirits? (c) extremely happy? (d) calm and peaceful? (e) satisfied? (f) full of life?	
Negative	(a) so sad that nothing could cheer you up? (b) nervous? (c) restless or fidgety? (d) hopeless? (e) that everything was an effort? (f) worthless?	
Sense of control		
General	The next set of questions deal with your views of yourself. Please indicate how strongly you agree or disagree with each of the following statements. Possible answers: 1 Strongly agree; 2 Somewhat agree; 3 A little agree; 4 Neither agree nor disagree; 5 A little disagree; 6 Somewhat disagree; 7 Strongly disagree 1) Personal Mastery: c. I can do just about anything I really set my mind to. f. When I really want to do something, I usually find a way to succeed at it. h. Whether or not I am able to get what I want is in my own hands. i. What happens to me in the future mostly depends on me. 2) Perceived Constraints: a. There is little I can do to change the important things in my life. b. I often feel helpless in dealing with the problems of life. d. Other people determine most of what I can and cannot do. e. What happens in my life is often beyond my control. g. There are many things that interfere with what I want to do. i. I have little control over the things that happen to me. j. There is really no way I can solve the problems I have. k. I sometimes feel I am being pushed around in my life.	Mean of 12 items, where personal mastery questions are reverse-coded so that higher scores represent higher levels of perceived control.

Table A6 continued

Area	Specific Questions	Scoring
Health	Please indicate how much you agree or disagree with the following statements by circling the appropriate number. Possible answers: 1. Strongly agree; 2 Somewhat agree; 3 A little Agree; 4 Neither agree or disagree; 5 A little disagree; 6 Somewhat disagree; 7 Strongly disagree. a. Keeping healthy depends on things that I can do. b. There are certain things I can do for myself to reduce the risk of a heart attack. c. There are certain things I can do for myself to reduce the risk of getting cancer. d. I work hard at trying to stay healthy.	Average across items
Psychological well-being	The next set of items explore your well-being. Please indicate how strongly you agree or disagree with each of the following statements. Possible answers: 1 Strongly agree; 2 Somewhat agree; 3 A little Agree; 4 Neither agree or disagree; 5 A little disagree; 6 Somewhat disagree; 7 Strongly disagree.	Sum across items, first reverse coding items with an (R) so that higher values imply greater agreement with the concept.
Autonomy	m. I tend to be influenced by people with strong opinions. s. I have confidence in my opinions, even if they are contrary to the general consensus. (R) kk. I judge myself by what I think is important, not by the values of what others think is important. (R)	
Environmental mastery	b. In general, I feel I am in charge of the situation in which I live. (R) h. The demands of everyday life often get me down. t. I am quite good at managing the many responsibilities of my daily life. (R)	
Personal growth	i. I think it is important to have new experiences that challenge how you think about yourself and the world. (R) aa. For me, life has been a continuous process of learning, changing, and growth. (R) gg. I gave up trying to make big improvements or changes in my life a long time ago.	
Positive relations with others	j. Maintaining close relationships has been difficult and frustrating for me. bb. People would describe me as a giving person, willing to share my time with others. (R) hh. I have not experienced many warm and trusting relationships with others.	

Table A6 continued

Area	Specific Questions	Scoring
Purpose in life	e. I live life one day at a time and don't really think about the future. oo. Some people wander aimlessly through life, but I am not one of them. (R) qq. I sometimes feel as if I've done all there is to do in life.	
Self-acceptance	f. When I look at the story of my life, I am pleased with how things have turned out. (R) x. I like most parts of my personality. (R) dd. In many ways I feel disappointed about my achievements in life.	
Somatic amplification	Please indicate the degree to which each of the following statements is true of you in general. Possible answers: 1 Not at all true; 2 A little bit true; 3 Moderately true; 4 Extremely true. a. I am often aware of various things happening within my body. b. Sudden loud noises really bother me. c. I hate to be too hot or too cold. d. I am quick to sense hunger contractions in my stomach. e. I have a low tolerance for pain.	Average across items

Table A7: Differences in Psychological Factors by Education

	<=High school	Some college	College grad	p-value: CG v. <=HS
Joint Pain				
Chronic knee pain onset	11.5%	9.9%	7.4%	.015
Psychological measures				
Life satisfaction (1-10)	7.86	7.83	7.99	.116
Affect (1-5)				
Positive affect	3.37	3.44	3.45	.052
Negative affect	1.57	1.47	1.44	.000
Sense of control (1-7)				
General	5.43	5.63	5.76	.000
Health	6.00	6.12	6.17	.001
Psychological well-being (10-49)				
Autonomy	35.9	37.0	37.3	.000
Environmental mastery	37.3	38.3	39.0	.000
Personal growth	37.2	39.5	40.3	.000
Positive relations with others	39.9	40.9	41.1	.003
Purpose in life	38.2	39.0	40.3	.000
Self-acceptance	36.8	37.8	39.7	.000
Somatic Amplification Scale (1-4)	2.45	2.40	2.35	.002

Note: Data are from MIDUS. The sample is people aged 45-74 in the 3rd wave of the survey. Chronic knee pain onset is the probability that a person without chronic knee pain in the second wave of the survey reports chronic knee pain in the third wave. The psychological variables are measured in the second wave.

Table A8: Impact of Reaching Age 65 on Access to Medical Care

Outcome	<=High School (N=13,270)	College Grad (N=2,689)	<=HS–Coll Grad
Any health insurance	.098**	.047**	.051
	(.023)	(.024)	(.033)
See a doctor for arthritis	.010	-.015	.026
	(.045)	(.111)	(.120)
Medication	-.007	-.199	.192
	(.046)	(.112)	(.121)
Joint surgery	-.030	-.012	-.018
	(.024)	(.061)	(.065)

Note: Data are from the Health and Retirement Study, 1995-2014. The sample is people aged 51-74 who report that arthritis limited their usual activity in the previous wave. Data are weighted to national totals. The first two columns present the regression discontinuity estimates of the impact of reaching age 65 on the indicated outcome. The N is the number of observations in the regression for taking medication and is approximately the same as for the other outcomes. The third column is the difference between the two regression discontinuity estimates. All regressions use a triangular kernel and control for gender, race, Hispanic ethnicity, and survey wave. Robust standard errors are reported in parentheses.
**(*) indicates statistically significant at the 5% (10%) level.