Socioeconomic Status, Perceptions of Pain, and the Gradient in Disability Insurance*

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Abstract

Reports of physical and mental pain differ markedly across socioeconomic groups. Musculoskeletal pain, the leading reason for new disability awards, is more prevalent among less educated people. This paper examines the differential experience of pain by education. We consider gaps in the rate of physical illness or injury, differences in behavioral or environmental factors that exacerbate pain, and factors that could mitigate pain differently across education groups. We focus on musculoskeletal pain, and in particular knee pain, the most common musculoskeletal complaint in population-based surveys. Comparing clinical interpretation of x-rays of knees evaluated for arthritis, there are remarkably few differences in presence or clinical severity of arthritis across education groups. In contrast, for any given objective measure of disease, less educated people report more knee pain. After confirming that reported pain maps to objective measures like walking speed, range of motion, and specific aspects of function, we test whether obesity, physically demanding occupations, or psychological factors more common among less educated individuals explain some of the gap in reported knee pain. Together, physical demands on the job and obesity explain nearly two-thirds of the education gradient in knee pain. In contrast, other job characteristics and psychological traits related to negative affect, life satisfaction, sense of control, and psychological well-being explain almost none of the educational gradient in knee pain. As physically demanding occupations like home health aides, personal service workers, janitorial services and construction are predicted to grow in coming decades, and given steady rise in obesity in the population, pain is expected to contribute to an increase in disability over time.

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There is a pronounced socioeconomic gradient in health and disability among older adults. Among people aged 60-64, those with a high school degree or less are more likely to report musculoskeletal pain (joint, back, or neck pain) and more likely to have had times in the past month when they were so sad that nothing could cheer them up. Since musculoskeletal pain and mental illness are the leading causes of disability insurance receipt (Social Security Administration, 2018), this leads one to wonder if there are fundamental differences in health across socioeconomic groups that lead to disability program receipt.

Our goal in this paper is to understand the differential experience of pain by education. Socioeconomic differences in health span many dimensions. Rather than characterize every health dimension, we focus on one example of musculoskeletal pain, knee pain, as an example of forces that contribute to socioeconomic differences in disability receipt. We chose knee pain because of its leading role in disability insurance receipt and because there are clinical measures of knee anatomy that allow us to measure physical injury. Rates of knee pain are about 5-10 percentage points lower among college graduates compared to high school graduates or dropouts (Figure 1).

Conceptually, differences in knee pain by education could arise from multiple sources. The less educated may have more underlying structural knee damage than better educated people. For any given physical difference in knee damage, multiple behavioral or environmental factors could exacerbate pain more in less educated groups. Examples include obesity, physically demanding occupations, and psychological differences (arising from depression, isolation, stress, or response to painful stimuli) across education groups that could alter pain perception and physical function. Finally, pain may be mitigated by access to medical treatment, another factor that differs by education.

Most knee pain is related to arthritis. Our first analysis thus asks whether differential rates of knee pain among those with fewer years of education is associated with greater prevalence of arthritis or greater impairment conditional on knee structure. Surprisingly, we find that x-ray assessments of structural knee damage are very similar for those with more and fewer years of education. Less than one-quarter of the difference in pain reports by education are a result of differential rates of knee degradation.

The finding makes one question whether the pain reports are 'real' or affected by the disability determination process required to obtain disability insurance. A variety of evidence suggests that the difference in pain is truly experienced. For example, pain reports correlate well with ability to do various physical activities such as walking time and leg strength and are related to subsequent medical intervention such as receipt of a knee replacement.

Beyond differential rates of arthritis, we consider four other hypotheses for the disparity in knee pain by education. The first hypothesis is behavioral: knee pain differs because people with fewer years of education weigh more, and excess weight has a long-term damaging effect on joint health. The second hypothesis is occupational: physical requirements on jobs differ systematically by education, and these differences lead to differential rates of knee pain. The third hypothesis is psychological: life satisfaction is lower for the less educated, and this translates somatically into greater musculoskeletal pain. The final hypothesis is somatic: the response to painful stimuli is greater among those with fewer years of education, and this somatic amplification leads people with similar clinical manifestations of disease to experience different rates of pain.

We test these hypotheses empirically using several sources of data. The primary data source used to test the role of obesity and job demands is the National Health and Nutrition

Examination Survey (NHANES). Using NHANES data from 1999-2004, we relate knee pain to measures of current and maximum BMI and physical demands in the individual's longest job. Both physical demands on the job and obesity help explain the education gradient in knee pain, each accounting for roughly one-third of the education gradient in knee pain.

The key question about the job demands measure is whether it is really capturing physical activity, or if instead it signals 'good' and 'bad' jobs, which affect knee pain for other reasons. We present several pieces of evidence suggesting that physical job demands are not just a proxy for more and less desirable jobs. The effect of job demands that we find is independent of the measures of abstract, routine, and manual jobs constructed by Autor, Levy, and Murnane (2003), none of which have any significant relationship with knee pain. Physical demands on the job are also separate from exposure to environmental conditions such as excessive heat and cold. In addition, job demands affect pain in weight-bearing joints such as the knee and hips more than non-weight-bearing joints. Finally, while greater physical job demands have a harmful effect on knee pain, greater physical activity in leisure has a favorable effect on knee pain.

We examine the role of psychological factors in the experience of knee pain using data from the Midlife in the US study (MIDUS). MIDUS is a longitudinal survey of people conducted over ~20 years from the 1990s through the 2010s. The second and third waves of the survey have information on chronic knee pain along with a host of psychological metrics: life satisfaction, positive and negative affect, sense of control over life, and well-being. We consider whether these psychological attributes affect the development of knee pain in people who do not have knee pain at baseline. We find some evidence that a more optimistic outlook reduces the incidence of knee pain. But the magnitude of the effect is small. Only about 11% of the development of knee pain is related to psychological factors, much less than the one-third resulting from each of physical demands and obesity.

Finally, we test for differential amplification of painful stimuli using data from MIDUS, which asks about somatic amplification, and from the Coronary Artery Risk Development in Young Adults (CARDIA) study. In CARDIA, people were given a set of physically and mentally demanding tasks, with their blood pressure taken before, during, and after the task. Changes in blood pressure in response to stimuli is a measure of somatic reactivity. The analysis shows no difference in the blood pressure response to stress between people with more and fewer years of education. We thus find no support for this theory.

One hypothesis that we do not test directly, and which we do not believe is important, is that differential access to medical care explains the gradient in knee pain. Empirically, we do not have exogenous measures of access to treatment which we can examine. More fundamentally, there was little effective medical treatment for pain and the treatment that was available for most of the time period we examine. Indeed, the existing treatments might even have been harmful (e.g. opioid medications). Thus, this is one area of health where differential access to medical care is unlikely to be very important.

Our overall conclusions are that the primary factors influencing the education gradient in pain and its associated impairments are having worked in a more physically demanding job and being obese. We explore the implications of these findings for future changes in disability in the last section.

The paper is structured as follows. Section I presents background information on differences in disability, functional limitations, and pain by education group. Second II relates knee pain to the degree of arthritis and pain conditional on arthritis. Section III considers whether knee pain has physical correlates. Sections IV and V considers the role of obesity, physical demands on the job, and psychological outlook in explaining differential knee pain. Section VI examines how the response to painful stimuli differs by education. Section VII summarizes and concludes. There are many data sets that we employ; these are detailed in an online appendix.

I. Pain, Functional Impairment, and Disability

Functional limitations are important measures of disability, and they predict participation in federal disability programs, so we start with basic information on educational gaps in functional limitations and the role of musculoskeletal impairments in explaining differential limitations by education. This analysis uses the 2009-16 National Health Interview Survey (NHIS). Our sample is people aged 25 and older, so that education is largely complete. Pooled across years, the sample contains just over 235,000 individuals.

Education is coded by highest years of schooling completed. We divide the population into three groups: <=high school degree, including a GED; some college, which includes an Associate degree but without a four-year degree; and college graduates. Because educational opportunities expanded over time, one might worry that educational differences in outcomes are higher at older ages than would be true for a constant educational distribution. The appendix shows an alternative calculation where we reallocate people across education groups so that people in each five-year age-sex cell have the same education distribution as does the population aged 55-59 (see Meara et al., 2008). Trends in knee pain by education are very similar by education in this simulation.

Figure 1(a) shows the share of people who have difficulty in at least one of 12 functional dimensions: walking ¼ mile; climbing 10 steps; standing for 2 hours; sitting for 2 hours; stooping, bending, or kneeling; reaching over head; grasping small objects; lifting/carrying 10 lbs; pushing large objects; going out to events; participating in social activities; and relaxing at home.[1] Since functional limitations are not specific to age, the figure shows this percentage for all ages. The pattern for functional limitations is similar to that for disability insurance receipt. Functional limitations are generally low in prevalence until about age 40, at which age they start to increase more for those with fewer years of education. By age 65, the average number of functional limitations is about 1 greater for those with a high school degree or less compared to those with a college degree. This gap persists up through age 84, after which it narrows.

For people who report a functional limitation, the NHIS asks them to identify the cause of the limitation. Eighteen choices are given, with people allowed to choose more than one. Figure 2 shows the self-reported causes of functional limitations by education. Even though the rate of functional impairment differs greatly by education, the reported cause of the limitation is very similar. Musculoskeletal impairments, particularly arthritis and back/neck pain, are far and away the most common cause of functional limitations. Nearly two-thirds of people select a musculoskeletal impairment as a cause of functional impairment.

A separate set of questions asks people about joint and muscle pain. People are asked three broad questions: whether they have had pain in their neck (18%) or lower back (33%) in the past 3 months, and whether they had symptoms of joint pain, aching, or stiffness in the past 30 days (45%). If people answer yes to the latter, they are asked which joints were affected. Figure 1(b) shows the share of people with pain in the neck, back, or a joint. Up until the oldest ages, the figure looks similar to that for functional limitations. At age 60 for example, the gap in musculoskeletal pain is about 6 percentage points. Musculoskeletal pain plateaus at about two-

[1] The exact question is: "By yourself, and without using any special equipment, how difficult is it for you to.." Possible answers are not-at-all difficult; only a little difficult; somewhat difficult; very difficult; can't do at all; and do not do this activity. We count people as functionally limited if they report any level above not-at-all difficult, though the qualitative pattern is similar limiting to only more severe levels of difficulty.

thirds of the population, reaching this rate at roughly age 60 for those with fewer years of education and about age 70 for those with more years of education.

The most commonly affected joint with pain is the knees (62%). We thus form a measure of knee pain. To more closely match our later focus on chronic pain, we subset those with knee pain to those who report that the pain began more than three months prior to the interview. Figure 1(c) shows the percentage of the population with chronic knee pain. The figure is very similar to that for any musculoskeletal pain. Knee pain rises until about age 60 for those with fewer years of education and about age 70 for those with more years at education, plateauing at later ages. Nearly one-third of the elderly population experiences chronic knee pain.

By itself, knee pain likely does not drive the bulk of the education difference in disabling conditions. For example, the gap in knee pain is only 8 percentage.[2] However, knee pain may be indicative of the full range of differences in musculoskeletal impairment. Table 5 below shows that there are education differentials in ten joints and muscles asked about in the NHANES, with the lone exception of toe pain. Thus, our results here may apply more broadly.

While figure 1 divides the population into three education groups, it is worth exploring whether that division is the right one. Figure 3 displays the percent of people with chronic knee pain by exact grade completed.[3] The data show a generally declining trend in knee pain with education, with the biggest break between those with a college degree and those without.

A. Changes in the Education Gradient in Knee Pain Over Time

One immediate question that arises is whether the link between education and knee pain is a recent development or a longstanding fact. If the relationship between knee pain and

[2] The gap in more severe pain might be higher or lower.
[3] These rates are adjusted for differences in the age-sex composition by education.

education is very recent, it would rule out some theories, such as long-term differences in work environments. To analyze trends in knee pain, we supplement the NHIS data with data from four National Health and Nutrition Examination Surveys (NHANES): NHANES I (1971-74); NHANES II (1976-80), NHANES III (1988-94), and the continuous NHANES (1999-2004).[4] In each survey, we limit our analysis to people aged 45-74. There are several reasons for this. First, NHANES I and II only sample people to age 74. Second, the sample sizes are small at more advanced ages, especially among those with more years of education. Third, differential mortality by education becomes increasingly important at older ages, and so selective survival is more important. Finally, most of the difference in reports of knee pain by education are at ages below the most advanced ones. The one remaining age issue is that NHANES III only asks about knee pain for the population aged 60 and older. When we form trends in knee pain in the NHANES, we assume that knee pain at ages 45-60 bears the same relationship to knee pain at ages 60-74 as in the NHIS. Table 1 shows that the sample sizes range from 4,100 to 6,500 per survey.

There are some differences in question wording over time that might affect aggregate trends in knee pain. In NHANES I, people are asked whether they ever had knee pain on most days for at least 6 weeks. In NHANES II, they were asked about pain or aching, again for at least 6 weeks. In NHANES III, the question is about pain, aching, or stiffness. In the continuous NHANES, people are asked about pain, aching, stiffness, or swelling, with a time period limited to the past 12 months. One should thus interpret the aggregate trend in knee pain with some caution. However, it is not obvious that these question changes should bias the education differential in knee pain.

[4] The continuous NHANES is ongoing, but only the 1999-2004 waves have the miscellaneous pain questionnaire with information on knee pain.

The third and fourth rows of Table 1 show the rate of knee pain unadjusted, and adjusted to the age distribution in the NHIS. Roughly 10% of the population in the early 1970s had knee pain. That rose to about 17% in the early 1990s and further increased to 25% between 2009-16 – though some of this latter increase may reflect the looser definition of knee pain in the NHIS. The trend in knee pain matches the trend in obesity, shown in the next row of the table. That said, the growth in knee pain is greater than the growth in obesity: 147% v. 77%. We return to this below, where we show that the history of obesity affects knee pain in addition to current obesity.

Figure 4 shows the differential in knee pain by education in the five surveys, in each case adjusted for age-sex differences. In 1971-74, there was no gap in knee pain by education. By the late 1970s, a gap of 3% had appeared. This rose to 9% in the early 1990s and has remained at 5% to 6% since. Thus, the link between education and knee pain has been a feature of the US for about 40 years.

II. Arthritis as a Cause of Differential Pain Prevalence

There are two primary causes of knee pain: acute injuries and chronic knee damage. Common injuries include torn cartilage and ligaments, as in the case of many sports injuries. The extent of acute damage is generally determined by MRI and these injuries are treated surgically or with pharmaceuticals.[5]

The most common cause of knee pain is arthritis. Arthritis is a condition characterized by

[5] Injuries can lead to later development of osteoarthritis.

a breakdown of the cartilage that cushions the space between bones.[6] With the cartilage worn down, bones rub against each other, creating pain and leading to stiffness and limited motion. About half of people aged 65 and older report having been diagnosed with arthritis (Barbour et al., 2017).

The severity of arthritis is typically measured via x-ray. Radiologists look for narrowing of the space between bones (joint space narrowing), bone spurs (osteophytes), sclerosis (hardening of the bone), and loose bodies in the knee. The most widely used scale of arthritis severity is the Kellgren-Lawrence Scale (KL scale or KL grade), named after the two researchers who developed it (Kellgren and Lawrence, 1957). The KL scale ranges from 0 to 4: 0 (normal); 1 (doubtful/questionable); 2 (mild arthritis); 3 (moderate arthritis); 4 (severe arthritis). Arthritis is defined as a KL score of 2 or higher. The final KL score is subjective. Even still, the KL scale has been shown to have high inter-rater reliability (Kohn et al., 2016).[7]

The KL grade is highly predictive of pain. In comparison to people with KL grade of 0, the relative risk of reporting knee pain is 9 for people with a KL grade of 4 and 4.9 for people with a KL grade of 3 (calculated from NHANES III data). The presence of the KL scale is a major advantage of analyzing knee pain, since it allows us to divide knee pain into a structural component and a perception component.[8]

Some part of arthritis is believed to be genetic (Fernández-Moreno, et al., 2008). However, behavioral and environmental factors appear to matter more than genes. The most

[6] Osteoarthritis is the most prevalent form of arthritis. Rheumatoid arthritis is second most common but has a much lower prevalence. Other causes of arthritis with even lower prevalence include gout, Lyme disease, lupus, and ankylosing spondylitis. See Arthritis Foundation (2019).

[7] Not surprisingly, there are efforts to use machine learning to automate KL scoring of x-rays (Tiulpin et al., 2018).

[8] By comparison, there is no common grading for back or neck pain. Many people with back pain have no abnormalities detectable on imaging, and many people with image abnormalities report no back pain (Brinjikji et al., 2015). For this reason, guidelines suggest not obtaining images for patients with non-specific lower back pain (Chou et al., 2007). In contrast, x-rays are highly recommended in diagnosing chronic knee pain (Fox et al., 2018).

common behavioral risk factor for arthritis is excess weight. Compared to people at the recommended weight (BMI between 25 and 30) the relative risk of arthritis is 2.5 in the overweight and 4.6 in the obese (Zheng and Chen, 2014). Excess weight has the largest effect on weight-bearing joints: hips, knees, and ankles. Excess weight also affects the spine, often manifest in lower back pain.

Excessive physical activity can also affect the development of arthritis, although not always in a constant direction. Repetitive motions that stress joints, for example carrying heavy loads and repeated kneeling or squatting, have been associated with the development of arthritis, especially in the hips and knees (Vignon et al., 2006). Thus, studies show higher rates of hip arthritis in loggers, construction workers, and firefighters, among others. Even some elite athletes are at higher risk for osteoarthritis (e.g., Kujala et al., 1995). On the other hand, exercise therapy is recommended for people with arthritis. Exercise can strengthen the muscles around the affected joint, improve movement, and reduce pain (Bennell et al., 2011).

There is no cure for arthritis, and treatment options are limited. Mild to moderate arthritis is generally treated with exercise and pharmaceuticals – either prescription (opioids) or non-prescription medications (non-steroidal anti-inflammatories, NSAIDs, such as ibuprofen or acetaminophen). These medications do not cure the disease; instead, they reduce the pain. NSAIDs are over the counter and generally inexpensive, so we would not expect their use to differ much because of price. Knee replacement is an option that was typically reserved for very severe cases of arthritis, although in recent years it has become more common (Sloan et al., 2018). However, for most of the time period we examine, there was very little effective treatment for knee pain. Thus, the rates of knee pain that we observe are likely reflective of true differences in knee pain in the population.

A. Severity of Arthritis and Perception of Pain

The NHANES III data allow us to determine whether the greater rate of knee pain for people with fewer years of education is a result of having more arthritic knees or of feeling more pain given the degree of arthritis. During the second part of the survey (1992-94) knee x-rays were taken for those aged 60 and older, which we match to pain reports in the relevant knee.[9] Figure 5(a) shows education differences in KL grade of the knee. We adjust the KL grade for differences in age and gender across education groups.

Knees of college graduates display slightly less arthritis than knees of people with a high school degree or less, but the difference is not large. For example, the share of knees with no sign of arthritis is 2 percentage points higher for those with a college degree. In contrast, figure 5(b) shows that reports of pain conditional on knee arthritis vary greatly. At every level of knee arthritis – including no sign of arthritis at all – people with fewer years of school report more knee pain.

We quantify these findings in Table 2. Column (1) of the table shows the relationship between education and knee pain reports in the NHANES data, adjusted for basic demographic information (five year age-sex cells, race [white/black/other], Hispanic ethnicity, a dummy variable for whether the person was born in the US, a dummy variable for whether the person is a veteran, and a dummy variable for side of the body) but not x-ray findings.[10] Demographically

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[9] The x-rays were first read by one reader. All x-rays showing any evidence of disease, and a sample of those without disease, were read by a second reader. In cases of discrepancy, the two radiologists concurred to form a consensus opinion.

[10] We do not include indicators of other medical conditions, since these may pick up other correlates of individuals that are better attributed to education. However, we have experimented with including controls for a number of other conditions – whether the person has respiratory disease, ischemic heart disease, congestive heart failure, stroke, cancer, diabetes, thyroid disease, lupus, gout, and osteoporosis. The education differences are similar but a little smaller with and without these controls. The Appendix has details.

adjusted, people with a college degree are 7.3% less likely to report knee pain.

The second column adjusts for clinical features of the knee. In addition to x-rays, examining physicians noted several aspects of the person's knees: the presence of crepitus (a cracking, crunching, or popping feeling when the knee is bent), whether the knee was swollen, and the maximum range of motion (included as a dummy variable for <115°; see Skinner et al., 2006). We include these variables as well. Relative to the results in 1, the coefficient on college education is 14% lower with these additional controls.

The NHANES data do not have MRI information. To validate these findings with MRI data, we analyze information from the OsteoArthritis Initiative (OAI). The OAI is a multi-center study of knee osteoarthritis. The survey enrolled 4,796 people at four sites in 2004 and followed them for the next decade. About one-third of the sample had arthritis and knee pain at baseline and essentially all of the remainder were considered at risk for arthritis and pain, based on weight, knee activities, and the like. A small sample of enrollees were healthy at baseline.

The OAI is non-random in several ways. First, about 60% of the sample is college educated, far above the national average.[11] Second, people likely enroll because they are experiencing knee pain and see a physician at one of the participating sites. Indeed, knee pain is much higher at enrollment than in the subsequent waves. That said, there is no indication that enrollment is differentially selected based on the relationship between knee pain and arthritis severity, the focus of our analysis.

X-rays for the entire OAI sample are available in many waves as is clinical determination of crepitus. MRI results are available for about 1,700 people and in some of the waves. We code several findings from the MRI: whether cartilage loss was >10% in each of the medial, lateral,

[11] The survey does not have sample weights.

and patella-femoral areas; whether there is evidence of a meniscal tear or moderate extrusion in the medial or lateral areas; and whether there are bone marrow lesions of at least 33% in the medical, lateral, or patella-femoral areas.

We estimate regression models in the OAI similar to those in the NHANES. We start by relating knee pain to demographics (five-year age-sex cells, race, Hispanic ethnicity, and side of the body) along with education. To control for selection into the sample, we include dummy variables for the specific site the person enrolled at and the ways in which people heard about the survey (doctor, flyer, etc.). we also omit the enrollment interview, utilizing data instead from the first follow-up of the survey.[12]

Columns (3)-(6) of table 2 show the education difference in knee pain in the OAI. Columns (3) and (4) use as an explanatory variable a dummy variable for whether the person had pain on most days of a month in the past year. In columns (5) and (6), we use a more detailed pain score from the Knee Injury and Osteoarthritis Outcome Score (KOOS), a grading of knee pain based on a 9-item questionnaire (see the appendix). The activities are very specific, for example bending the knee fully or twisting/pivoting the knee. The KOOS pain score ranges from 0-100, where a higher number denotes less pain. We reverse the order so that the response ranges no pain being 0 to maximum pain being 100. The average person reports a pain score of 13.[13]

Using both the binary measure of knee pain and the graded scale, people with a college degree report less pain than people with a high school degree or less. The gap is 7.7 percentage points with the binary measure of knee pain, close to our estimate in the NHIS and NHANES. This is reassuring given the non-random selection into the OAI. The gap is 46% of the mean

[12] The appendix shows that a large reduction in knee pain takes place between the enrollment wave and the first follow-up wave.
[13] Conditional on reporting knee pain, people with a high school degree or less report greater pain than do people with a college degree.

KOOS score for people with a high school degree or less using the more continuous measure of pain.

As columns (4) and (6) show, controlling for x-ray, examination, and MRI results reduces the education disparity in pain reports by 14-29%, depending on the measure of pain. The effect is higher with the binary measure than with the more graded measure, but neither is very large. More than 2/3 of the education gap in knee pain reports is not due to structural differences in knee anatomy.

III. Is the pain real?

The finding that differential knee pain for those with fewer years of education is not associated with structural damage in the knee makes one wonder whether the pain is real. It could be, for example, that less educated people report more pain as a way to qualify for disability insurance or other compensation programs. Several factors suggest that this is not the case, however. First, the difference in pain reports is found even with very specific questions as in the KOOS scale, not just a general knee pain question.

Second, the share of the population reporting knee pain exhibits no reduction around retirement ages. Using data from the OAI, figure 6 plots the trend in knee pain by age, where we have subtracted the mean pain level for each knee, so that differences across individuals between average pain and age of retirement are removed. Within individuals, there is no reduction in knee pain around retirement ages. Indeed, knee pain appears relatively constant even as the retired population doubles.[14]

Further, pain reports appear to correlate with physical performance. The OAI has several

[14] The rate of employment is higher than in national totals because enrollment is disproportionate among those with more years of education.

performance tests: the time required to walk 20 meters, whether the person can do a chair stand with their arms folded (thus using only their legs); and the maximum force the person can exert on knee extension. We relate walking time and the ability to do a chair stand to the average pain report across the two knees and force exertion in each knee to the pain report in the relevant knee.[15]

Figures 7(a)-(c) show the relationship between knee pain and performance in these three dimensions. In each case, pain is negatively related to performance. People in the highest vingtile of pain reports have a walking speed that is about 20% slower than people in the lowest vingtile of pain reports; the difference in force exertion is about 40%. The ability to do a chair stand is universal in the lowest pain groups but only 85% of people can do so in the highest pain group. Finally, knee pain is predictive of medical intervention. Figure 7(d) shows that subsequent knee replacements are far more common for people with higher initial levels of knee pain than for people with lower levels.

For these reasons, we suspect the pain reports are accurate assessments of perceived pain.

IV. Obesity and Physical Demands on the Job

In this section, we consider the impacts of behavior and occupational requirements on knee pain. Our methodology is similar to Cutler and Lleras-Muney (2010). We start with a model relating knee pain to education and demographics (X_D):

$$\text{Knee Pain}_i = \text{Education}_i\, \alpha^E + X_{D,i}\, \alpha^D + \varepsilon_i \qquad (1)$$

The coefficient α^E is the impact of education on knee pain adjusted only for demographics.[16] We

[15] Report what happens if we use maximum pain report.
[16] Equations (1) and (2) are linear in knee pain. In some of our data, knee pain is a binary variable. We have explored using logit and probit analysis for these equations, with very similar marginal effects. Estimating the

then modify equation (1) to include measures of obesity (BMI) and physical demands associated with the person's job (Phys):

$$\text{Knee Pain}_i = \text{Education}_i\ \beta^E + X_{D,i}\ \beta^D + \text{BMI}_i\ \beta^{BMI} + \text{Phys}_i\ \beta^{Phys} + \xi_i \qquad (2)$$

The change in the coefficient on education, $1\text{-}\beta^E/\alpha^E$, indicates how BMI and job demands as a whole mediate the relationship between education and knee pain. We can estimate the impact of each independently using the regression coefficients. For example, the impact of differences in job demands between two groups, c and h, in mediating the education difference in knee pain is given by $(\text{Phys}_c\text{-Phys}_h)\ \beta^{\text{Phys}}/\alpha^E$.

The primary data that we analyze are from the continuous NHANES, 1999-2004, since it has the richest collection of data on age, pain, and obesity; we supplement this with other data as described below. As above, the sample is people aged 45-74. Demographic controls include five-year age-sex dummy variables, dummy variables for race/ethnicity, a dummy variable for being a veteran, and a dummy variable for being US born.

Knee pain is defined in Table 1. BMI is based on self-reported height and weight. In addition to current BMI, NHANES asks about maximum weight, weight one year prior to the survey, weight ten years prior to the survey, and weight at age 25. We compared results including all of these BMI variables. Current and maximum BMI are both related to knee pain even controlling for the other measures of obesity, while BMI at other ages was not. Thus, our regressions include current and maximum BMI. We divide the population into five BMI groups: underweight (<18.5); normal weight (18.5-25); overweight (25-30); obese (30-35); and morbidly

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models linearly helps with the decomposition of the education effect.

obese (35+).[17] The data appendix shows the distribution of current and maximum BMI; 28% of people are obese at the time of the survey, and 40% were obese at maximum weight. Obesity rates are higher for those with fewer years of education than for those with more years of education.

The data on job characteristics are similar to those in Autor, Levy, and Murnane (2003) and Autor and Dorn (2013); see the appendix. The original source is the 1977 Dictionary of Occupation Titles (DOT), which estimated task requirements for over 12,000 detailed occupations. These occupations were matched to 495 3-digit 1980 Census occupations. We developed a crosswalk between 1980 Census occupation codes and the 1990 Census occupation codes, which are used in the NHANES. For the older population that we analyze, data from the 1970s is roughly coincident with the period of longest employment. Even so, occupation data do not change greatly over time (Autor, Levy, and Murnane, 2003).

To form a measure of physical demands on the job, we use the first principal component of a factor analysis of four variables: a five-point strength score (sedentary, light, medium, heavy, very heavy); the percent of workers whose job involves climbing and/or balancing; the percent whose job requires stooping, kneeling, crouching, and/or crawling; and the percent whose job requires reaching, handling, fingering, and/or feeling. Empirically, these four variables are highly correlated, so the results are similar if we use the strength requirement alone or other combinations of the data. The appendix shows average physical demands by education. The difference in job demands between college graduates and people with a high school degree or less is about one standard deviation.

A central concern is whether the physical demands measure is truly measuring physical

[17] About two percent of people are missing information on height or weight. They are included in the regression with a missing BMI dummy variable.

demands, or whether instead it is simply an indicator for less skilled jobs. To examine this, we compare the impact of physical demands to that of three other job characteristics, taken from Autor and Dorn (2013): abstract work (a combination of math utilized and direction, control, and planning of activities), routine work (a combination of finger dexterity and situations requiring precise attainment of set limits, tolerances, or standards), and manual work (eye-hand-foot coordination).

Table 3 shows the correlation between the different measures of job attributes. The physical demands measure is most correlated with manual work (ρ=0.61). Physical demands and routine work are not highly correlated (ρ=0.23), and physical demands are negatively correlated with abstract work (ρ=-0.44). Physically demanding jobs do not seem to be a proxy for `bad' jobs (i.e. jobs that are undesirable and thus, held by individuals less advantaged in the labor market.)

We match job characteristics in table 3 to the longest job the individual reports working at, which NHANES aggregates into 40 groups.[18] Job characteristics are not available for people in the armed forces, for people who never worked, and for people who did not report a longest occupation. We create dummy variables for belonging to each of these groups.

Figure 8 shows the relationship between physical demands on the job and knee pain. The relationship is positive and statistically significant; we return to the magnitude below.

Table 4 shows regression equations relating physical demands and obesity to knee pain. The first column presents estimates of equation (1), controlling for demographics only. Adjusted for demographics, people with a college degree are 4.5 percentage points less likely to report knee pain than those with a high school degree or less.

[18] Generally, the variability of job requirements within these occupation groups is small. 82% of the (employment weighted) variation in physical demands across 3-digit occupation codes is explained by the 40 occupation groups.

The second column includes the measure of physical demands, in which a one unit increase represents a one standard deviation increase in the first principal component of four attributes of physical demands within an occupation category. People whose longest job was more physically demanding are more likely to have knee pain than those whose longest job was less physically demanding; the analogue to figure 8. The coefficient on physical demands is large. A one standard deviation increase in physical demands leads to a 2.6 percentage point increase in the probability of having knee pain. As the last rows of the table show, this is 48% of the baseline difference in knee pain across education groups.[19]

The third column includes the measures of abstract, routine, and manual work in addition to the physical demands measure. The physical demands measure is not just a proxy for being in a blue-collar job. The coefficient on abstract job is actually positive (people with more abstract jobs are more likely to report knee pain), although not statistically significant. The measure of routine work is statistically positively associated with knee pain at the 10% level. However, the coefficient is only half as big as the coefficient on physical demands. Manual work by itself is not associated with knee pain. Controlling for these other job attributes, physical demands explains 42% of the gradient. The other job attributes actually reduce the gradient by 4%.

Column (4) omits the job characteristics variables and examines the relationship between obesity and knee pain. People with higher current BMI as well as higher maximum BMI are more likely to experience knee pain. The effect is graded throughout the distribution of maximum BMI, and the coefficients are large. Compared to people of recommended weight, people who were obese at maximum weight are about 10% more likely to report knee pain. Conditional on maximum BMI, those who are currently morbidly obese are another 13% more

[19] The difference between the 49% and 48% is the impact of different rates of having been in the armed forces, not having worked, and not reporting a longest job.

likely to experience knee pain. Because obesity declines with education, the obesity results help explain the education gradient in knee pain. As the last row of the table shows, obesity explains 36% of the education gradient in knee pain, roughly comparable to the impact of more physically demanding jobs.

The final column includes job characteristics along with obesity in the regression. The two sets of variables have generally independent effects. In total, job characteristics and obesity explain 70% of the education gradient in knee pain, 40% of which is due to physical demands on the job and 36% of which is due to greater obesity. Other job attributes reduce the education gap by 7%. Thus, two-thirds of the link between education and knee pain is explained by behaviors and occupational characteristics.

A. Robustness of the Results

We have examined the robustness of the results in table 4 in several ways. One key test is whether the physical demand variable is distinct from other job attributes. Some information on this was presented above, where we showed that physical demands are independent of whether the job involves abstract, routine, and manual work.

A related test is whether physical demands are separate from environmental exposure. Jobs that are more physically demanding tend to be exposed to the elements more: heat, cold, rain, and so on. We test for the distinction between physical demands and environmental exposure using DOT data on the percent of workers in each occupation whose job involves exposure to extreme cold, extreme heat, wet or humid conditions, noise or vibrations, hazards, and atmospheric conditions. We form a summary of environmental exposure using a factor analysis of these variables (see the appendix). Including the measure of environmental exposure has no qualitative and virtually no quantitative impact on the results. For example, using the specification in column (5) of table 4, the coefficient on environmental exposure is .001 (.014), and the coefficient on physical demands is .021 (.011).

The second robustness test is to examine the relationship in other surveys. Both NHANES III and the 2010 and 2015 waves of NHIS have information on the individual's occupation in their longest job, which we match to the same job attributes.[20] We estimate models similar to those in the continuous NHANES, with the exception that NHIS has information only on current weight, not maximum weight. The coefficients on job attributes are similar across surveys, indeed somewhat larger in other surveys. Relative to the coefficient on physical demands of 0.022 (0.009) in column (5) of table 4, the coefficient in NHANES III is 0.033 (0.011) and the coefficient in NHIS is 0.037 (0.011). These coefficients are statistically different from zero and not statistically distinguishable from each other. Obesity also has a similar effect across surveys. Being morbidly obese at the time of the current survey (and thus at maximum BMI) raises the probability of knee pain by 23% in the continuous NHANES, 31% in NHANES III, and 26% in NHIS.

The third robustness test is to include other health conditions in the regression. Equations (1) and (2) do not include conditions such as heart disease or cancer because they would not be expected to directly affect knee pain but might be a general sign for poor health, which we wish to capture with variables such as obesity. As a specification test, we include a series of dummy variables for report of having been diagnosed with respiratory disease, coronary heart disease, congestive heart failure, stroke, cancer (divided into skin cancer and other cancers), thyroid

[20] The occupation codes in NHIS are the 2000 Census occupation codes. We created a crosswalk from the 1980 Census codes to the 2000 Census codes. The other NHIS surveys, along with NHANES I and II, ask only about current occupation, not longest occupation.

disease, liver disease, diabetes, and osteoporosis. The appendix shows that controlling for these conditions reduces the demographically adjusted coefficient on college graduate from 4.5% to 3.2% (see the appendix).[21] However, including these conditions has essentially no effect on the coefficients on job attributes and only minimal effects on the coefficients on obesity. As a result, the explained share of the education gradient in knee pain increases: job-related physical demands explain 59% of the education gradient in knee pain and obesity explains 44%.

The fourth robustness test considers how physical demands and obesity affect pain in different joints. Both physically demanding jobs and obesity should have a greater effect on weight-bearing joints than non-weight bearing joints – hips and knees in particular, along with lower back pain. Other job characteristics might affect other joints, for example finger dexterity (a part of routine work) might affect wrist and finger joints more than knee or hip joints.

The NHANES contains information on pain in a number of joints, shown in table 5. Lower body joints are the hips, knees, ankles, and toes. Upper body joints are the shoulders, elbows, wrists, and fingers. In addition to joint pain, the survey asks about neck and lower back pain. The measure of neck and back pain is somewhat less chronic than for joint pain; people are asked whether they have had pain in the neck or lower back pain in the past 3 months that lasted a day or longer. While not ideal, we examine these outcomes as well.

Table 5 shows how physical demands and obesity are related to pain in each of these areas. The results for knee pain are the same as in table 4 and are repeated for ease of comparison. Panel A shows estimates of the impact of years of education on pain controlling only for demographics. With the exception of toe pain, there is an education gradient in every

[21] One sign that these variables are simply picking up poor health more than a structural relationship is that all of the other conditions are associated with knee pain with the exception of skin cancer. This includes conditions such as thyroid and liver disease that would have no logical physiological relationship to knee pain.

measure of musculoskeletal pain examined. The effects range from 2% (hip pain) to 15% (lower back pain).

Panel B estimates equation (2), where we include job attributes and obesity. In general, both obesity and job attributes are related to pain in the way one would expect. Obesity has its greatest impact on joints in the lower body – hips, knees, and ankles, where it explains 19-36% of the education gradient in pain. The effect of obesity is much smaller in the other joints. Surprisingly, obesity does not explain a large share of the education gradient in lower back pain. This may be related to the short-term nature of the back pain question.

Physical demands on the job also have the largest explanatory power for knee pain and hip pain. For these joints, physical demands explain 40% and 57% of the education gradient. The other areas for which physical demands have a significant effect on the education gradient are shoulder pain (26%), elbow pain (26%), and lower back pain (16%). The findings for knee and hip pain are consistent with our hypothesis that weight bearing joints should be most affected, as is the impact on lower back pain. The findings for shoulder and elbow pain are a little more difficult to understand, though they are not inconsistent with a role for some job demands (for example people who reach significantly while on the job). The absence of a relationship between physical demands and pain in the toes, wrists, fingers, and neck is also consistent with the theory, as physically demanding jobs are generally less demanding on these joints.

In addition to impact of physically demanding jobs, the impact of routine jobs on pain is also worth noting. One of the inputs into the measure of routine work is the degree of finger dexterity. As table 5 shows, jobs that involve routine work are associated with more wrist and finger pain, along with knee pain. indeed, of the two measures that make up routine work, the relationship with pain is entirely through the manual component (finger dexterity) as opposed to the cognitive component (situations requiring the precise attainment of set limits, tolerances, or standards).

The fifth robustness test is to compare the impact of physical demands at work to the impact of other types of physical activity. As noted above, repetitive physical movements may be harmful to joints, while regular exercise may be helpful. Thus, we expect fewer adverse impacts from leisure activities than from work activities, even if both are active.

The NHANES data ask about leisure activities, but the questions are limited to current activities. This is not appropriate for our analysis, as people may stop engaging in strenuous leisure activities when they experience knee pain. Instead, we utilize longitudinal data from the OAI. We consider people in the incidence cohort in the OAI data – people who are at risk for knee arthritis and pain but are not experiencing severe pain and arthritis yet. In this cohort, we see how work activities, leisure activities, and household activities influence the subsequent development of knee pain. We sample people who are aged 45-60 and working at survey enrollment; in this group, job tasks are most likely to correspond to longest occupation.

The OAI asks people about physical activities using the Physical Activity Scale for the Elderly (PASE).[22] Leisure activity is based on a series of 6 questions (including walking, light sports, and the like), and household activities are based on 6 questions (light housework, home repairs, etc.). We score each using the recommended scoring and convert the results to a standard normal. Work is asked about on a four-point scale:[23] whether the job involves sitting; sitting, standing, and walking; walking and handling <50 lbs; and walking and handling >50 lbs. Because very few people report work with heavy lifting (3% of the population), we combine the

[22] These measures are taken from the first wave of the survey, to avoid people changing jobs in response to knee pain.
[23] The OAI does not ask about occupation.

latter two categories into a single measure of strenuous work.

Figure 9 graphs the trend in knee pain for people with more and less strenuous jobs, leisure activities, and household work. Knee pain increases more over time for people whose jobs involve walking, with or without carrying heavy loads (panel a). Trends in knee pain are similar for people with greater than median and less than median leisure activities (panel b). Knee pain increases somewhat more for people who engage in above median physical housework than people with below median physical housework.[24] Regression analysis confirms this finding. The appendix shows results that relate knee pain for each person-knee over time to job characteristics, leisure activities, and household work at the initial wave, each interacted with a time trend. We also control for standard demographics, current BMI, and maximum BMI dummies interacted with time trends. There are clear differences in how different activities affect the development of knee pain. People in more physically demanding jobs experience increases in knee pain over time, as do people who engage in more housework. In contrast, people who engage in more active leisure activities experience less rapid increases in knee pain over time.

The sixth test is to examine whether people in different occupations had pain at the beginning of their career, before significant exposure to work-related physical demands. We test this by estimating the regression in column (5) of table 4 for people aged 25-34, the youngest ages in our sample. In this case, we relate knee pain to current occupation, since this is more meaningful as a measure of the longest job such a group will likely have. In this sample, there is no significant or substantive relationship between knee pain and current occupation.[25] It is clear that relationship between knee pain and physical requirements on the job postdates the entry into

[24] Note that the initial level of knee pain is unrelated to the amount of physical housework the person engages in, suggesting that people have not yet changed their lifestyle because of knee pain.
[25] For example, the coefficient on physical job characteristics is -0.004 (0.012).

employment on those jobs.

V. Psychological Correlates of Pain

There are few psychological variables in the NHANES data; thus, we need to test this theory elsewhere. To examine impact of psychological factors on pain, we utilize data from the Midlife in the United States survey (MIDUS). MIDUS is a survey of individuals conducted to understand the aging process; see the appendix. Just over 7000 people were sampled in the mid-1990s. Part of the survey was administered randomly, but other parts were non-random: siblings of those enrolled randomly, people from certain cities in the country, and twins. As a result, there are no national weights in the survey. Follow ups were conducted approximately one decade and two decades later, referred to as MIDUS 2 and MIDUS 3.

The first round of the survey did not ask any questions about knee pain but rounds 2 and 3 did. People were asked "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?" Our goal is to examine how psychological factors predict the onset of knee pain. Of course, psychological factors may themselves be responsive to health. To account for this, we consider the onset of pain between the second and third waves among those who report no chronic pain in wave 2. We further restrict the sample to people aged 45 and 74 in wave 3 of the survey, to minimize selective mortality by education, leaving a sample of 1,784 people total.

In the second wave, individuals were asked a variety of questions about the physical demands in their current job or most recent job in the past 10 years. We utilize the question "how often does your job require a lot of physical effort?" The possible answers were all of the time, some of the time, most of the time, little of the time, never. We include the response as a series of dummy variables. MIDUS asks about current weight but not maximum weight; we include BMI in the second wave as a proxy for BMI at maximum weight.[26]

MIDUS contains a number of questions about psychological well-being, which we consider in our analysis. We describe the variables briefly here, with limited examples, and in more detail in the appendix, which also shows summary statistics by education. The first measure is overall life satisfaction, scored on a 1 to 10 scale. People with more years of education report greater life satisfaction than people with fewer years of education. Positive and negative affect are based on a series of questions of the form, "During the past 30 days, how much of the time did you feel… cheerful" (positive affect) or "so sad that nothing could cheer you up" (negative affect). People with more years of education report higher levels of positive affect and lower levels of negative affect.

The survey has several measures about the person's sense of control. An overall control scale is formed from questions about personal mastery (e.g., "I can do just about anything I really set my mind to") and perceived constraints ("There is little I can do to change the important things in my life"). Questions are also asked about the individuals' control over their health ("Keeping healthy depends on things that I can do"). We form scales for overall and health-related control. Both are higher for people with more years of education.

The final variables measure psychological well-being in six dimensions: personal autonomy ("I have confidence in my opinions, even if they are contrary to the general consensus"), environmental mastery ("In general, I feel I am in charge of the situation in which I live"), personal growth ("For me, life has been a continuous process of learning, changing, and growth"), positive relations with others ("Maintaining close relationships has been difficult and

[26] We have also estimated models including as independent variables weight in the first wave of the survey. This did not materially affect the results.

frustrating for me"), purpose in life ("I live life one day at a time and don't really think about the future"), and self- acceptance ("When I look at the story of my life, I am pleased with how things have turned out"). All of these measures are higher for people with more years of education.

Table 6 shows the factors influencing the onset of chronic knee pain. The first column includes education dummies and standard demographics: five-year age-sex dummy variables, race and ethnicity, and a dummy variable for being US born. Among people who do not report knee pain in the second wave of the survey, respondents with a college degree are 3.8 percentage points less likely to develop chronic knee pain by the wave 3 than people with a high school degree or less. The second column includes physical demands on the job and wave 2 BMI categories in the regression. The coefficients of each are reported in the appendix. As the last rows of the table show, roughly 1/3 of the onset of knee pain is explained by physical demands on the job and another 1/3 by obesity. This is very similar to the estimates in the NHANES data, even with a very different sample and estimation strategy.

The next columns of the table add to this regression the psychological variables noted above, first individually (columns 3-6) and then as a group (column 7). Very few of these variables have a significant effect on the onset of knee pain, and when they do, the effect is modest. The strongest relationship is between a negative affect and the onset of the pain. People who score one standard deviation higher on the negative affect scale are 3 percentage points more likely to report knee pain a decade after the affect was measured. However, the gap in negative affect by education is relatively small. Differences in negative affect explain only 14% of the difference in knee pain onset across education groups. Indeed, including all the psychological variables together only explains 11% of the education grade in the onset of the pain. This is less than half the impact of job requirements at work and obesity. In sum, therefore, we do not find a significant role for an individual's psychological profile in explaining the development of knee pain.

VI. Somatic Amplification

The final hypothesis we examine is one of differential physiological sensitivity – what is also termed somatic sensitivity or somatic amplification (Nakao and Barsky, 2007). The theory is that different people have greater and lesser responses to the same physical stimuli, and this responsiveness may differ by education. It is known that people respond to painful stimuli in different ways. For example, when a person puts their hand into a bucket of ice water, they will feel pain, their blood vessels will constrict, their heart rate will rise, and their blood pressure will increase. The extent to which blood pressure rises in response to this "cold pressor" differs across individuals. Such differences might be associated with different pain responses to chronic stress on joints.

We test for differences in somatic amplification in several ways. A first piece of evidence comes from the MIDUS. People are asked four questions about their somatic sensitivity.[27] We form a somatic amplification scale by averaging responses to these different questions. People with more years of education report less somatic amplification than do people with fewer years of education. For example, 32% of people with a high school degree or less agree extremely or moderately that they have a low pain tolerance, compared to 27% of people with a college degree.

[27] The questions are: 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". The somatic amplification scale is similar to the results of a factor analysis of these questions.

Column (8) of table 6 shows the relationship between somatic amplification and the onset of chronic knee pain. There is no statistically significant relationship between the two. Indeed, at the point estimate, only 4% of the education gap in the onset of chronic knee pain can be related to differential rates of somatic amplification.

We also test for the role of somatic amplification using physiological data. The Coronary Artery Risk Development in Young Adults (CARDIA) study is a longitudinal analysis of the development of cardiovascular disease. The study enrolled about 5,000 young adults at four sites in the mid-1980s and has followed them since. In the second wave of the study, enrollees were given three stressful tests: star tracing with a mirror image; playing the ATARI breakout game; and hand immersion in ice water for 45 seconds. Blood pressure was measured several times before, during, and after the test. The increase in blood pressure during the test is a measure of physical response to stress and the degree to which blood pressure remains high after the test is a measure of prolonged response. Blood pressure reactivity on these tests has been shown to correlate with the later development of hypertension (Matthews et al., 2004).

Figure 10 shows the change in systolic blood pressure by education during and after each of the tests.[28] Even at young ages, people with more years of education have lower blood pressure than people with fewer years of education. However, the response to stressful tests is similar by education and if anything slightly larger for the college graduates.[29] This is true of both mental stress (ATARI breakout and image drawing) and physical stress (cold pressor).

[28] The people were relatively young when given the test. We relate reactivity to final education, which may have been realized after the test was administered. The results are similar examining diastolic blood pressure.

[29] These findings are also true controlling for age, race, and baseline blood pressure. This is not to say that everyone responds the same to the test. The mean (standard deviation) of the increase in blood pressure is 11.2 (8.4) during the breakout game, 9.6 (7.8) during the star drawing, and 22.9 (12.8) during the cold pressor.

Overall, therefore, we find no evidence that differential responses to stimuli can explain the difference in knee pain by education.

VII. Implications for Disability Insurance and Conclusion

Chronic knee pain is differential by education and is related to physical demands at work as well as obesity. One question left open by these results is how this relation to pain translates into receipt of disability insurance. Figure 11 displays the trend in receipt of Social Security Disability Insurance (SSDI) or Supplemental Security Income (SSI) by age and education. Because people transition from SSDI onto Old Age Insurance at the full retirement age, these data are only meaningful through age 64. There are modest differences in disability insurance receipt at younger ages that grow over time. Between ages 25 and 34, about 5% of those with a high school degree or less are receiving disability insurance, compared to virtually none of those with a college degree. People with a high school degree or less experience increases in disability insurance rates around age 40. People with a college degree experience increases around age 50, but even then the increases are smaller. As a result, between ages 55 and 64, 18% of people with a high school degree or less are receiving disability insurance, compared to 4% of college graduates. People with some college but not a degree are in between the other two groups.

To consider one example of how differential pain may translate into differences in disability receipt, we use the data from the NHIS, relating job characteristics and obesity to disability insurance receipt. Table 7 shows the impact of job characteristics and obesity on knee pain (column 1) and receipt of SSDI or SSI (column 2). The sample in each case is people aged 45-64, when disability insurance is common. Both estimates show a significant relationship between job demands, obesity, and outcomes. For example, 10% of the education gradient in disability insurance receipt is due to job characteristics related to physical demands and 5% is due to obesity. In the case of disability, there is also a sizeable impact of having worked in an abstract job in explaining the education gradient, such that 24% of the gradient in disability is explained by other job attributes.

It is tempting to view this latter finding as suggesting that 'good jobs' (desirable jobs) induce people not to apply for disability insurance programs. But this is not necessarily correct. Whether the job involves abstract work or not may influence other aspects of health that affect ability to work, for example the degree of pain or the ability to accommodate pain. While there is a clear relationship between job characteristics and disability insurance receipt, untangling why it occurs requires more evidence.

We can use our results to make guesses about the future of knee pain and its associated disability. Forecasts of employment by occupation are made periodically by the Bureau of Labor Statistics. The most recent set of projections used data through 2016 and forecast through 2026. Matching employment forecasts with our measure of physical demands on the job, the data surprisingly suggest that work-related physical demands are likely to rise modestly over the next decade.[30] The reason is that many jobs that are expected to grow in employment involve significant physical demands, for example home health aides, personal care workers, janitors and cleaners, and construction laborers. Similarly, many occupations expected to decline in importance have relatively low physical demands – secretaries, for example. These changes outweigh the beneficial pain trends from forecast growth in computer programming and slower growth of blue collar manufacturing.

Obesity is more difficult to forecast. Even still, we have some information on obesity

[30] The physical demands measure for the 2016 data is -0.162; the forecast for 2026 is -0.154.

from the NHANES surveys. Since BMI at maximum weight is more important for knee pain than is current obesity, we focus on trends in BMI at maximum weight. The share of people obese at their maximum weight has been rising over time. Among the population aged 45-74, the share of the population obese at maximum weight was 41% in 1988-94, 45% in 1999-2004, 48% in 2009-10, and 55% in 2015-16, the most recent year available. Based on these trends, it seems reasonable to forecast that knee pain and associated impairments will continue to increase. It may be that the disability insurance system will have to adapt to a continued increase in the share of people with severe pain, for which the optimal policy is not clear.

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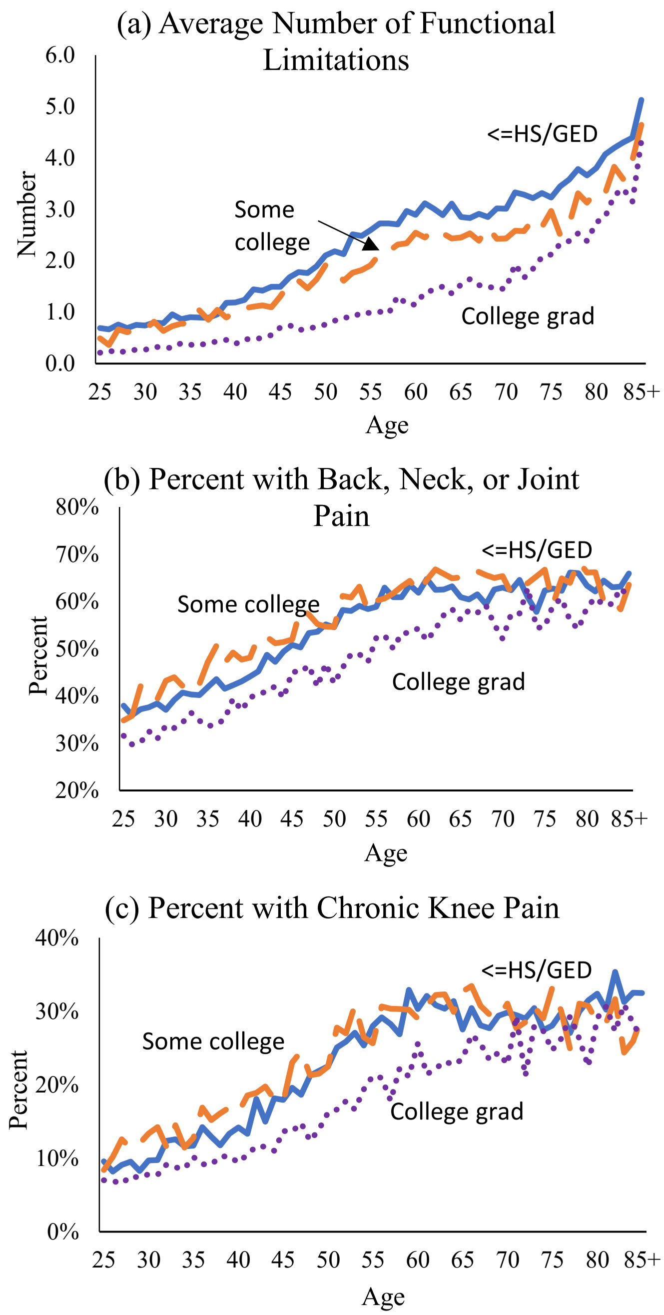
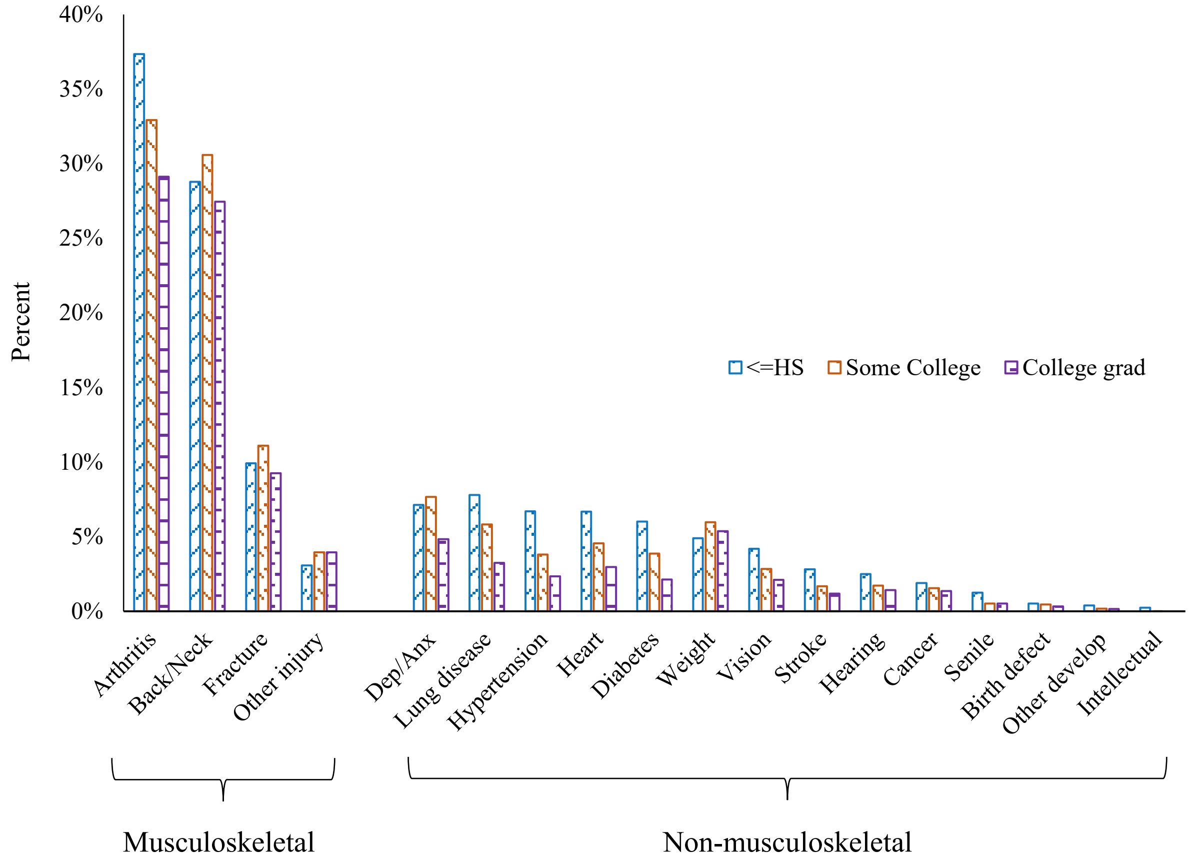
Figure 1: Components of Disability by Education and Age



Note: Data are from the National Health Interview Survey, 2009-2016. Panel (a) shows up to 12 functional limitations: walking ¼ mile; climbing 10 steps; standing for 2 hours; sitting for 2 hours; stooping, bending, or kneeling; reaching over head; grasping small objects; lifting/carrying 10 lbs; pushing large objects; going out to events; participating in social activities; and relaxing at home. Panel (b) shows symptoms of joint pain, aching, or stiffness in the past 30 days in either hip or knee, or neck or low back pain in the past three months. Panel

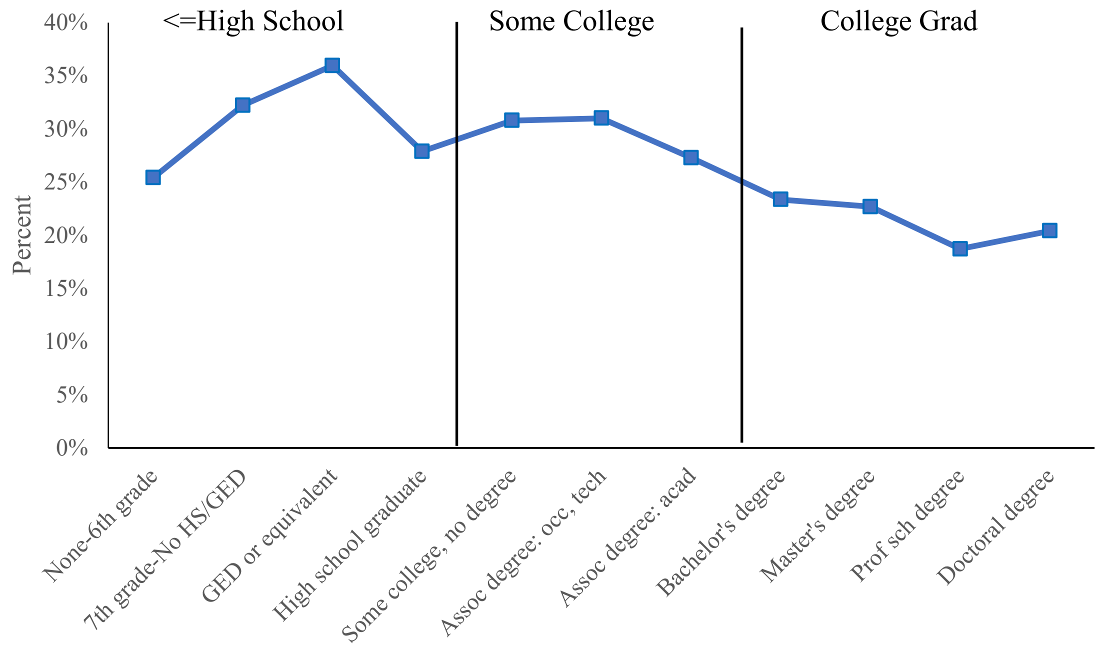
(c) shows symptoms of joint pain, aching, or stiffness in the past 30 days that began at least three months prior.

Figure 2: Reported Cause of Functional Limitations



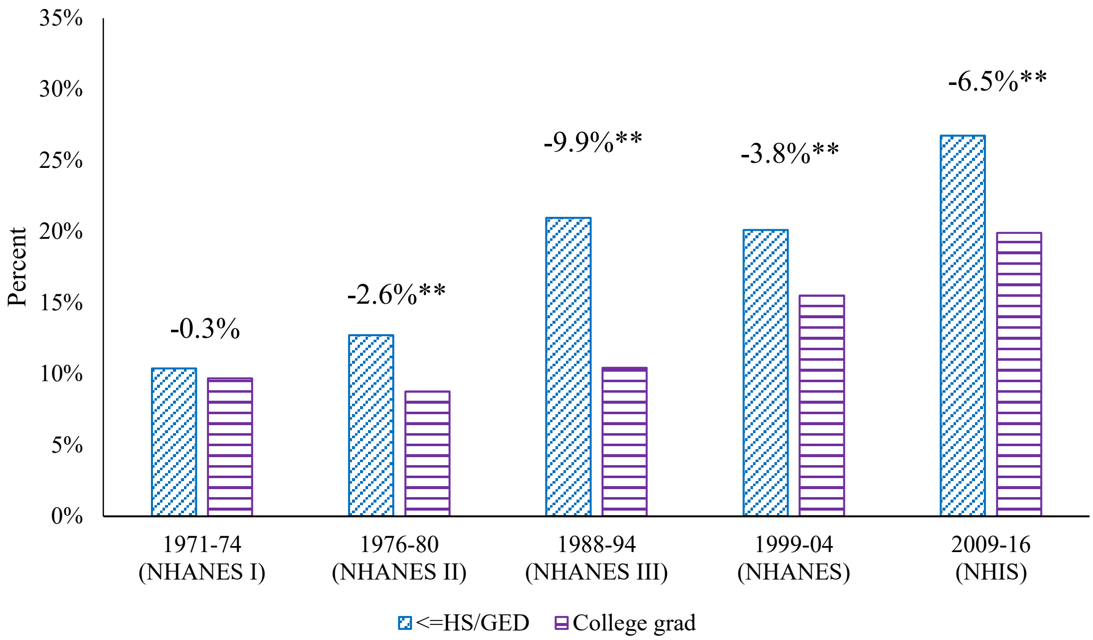
Note: Data are from the National Health Interview Survey, 2009-2016. The sample is people who report at least one functional limitation. People can select more than one cause. "Dep/Anx" stands for depression/anxiety. "Other develop" stands for other developmental difficulty.

Figure 3: Prevalence of Chronic Knee Pain by Exact Education



Note: Data are from the National Health Interview Survey, 2009-2016, aged 45 and older. Education effects are adjusted for age and sex differences. Knee pain includes symptoms of joint pain, aching, or stiffness in the past 30 days in either knee, with an onset at least three months prior.

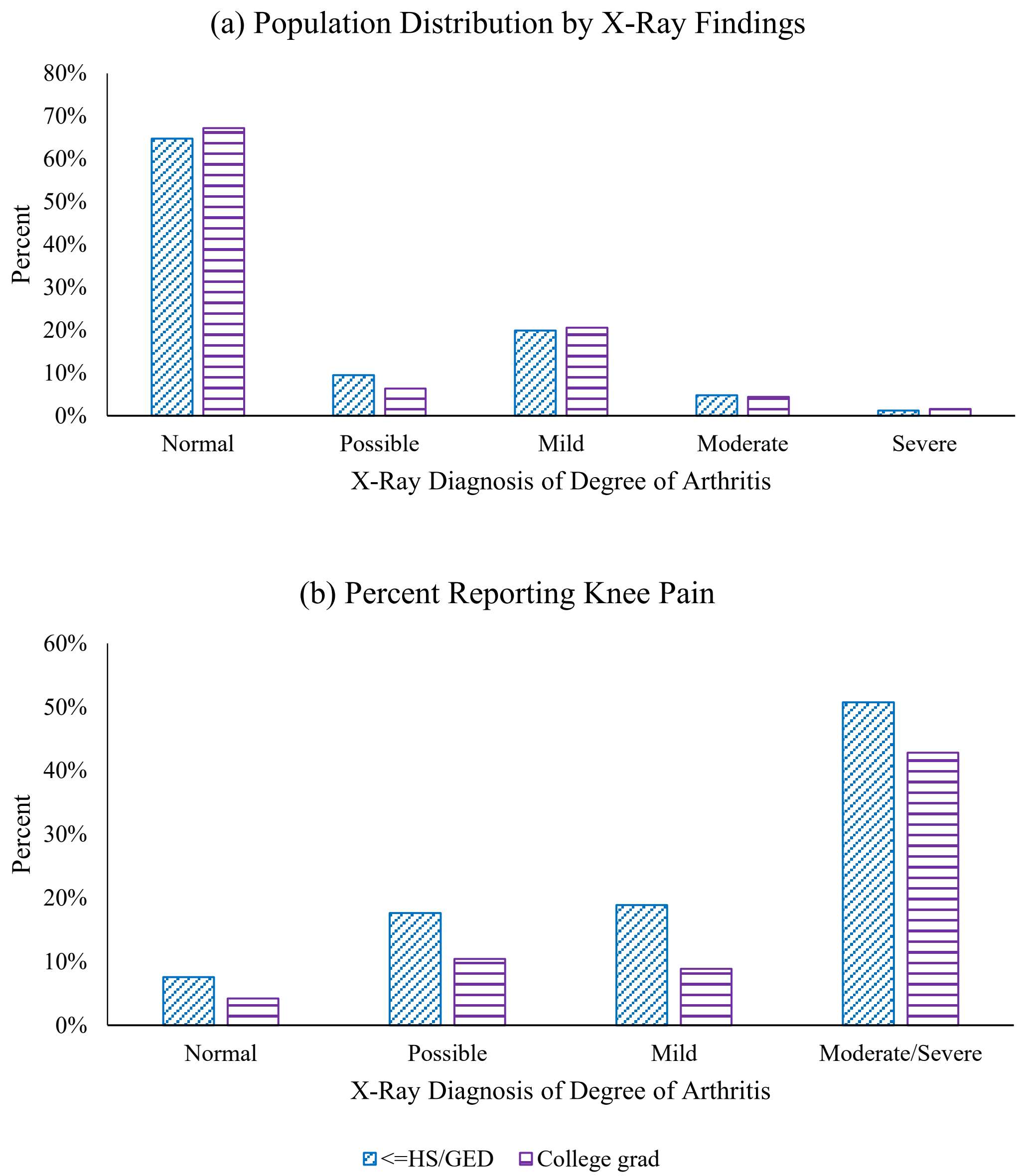
Figure 4: Percent of People Reporting Knee Pain, by Education and Time



Note: Data are from the NHANES I, NHANES II, NHANES III, continuous NHANES, and NHIS. The sample is people aged 45-74 with the exception of NHANES III, where the sample is ages 60-74. Description of the data and question about knee pain are in Table 1. Data in each survey are weighted to reflect the age and sex distribution of the population in the 2009-16 NHANES.

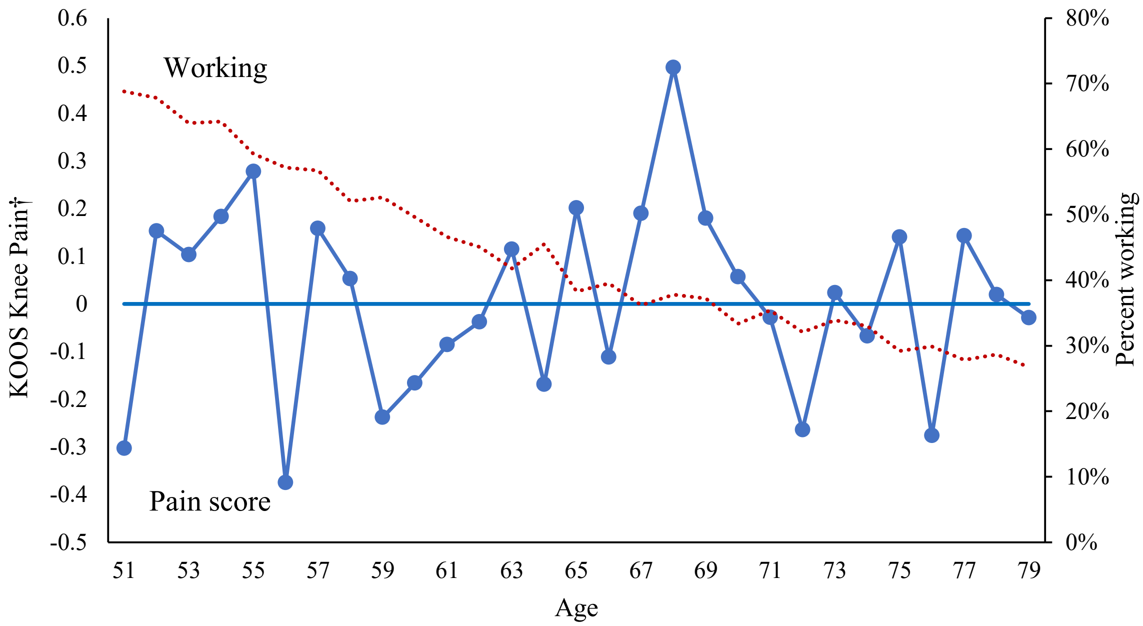
**(*) indicates that difference for between the <=HS/GED group and the college graduates is statistically significant at the 5% (10%) level.

Figure 5: Severity of Knee Arthritis and Pain Conditional on Arthritis



Note: Data are from the second phase of NHANES III, 1992-94. The sample is people aged 60-74 with both reports of knee pain and x-ray readings. Each observation is a knee.

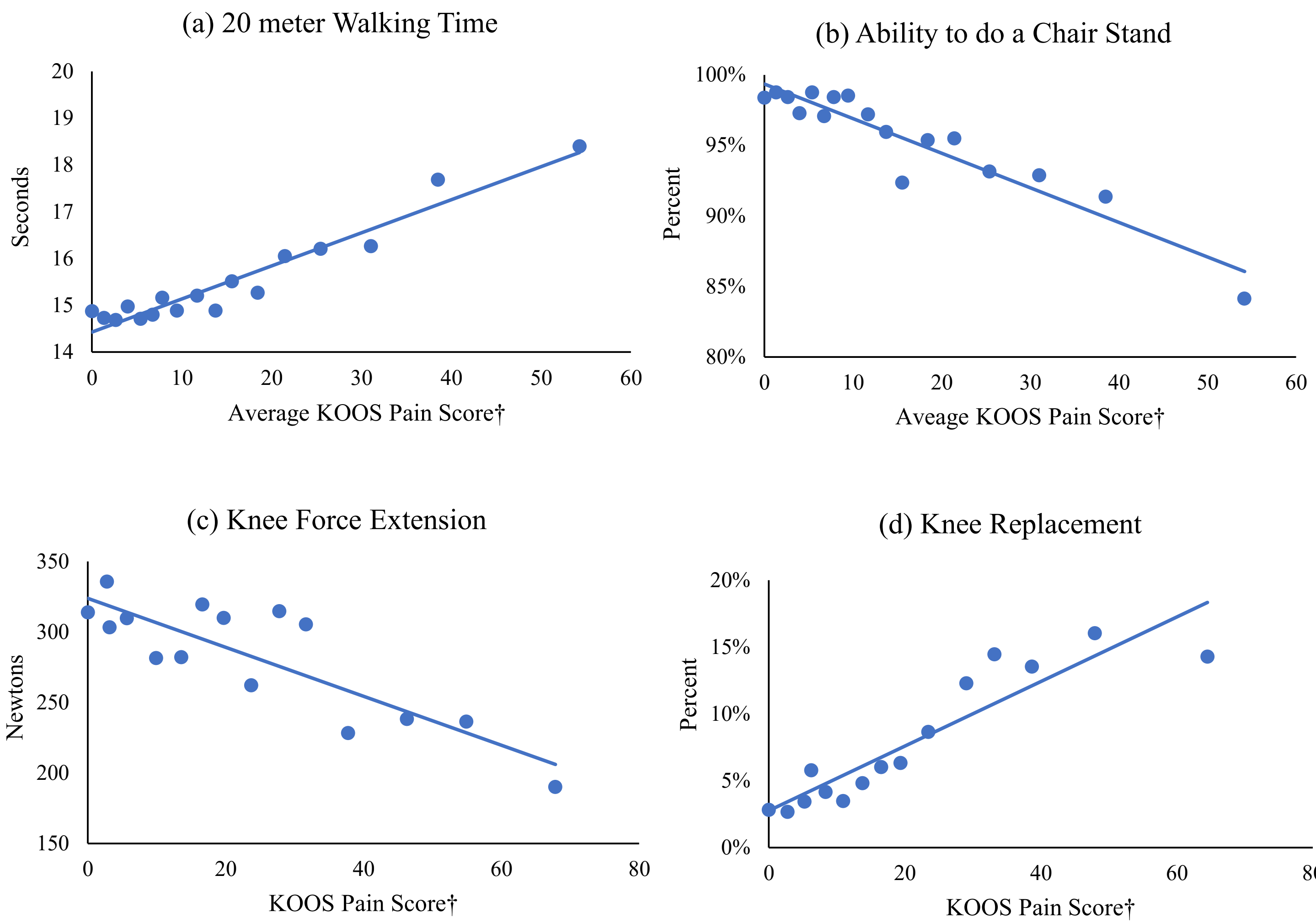
Figure 6: Change in Knee Pain Around Retirement Ages



Note: Data are from the first follow-up wave in the OsteoArthritis Initiative. Working is defined as having worked in the past week.

† The KOOS score is subtracted from 100 so that a higher value corresponds to more pain.

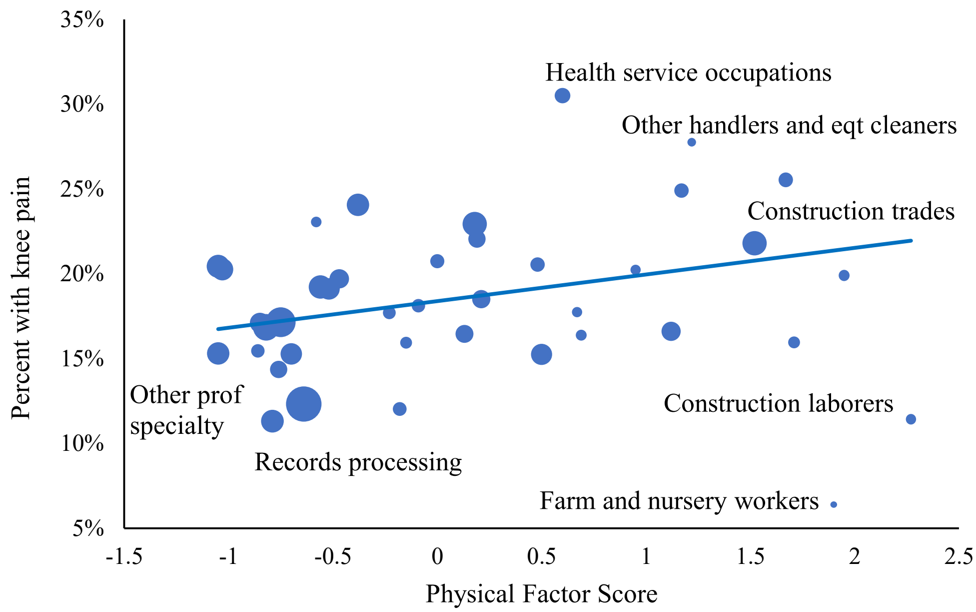
Figure 7: Relationship Between Knee Pain, Physical Performance, and Subsequent Medical Care



Note: Data are from the OsteoArthritis Initiative (OAI). In panels (a)-(c), performance measures and pain are taken from the second wave of the survey. Walking time is in seconds. Ability to do a chair stand is the percent of people who can stand from a chair with their arms crossed. Both are related to the average level of pain in the two knees. Maximum force at exertion is specific to the knee. In panel (d), knee replacement is at any time over the course of the survey and is related to pain score at enrollment.

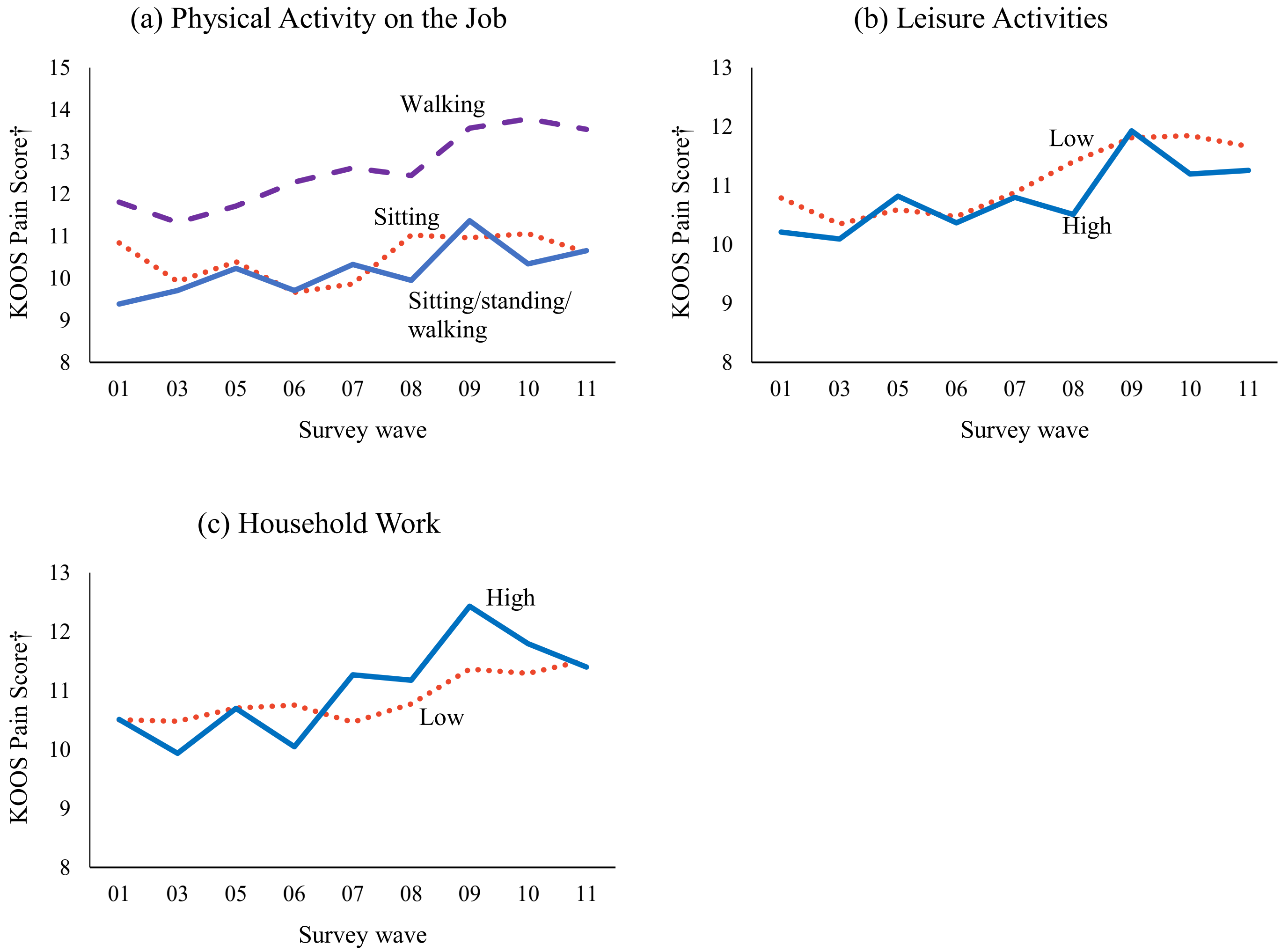
† The KOOS score is subtracted from 100 so that a higher value corresponds to more pain.

Figure 8: Relationship Between Knee Pain and Physical Activity on the Job



Note: Data are from the NHANES, 1999-2004. The sample is people aged 45-74. The physical factor is the first factor from a principal component model including strength requirements, reaching, climbing, and 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. Each circle is weighted by the population in the occupation.

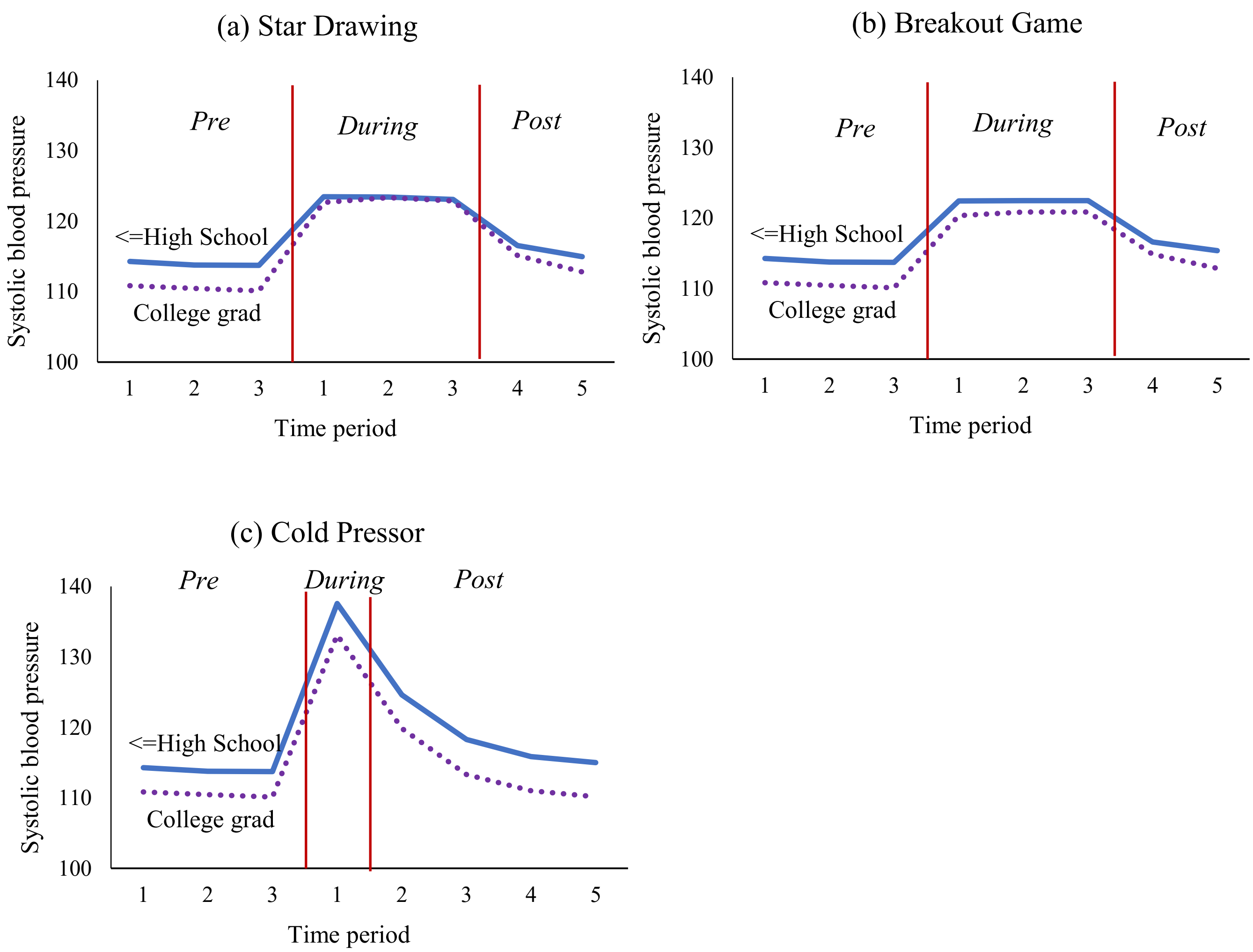
Figure 9: Physical Activity and the Development of Knee Pain



Note: Data are from the OsteoArthritis Initiative (OAI). The sample is people in the incidence cohort (without prior knee arthritis and pain, but at risk for arthritis), aged 45-59 at wave 01 and working. Job, leisure and household activity scales are from the Physical Activity Scale for the Elderly (PASE). Household work and leisure activities are scored on a continuous scale

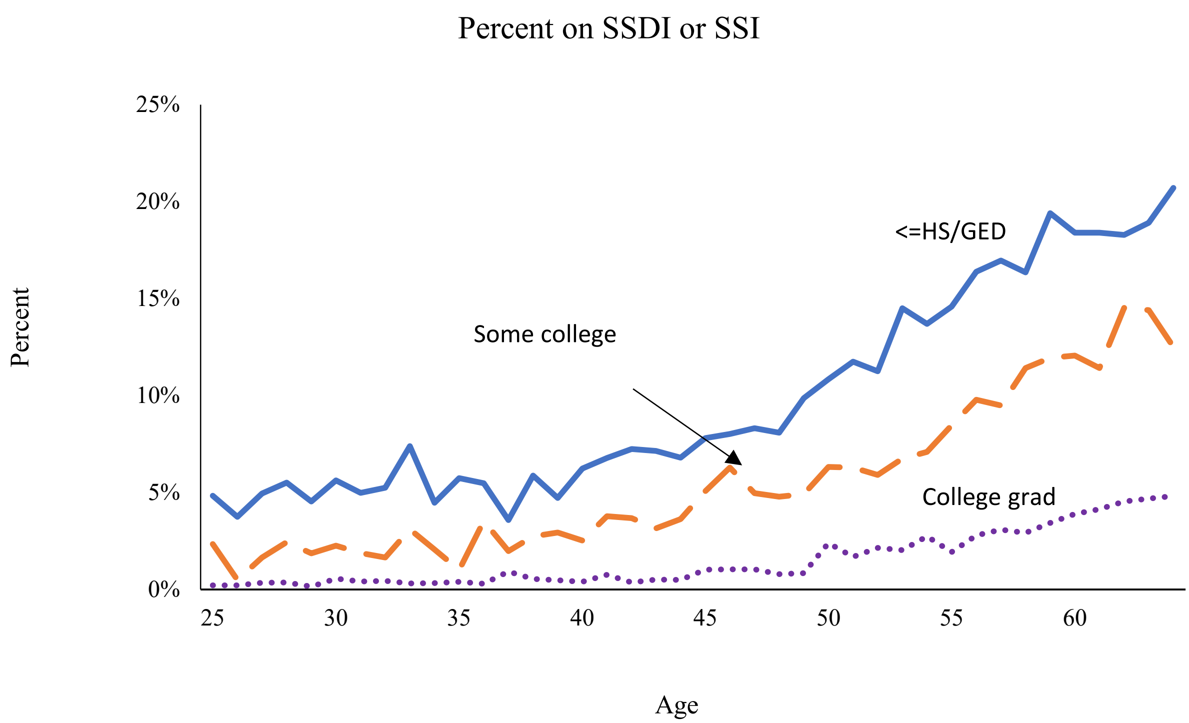
† The KOOS score is subtracted from 100 so that a higher value corresponds to more pain.

Figure 10: Blood Pressure Response to Stressor by Education



Note: Data are from the Coronary Artery Risk Development in Young Adults (CARDIA) study. Each observation is a blood pressure reading. The first values of 1-3 are before the test. The remaining values are during and after the test. All readings are systolic blood pressure.

Figure 11: Disability Insurance Receipt by Education and Age



Note: Data are from the National Health Interview Survey, 2009-2016. Figure shows the percent of people receiving SSDI or SSI.

Table 1: Population Samples with Knee Pain Data

	NHANES I (1971-74)	NHANES II (1976-80)	NHANES III (1988-94)	NHANES (1999-04)	NHIS (2009-16)
Sample size (45-74)	4,104	6,549	6,227	6,371	106,999
Knee pain question	Pain most days in for at least 6 weeks	Pain or aching most days for at least 6 weeks	Pain, aching, or stiffness most days for at least 6 weeks	Pain, aching, stiffness, or swelling in past 12 months	Pain, aching, or stiffness in past 30 days, began at least 3 months ago
Percent with knee pain					
Unadjusted	10.1%	11.9%	19.1%	18.3%	24.9%
Age-sex adjusted	10.1%	11.7%	16.7%	18.8%	24.9%
Percent obese (age-sex adjusted)	18.6%	14.1%	28.0%	31.3%	33.0%
X-rays	Yes	---	1992-94	---	---
Occupation in longest job	---	---	40 categories	40 categories	93 categories

Note: The exact questions on knee pain are as follows. NHANES I: Yes to both of “Have you had pain in or around knee most days for at least one month?” and “Has the pain in knee area been present on any one occasion for at least six weeks?” NHANES II: “Have you had pain or aching in any joint other than the back or neck on most days for at least six weeks?” NHANES III: “Have you ever had pain in your knees on most days for at least 6 weeks? This also includes aching and stiffness.” Continuous NHANES: “During the past 12 months, {have you/has SP} had pain, aching, stiffness or swelling in or around a joint?” NHIS: Yes to both of “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?” and “Did the joint symptoms begin more than 3 months ago?”

Table 2: Impact of Imaging on Education Gradient in Knee Pain

			OsteoArthritis Initiative (2005)			
	NHANES III (1992-94)		Knee Pain (Binary)		KOOS Pain Scale†	
Independent Variable	(1)	(2)	(3)	(4)	(5)	(6)
Education						
Some college	.042	.046	.012	.016	-2.10	-2.07
	(.036)	(.033)	(.035)	(.033)	(1.42)	(1.28)
College grad	-.073**	-.063**	-.077**	-.047*	-6.21**	-5.34**
	(.023)	(.021)	(.031)	(.029)	(1.23)	(1.10)
Imaging / observation controls	---	KL grade, crepitus, swelling, range of motion	---	KL grade, crepitus, cartilage, meniscus, bone marrow lesion	---	KL grade, crepitus, cartilage, meniscus, bone marrow lesion
Other controls	Age-sex, healt history, race, US born, veteran, side	Age-sex, health history, race, US born, veteran, side	Age-sex, health history, hear about survey, site, side	Age-sex, health history, hear about survey, site, side	Age-sex, health history, hear about survey, site, side	Age-sex, health history, hear about survey, site, side
N	3,126	3,126	2,495	2,495	2,498	2,498
R^2	.024	.163	.035	.143	.068	.233
Change in coefficient on college grad	---	14%	---	29%	---	14%

Note: Each observation is a knee. Standard errors are clustered at the individual level. Columns (1) and (2) are from NHANES III, 1992-94. Columns (3)-(6) are from the Osteoarthritis initiative. **(*) indicates that difference for between the <=HS/GED group and the college graduates is statistically significant at the 5% (10%) level.

† The KOOS score is subtracted from 100 so that a higher value corresponds to more pain.

Table 3: Correlation Among Job Attributes

	Measure			
	Physical effort	Abstract work	Routine work	Manual work
Physical effort	1.000			
Abstract work	-.440	1.000		
Routine work	.229	-.176	1.000	
Manual work	.613	-.241	.070	1.000

Note: The correlations are based on job characteristics from the 1977 Dictionary of Occupation Titles (DOT). The sample size is 495 occupations. Physical effort is the first principle component from a factor model using four measures of physical demands: a five-point strength scale; the share of workers engaged in climbing; the share engaged in reaching; and the share engaged in stooping. Abstract work, routine work, and manual work are as defined in Autor, Katz, and Kearney (2006) and Autor and Dorn (2013).

Table 4: Impact of Obesity and Job Attributes on Knee Pain

	Dependent variable: Pain in either knee				
Independent Variable	(1)	(2)	(3)	(4)	(5)
Education					
Some college	-0.008	0.003	-0.001	-0.005	0.001
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
College graduate	-0.045**	-0.023*	-0.028*	-0.029**	-0.014
	(0.012)	(0.014)	(0.015)	(0.012)	(0.014)
Job attributes on longest job					
Physical demands	---	0.026**	0.023**	---	0.022**
		(0.007)	(0.009)		(0.009)
Abstract work	---	---	0.012	---	0.013*
			(0.008)		(0.008)
Routine work	---	---	0.012*	---	0.014**
			(0.006)		(0.006)
Manual work	---	---	0.010	---	0.008
			(0.008)		(0.008)
Current BMI					
Underweight	---	---	---	0.089	0.092*
				(0.055)	(0.055)
Overweight	---	---	---	-0.004	-0.003
				(0.016)	(0.016)
Obese	---	---	---	0.032	0.035
				(0.022)	(0.022)
Morbidly obese	---	---	---	0.132**	0.137**
				(0.029)	(0.029)
Maximum BMI					
Underweight	---	---	---	-0.106	-0.107
				(0.082)	(0.082)
Overweight	---	---	---	0.055**	0.055**
				(0.018)	(0.018)
Obese	---	---	---	0.117**	0.115**
				(0.022)	(0.022)
Morbidly obese	---	---	---	0.100**	0.095**
				(0.028)	(0.028)
N	6,366	6,366	6,366	6,366	6,366
R^2	.018	.021	.022	.049	.053
Change in coefficient on college grad	**---**	**49%**	**38%**	**36%**	**70%**
From physical demands	**---**	**48%**	**42%**	**---**	**40%**
From obesity	**---**	**---**	**---**	**36%**	**36%**

Note: Data are from the NHANES, 1999-2004. The sample is people aged 45-74. 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 columns 2, 3, and 5, dummy variables are included for whether the person's longest job was in the armed forces, was missing, and whether the person never worked. In columns 4-5, dummy variables are included for missing current BMI and missing maximum BMI. **(*) indicates statistically significant at the 5% (10%) level.

Table 5: Impact of Job Attributes and Obesity on Musculoskeletal Pain

	Joint Pain								Muscle Pain	
Independent variable	Knees	Hips	Ankles	Toes	Shoulders	Elbows	Wrists	Fingers	Lower back	Neck
Prevalence	18%	8%	10%	4%	13%	8%	8%	12%	40%	23%
A. Demographics only										
College graduate	-0.045**	-0.024**	-0.059**	-0.006	-0.072**	-0.066**	-0.056**	-0.039**	-0.149**	-0.093**
	(0.012)	(0.009)	(0.010)	(0.006)	(0.011)	(0.009)	(0.008)	(0.010)	(0.016)	(0.013)
N	6,366	6,366	6,366	6,366	6,366	6,366	6,366	6,366	6,368	6,367
B. Adding jobs and obesity										
College graduate	-0.014	-0.007	-0.039**	-0.004	-0.041**	-0.050**	-0.040**	-0.025**	-0.115**	-0.082**
	(0.014)	(0.010)	(0.011)	(0.007)	(0.013)	(0.010)	(0.010)	(0.012)	(0.018)	(0.016)
Job attributes										
Physical demands	0.022**	0.016**	0.007	-0.002	0.022**	0.020**	0.008	0.009	0.028**	0.006
	(0.009)	(0.006)	(0.007)	(0.004)	(0.008)	(0.006)	(0.006)	(0.007)	(0.011)	(0.009)
Abstract work	0.013*	0.001	0.001	0.002	-0.006	-0.004	-0.005	0.003	-0.003	-0.004
	(0.008)	(0.006)	(0.006)	(0.004)	(0.007)	(0.006)	(0.006)	(0.007)	(0.010)	(0.009)
Routine work	0.014**	0.006	-0.001	0.001	0.003	-0.008*	0.008*	0.011**	-0.005	-0.007
	(0.006)	(0.004)	(0.005)	(0.003)	(0.005)	(0.004)	(0.004)	(0.005)	(0.008)	(0.007)
Manual work	0.008	-0.012*	0.012*	0.010**	0.007	-0.009	-0.002	0.005	0.007	0.006
	(0.008)	(0.006)	(0.006)	(0.004)	(0.007)	(0.006)	(0.006)	(0.007)	(0.011)	(0.009)
N	6,366	6,366	6,366	6,366	6,366	6,366	6,366	6,366	6,368	6,367
Ch in coef on college grad	**70%**	**72%**	**34%**	**---**	**43%**	**24%**	**29%**	**38%**	**23%**	**12%**
From physical demands	**40%**	**57%**	**9%**	**---**	**26%**	**26%**	**12%**	**18%**	**16%**	**5%**
From obesity	**36%**	**25%**	**19%**	**---**	**7%**	**2%**	**6%**	**10%**	**6%**	**4%**

Note: The sample size is 6,366 for joint pain, 6,368 for lower back pain, and 6,367 for neck pain. Regressions include dummy variables for armed forces, no work, and missing work. **(*) indicates statistically significant at the 5% (10%) level. "Physical demands" is the first principle component from a factor model using four measures of physical demands: a five-point strength scale; the share of workers engaged in climbing; the share engaged in reaching; and the share engaged in stooping. Abstract work, routine work, and manual work are as defined in Autor, Katz, and Kearney (2006) and Autor and Dorn (2013).

Table 6: Impact of Psychological Factors on Knee Pain

Independent Variable	Dependent variable: Onset of Knee Pain							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Education								
Some college	-0.015	0.000	0.000	0.004	0.001	0.001	0.004	0.000
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
College graduate	-0.038**	-0.009	-0.007	-0.005	-0.006	-0.006	-0.005	-0.008
	(0.017)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Physical effort on job	---	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Current BMI	---	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Psychosocial variables								
Life satisfaction	---	---	-0.009*	---	---	---	-0.004	---
			(0.005)				(0.006)	
Affect								
Positive affect	---	---	---	-0.003	---	---	-0.006	---
				(0.012)			(0.014)	
Negative affect	---	---	---	0.039**	---	---	0.043**	---
				(0.017)			(0.018)	
Sense of control								
Overall	---	---	---	---	-0.014*	---	-0.008	---
					(0.008)		(0.011)	
Health – self	---	---	---	---	0.004	---	0.005	---
					(0.009)		(0.009)	
Psychological well-being[a]	---	---	---	---	---	[.899]	[.914]	---
Somatic amplification	---	---	---	---	---	---	---	0.014
								(0.013)
N	1,784	1,784	1,784	1,784	1,784	1,784	1,784	1,784
R^2	.016	.050	.053	.056	.052	.051	.059	.051
Change in coefficient on college grad	**---**	**77%**	**81%**	**88%**	**83%**	**84%**	**87%**	**79%**
From phys. demands	**---**	**39%**	**37%**	**35%**	**36%**	**37%**	**35%**	**38%**
From obesity	**---**	**38%**	**37%**	**37%**	**37%**	**37%**	**37%**	**38%**
From psych. var(s)	**---**	**---**	**3%**	**14%**	**10%**	**8%**	**11%**	**4%**

Note: Data are from MIDUS. The sample is people aged 45-74 in the third wave who reported no knee pain in the second wave. All regressions control for five year age-sex cells, race and ethnicity dummy variables, a dummy variable for being US born, and dummy variables for missing or refused answers. In the psychological well-being row, the value in [.] is the p-value for the hypothesis test that the psychological well-being variables are jointly zero.

**(*) indicates statistically significant at the 5% (10%) level.

a- In column 7, psychological well-being variables include measures of autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance (see tables A6 and A7 for definitions and means).

Table 7: Impact of Job Attributes and Obesity on Pain and Disability Insurance Receipt

Independent variable	Knee Pain	SSDI/SSI Receipt
Prevalence	24%	9%
College graduate	-0.075**	-0.106**
	(0.007)	(0.005)
College graduate	-0.033**	-0.068**
	(0.008)	(0.005)
Job attributes		
Physical demands	0.035**	0.014**
	(0.006)	(0.004)
Abstract work	0.004	-0.024**
	(0.005)	(0.003)
Routine work	0.006	-0.007**
	(0.004)	(0.003)
Manual work	0.000	-0.005
	(0.005)	(0.004)
Obesity		
Underweight	-0.006	0.084**
	(0.028)	(0.019)
Overweight	0.058**	-0.008
	(0.008)	(0.005)
Obese	0.126**	0.013**
	(0.009)	(0.006)
Morbidly obese	0.267	0.073**
	(0.010)	(0.007)
N	20,364	20,375
Change in coef on college grad	**56%**	**36%**
From physical demands	**36%**	**10%**
From other job attributes	**-7%**	**24%**
From obesity	**29%**	**5%**

Note: The data are from the National Health Interview Survey, 2010 and 2015 waves. The sample is people aged 45-64. Physical demands is the first principle component from a factor model using four measures of physical demands: a five-point strength scale; the share of workers engaged in climbing; the share engaged in reaching; and the share engaged in stooping. Abstract work, routine work, and manual work are as defined in Autor, Katz, and Kearney (2006) and Autor and Dorn (2013).

Data Appendix – For Online Publication

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

National Health Information Survey (NHIS)

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 being 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 1 shows the education gradient in functional limitations, musculoskeletal impairments, and chronic knee pain, while figure 11 shows the educational gradient in receipt of SSDI or SSI. 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 has 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.[31] Specifically, 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 receiving SSDI or SSI and the percent with chronic knee pain using this alternative measure of education. the results are very similar to those in Figures 1 and 11.

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 we do not include indicators for other conditions in our primary specification. Table A2 shows the impact of including other conditions. These conditions include respiratory disease (asthma, 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

[31] 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.

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

The OAI is a longitudinal sample of people 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 enrollment wave is termed waved "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 one we utilize is the pain subcomponent of the Knee Injury and Osteoarthritis Outcomes Score (KOOS).[32] The pain subcomponent consist 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 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.

Section IV of the paper shows that knee pain increases more for people whose job involved more physical activity. Figure 8 shows descriptive trends of the phenomenon. To consider other hypotheses, as well as to provide standard errors, we estimate the relationship more formally using regression analysis. Our model is of the form:

$$\text{Knee Pain}_{i,t} = \text{Education}_i \cdot t\,\beta^{E} + X_{D,i,t}\,\beta^{D} + \text{BMI}_{i,t}\,\beta^{BMI} + \text{BMIMAX}_i \cdot t\;\beta^{BMI} + \text{BaseActivity}_i \cdot t\,\beta^{Act} + \theta_i + \xi_i \qquad \text{(A1)}$$

Person-knee fixed effects (θ_i) so that average differences in pain for each person-knee are taken out. We include education trends in knee pain, current BMI, and maximum BMI interacted with a time trend. The key coefficients are β^{Act}, the impact of baseline work, leisure, and household activities on trends in knee pain.

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

Table A3 shows the results of the estimation. Column (1) includes the entire incidence sample; column (2) narrows the sample to people without chronic pain in the indicated knee at baseline.[33] In both samples, people with more physically demanding jobs experience greater increases in knee pain over time. The pattern for housework is similar, although only statistically significant in those without pain at baseline. Similarly, more active leisure activities reduce trends in knee pain, though only statistically in those without knee pain at baseline.

Midlife Development in the US (MIDUS)

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 question. 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.

Job Characteristics Data

Our data on job characteristics come from England and Kilbourne.[34] The original sources are as follows. The National Academy of Sciences assembled a file linking information from the

[33] People aged asked to describe their pain in three groups: no pain in the past 12 months; pain in the past month but not most days in the month; and pain most days of a month in the past month. Tis sample excludes people in the third group.

[34] 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

1977 Dictionary of Occupation Titles (DOT) to 1970 Census occupation and industry codes.[35] 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,[36] 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[37] (which are in the NHANES) and 2000 occupation codes[38] (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 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 to group 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. Table A8 shows the factor analysis results. In both cases, the first eigenvalue is very high and the second is very small. Thus, the data are fit well with a single factor.

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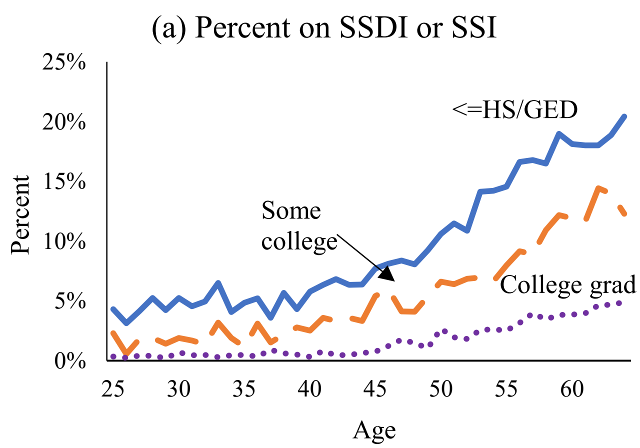
[35] National Academy of Sciences. Committee on Occupational Classification and Analysis. Dictionary of Occupational Titles (DOT): Part I - Current Population Survey, April 1971, Augmented With DOT Characteristics and Dictionary of Occupational Titles (DOT): Part II - Fourth Edition Dictionary of DOT 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

[36] 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.

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

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

Figure A1: NHIS results with simulated education



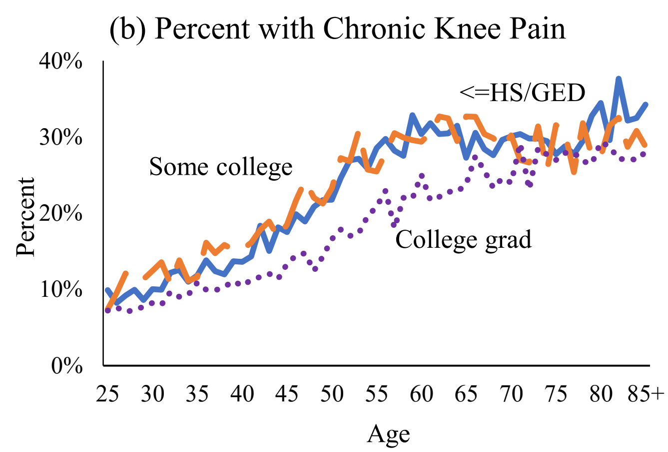
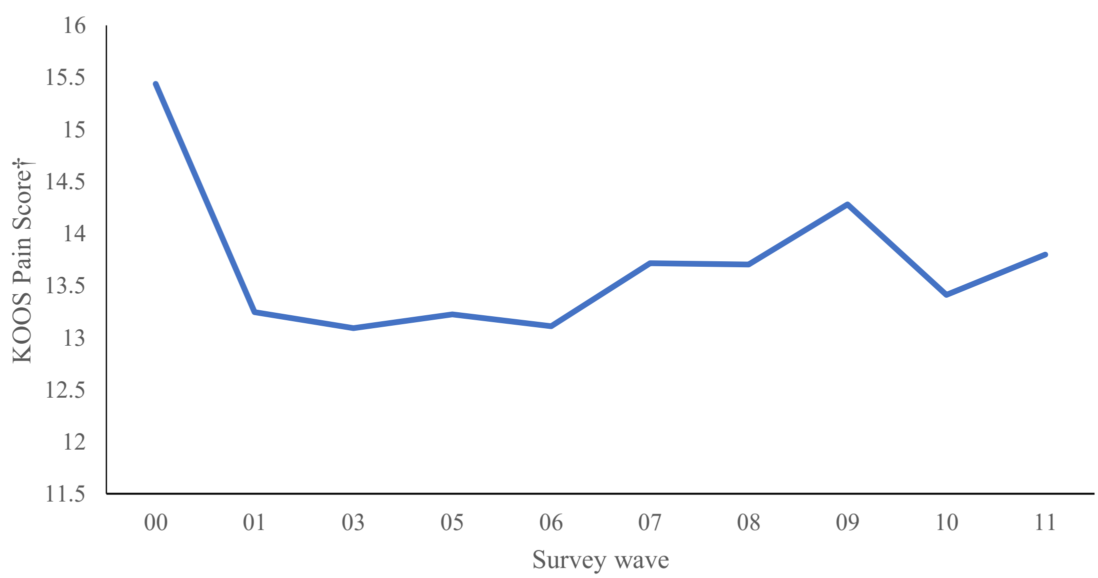


Figure A2: Evidence of Selection in OAI Data



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 any 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.

Table A1: Summary Statistics for Continuous NHANES

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: Robustness of Knee Pain Results to Including Other Conditions

Independent Variable	Dependent variable: Pain in either knee			
	(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. 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 A3: Impact of Jobs, Leisure, and Housework on Progression in Knee Pain

Independent Variable	Dependent variable: KOOS Knee Pain† Full sample	Dependent variable: KOOS Knee Pain† Without chronic pain at base
Education * time		
Some college	-0.186*	0.174
	(0.113)	(0.129)
College graduate	0.048	0.191*
	(0.102)	(0.116)
Work scale * time		
Walking	0.269**	0.291**
	(0.073)	(0.081)
Sitting, standing, walking	0.079	0.051
	(0.066)	(0.072)
Leisure activity scale * time	-0.037	-0.070**
	(0.027)	(0.031)
Housework activity scale * time	0.044	0.058*
	(0.028)	(0.031)
Current BMI		
Overweight	0.504	0.087
	(0.327)	(0.362)
Obese	1.530**	1.333**
	(0.387)	(0.043)
Morbidly obese	2.086**	1.304**
	(0.511)	(0.057)
Maximum BMI * time		
Overweight	0.147*	0.033
	(0.079)	(0.087)
Obese	0.197**	0.138
	(0.086)	(0.097)
Morbidly obese	0.376**	0.148
	(0.102)	(0.112)
N – people	2,416	1,818
N - observations	19,556	14,389
R^2	.613	.564

Note: Data are from the OsteoArthritis Initiative. Each observation is a knee. The sample is people aged 45-60 and who were working in the second wave. Regressions control for wave dummies, five year age-sex cells, dummy variables for knee injury or knee surgery prior to the second wave each interacted with time, and dummy variables for missing current and maximum BMI. Standard errors are clustered at the knee level. **(*) indicates statistically significant at the 5% (10%) level.
† The KOOS score is subtracted from 100 so that a higher value corresponds to more pain.

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: Eigenvalues from Factor Analyses

	Physical Factor	Environmental Exposure Factor
Factor 1	2.28	1.74
Factor 2	0.18	0.38
Factor 3	-0.14	-0.01

The sample is 495 occupations.