

# Perceived Physical Activity and Mortality: Evidence From Three Nationally Representative U.S. Samples

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**Objective:** This research sought to examine the relationship of individuals' perceptions about their level of physical activity with mortality outcomes at the population level. **Method:** This study used 3 nationally representative samples with a total sample size of 61,141 U.S. adults (weighted  $N = 476$  million). Data from the 1990 National Health Interview Survey (NHIS) and the 1999–2002/2003–2006 National Health and Nutrition Examination Survey (NHANES) were linked to prospective National Death Index mortality data through 2011, yielding follow-up periods of up to 21 years. Cox proportional hazards models were used to determine the association between respondents' perceptions of their relative level of physical activity (compared with other people their age) and all-cause mortality, adjusting for actual levels of physical activity, health status and behavior, and sociodemographic variables. **Results:** Perceived physical activity relative to peers was associated with mortality risk. Individuals who perceived themselves as less active than others were up to 71% more likely to die in the follow-up period than those who perceived themselves as more active. This finding held across 3 samples and after adjusting for actual levels of physical activity and other covariates. **Conclusions:** Individuals' perceptions about their level of physical activity strongly predicted mortality, even after accounting for the effects of actual physical activity and other known determinants of mortality. This suggests that perceptions about health behaviors may play an important role in shaping health outcomes.

**Keywords:** physical activity, perception, social comparison, mindset, mortality

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Physical inactivity is estimated to account for 1 in 10 deaths worldwide and constitutes a major risk factor for noncommunicable disease (Lee et al., 2012). Public health and research initiatives have spent enormous resources promoting behavior change through media campaigns, school and workplace programs, and changes to social and physical environments (Chokshi & Farley, 2014; Heath et al., 2012). Despite all efforts, 79% of U.S. adults do not meet exercise guidelines (Ward, Clarke, Nugent, & Schiller, 2016), and yearly deaths from noncommunicable diseases worldwide are projected to increase from 38 to 52 million between 2012 and 2030 (World Health Organization, 2014).

Increasing engagement in physical activity is a necessary step toward solving this public health crisis (Warburton, Nicol, & Bredin, 2006), but it may not be sufficient. People's *perceptions*

about their level of physical activity and its expected risks and benefits are an important—albeit often overlooked—variable that can influence health outcomes and strengthen or weaken the benefits of physical activity. For any given level of physical activity, people may perceive themselves as more or less active, fit, and healthy, depending on what they believe is the “right” type and amount of activity based on health guidelines, social comparison, and other sources of information. We present suggestive evidence that such perceptions meaningfully affect health outcomes. Specifically, we establish the predictive power of individuals' perceptions of their physical activity in explaining U.S. mortality rates.

To illustrate our argument, consider the example of hotel room attendants. Room attendants objectively meet recommended levels of physical activity simply by carrying out their daily work. However, they may still perceive themselves as physically inactive if they do not realize that all the walking, pushing, and lifting involved in cleaning rooms constitutes good exercise. In one study, researchers conducted a 20-minute intervention informing room attendants that their daily work satisfied exercise recommendations and highlighting the benefits of this active lifestyle. This intervention not only shifted room attendants' perceptions, but also resulted in significant physiological health improvements including reductions in weight, body fat, and blood pressure (Crum & Langer, 2007). This study offered initial evidence that individuals' perceptions about their level of physical activity can influence the relationship between physical activity and health.

Other studies have shown that perceptions—often referred to as mindsets—about health behaviors, including stress, aging, and

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diet, play an important role in shaping health outcomes (Crum, Corbin, Brownell, & Salovey, 2011; Crum, Salovey, & Achor, 2013; Keller et al., 2012; Levy, Slade, Kunkel, & Kasl, 2002). For example, highly stressed U.S. adults who perceived stress as harmful were 43% more likely to die prematurely than their stress-free peers. However, absent the perception that stress is harmful, highly stressed adults were no more likely to die prematurely (Keller et al., 2012). In fact, the perception that stress enhances (rather than harms) health and vitality produces more adaptive cortisol profiles under acute stress (Crum et al., 2013). At the broadest level, perceptions of general health strongly predict mortality even after accounting for numerous indicators of physical and mental health (Idler & Benyamini, 1997).

How do perceptions have such powerful effects? Prior work highlights three potential mechanisms that might explain the association between perceptions and health. First, perceptions can affect motivation. A room attendant's awareness that she is getting exercise at work might increase her self-efficacy (Bandura & Locke, 2003) and commitment to a healthy lifestyle (Fishbach, Eyal, & Finkelstein, 2010), and motivate her to act on this "active" identity (Rise, Sheeran, & Hukkelberg, 2010) by making beds more energetically or exercising in her leisure time. Conversely, longitudinal research shows that individuals who perceive themselves as unfit compared with their friends are less likely to exercise a year later, even after controlling for their current level of activity (Shakya, Christakis, & Fowler, 2015). This suggests that regardless of current behavior, individuals' perceptions of their physical activity affect their motivation and future behavior.

A second potential mechanism is that perceptions can have affective consequences such as fear, stress, or depression. Since the release of the Surgeon General's physical activity guidelines in 1996 (Centers for Disease Control and Prevention [CDC], 1996), it has become widely known that physical inactivity is a major threat to health (Johnson & Ballin, 1996). Public health messages often warn of the "life-threatening consequences" of physical inactivity and the "obesity epidemic" (CDC, 1996; White House Task Force on Childhood Obesity, 2010). A room attendant's perception that she is inactive might thus arouse fear of adverse health consequences and stress about fitting exercise into her busy schedule. The resulting negative affect, chronic stress or depression may compromise health and even predict premature mortality (Charney & Manji, 2004; Salovey, Rothman, Detweiler, & Steward, 2000).

A third mechanism is that perceptions can elicit physiological responses directly. This is demonstrated by the occurrence of placebo effects, in which individuals' perceptions elicit physiological responses to treatments in the absence of active medical treatment properties (Price, Finniss, & Benedetti, 2008). Placebo responses yield clinically significant benefits for numerous conditions and medical procedures, including pain, Parkinson's disease, and surgeries; they work via neurobiological mechanisms such as changes in the nervous, endocrine, cardiovascular, and immune systems (Price et al., 2008). Strong active drugs and medical treatments can be significantly less effective when administered without the patient's awareness or positive expectation (Kam-Hansen et al., 2014). Likewise, negative expectations can evoke "nocebo" responses, that is, adverse health symptoms such as side effects from medication. Following this logic, a room attendant who fails to realize that she is getting good exercise may not

experience its full physiological benefits (Crum & Langer, 2007). Moreover, the expectation of adverse health consequences of physical inactivity can become self-fulfilling because of nocebo-like effects. In sum, perceptions of physical activity may have significant long-term effects on health through shifts in behavior, affect, and physiology.

However, evidence for the health effects of perceived physical activity is limited to short-term physiological changes in a small sample of room attendants. Therefore, we investigate the relationship between physical activity perceptions and mortality at the level of the U.S. population. Though population surveys offer insight into long-term trends in behavior and health, none of them (to our knowledge) have directly assessed individuals' perceived amount of physical activity and expected risks and benefits. Nevertheless, the National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Survey (NHANES) include questions assessing how much exercise individuals perceive themselves to be getting *as compared with other people their age*. This is a good proxy for perceived physical activity, as social comparison is an important source of people's perceptions about their everyday behaviors and health (Gibbons & Gerrard, 2013; Suls, Marco, & Tobin, 1991; Trautwein, Gerlach, & Lütke, 2008). Questions assessing general health perceptions directly or through social comparison yield consistent results, and it is commonly assumed in the empirical literature that self-ratings of health reflect social comparison with relevant social reference groups (Idler & Benyamini, 1997; Suls et al., 1991). The effects of social comparison may be especially strong in the domain of physical activity, as exercise behavior and its effects (e.g., body shape and fitness) are highly visible and salient (Gibbons & Gerrard, 2013). Thus, social comparison may shape individuals' perceptions of their physical activity level as high or low, sufficient or insufficient, and thus, healthy or unhealthy—independently of how much exercise they actually get.

## Method

### Data Source and Study Samples

The data originate from the NHIS and the NHANES, two cross-sectional surveys conducted by the National Center for Health Statistics (NCHS). Data are collected through personal interviews at respondents' homes. Additionally, NHANES respondents complete a clinical examination at a mobile examination center. Selected data sets from both survey programs have been linked to the National Death Index (NDI) from 2011, allowing researchers to determine respondents' mortality (National Center for Health Statistics [NCHS], 2016c). Both NHIS and NHANES use a multistage area probability design resulting in the selection of a nationally representative sample of the U.S. civilian noninstitutionalized population. When accounting for this complex sampling design and using proportional weights for each unit in the sample, results are representative of the mortality risk of the population (Massey, Moore, Parsons, & Tadros, 1989).

The first sample consisted of survey data from the 1990 wave of NHIS. This specific NHIS survey wave was selected because it had the longest mortality follow-up period (21 years) among the NHIS waves that contained our independent variable of interest, that is, perceptions about physical activity relative to others. In addition, this survey wave featured comprehensive self-report

measures of actual physical activity. NHIS measures were drawn from the 1990 NHIS Health Promotion and Disease Prevention (HPDP) Sample Person Supplement from the NHIS Public Use Data Records (NCHS, 1990).

All analyses were replicated in an NHANES sample using similar measures to test the robustness of our findings. To ensure adequate sample size and produce statistically reliable estimates, survey data from the 1999–2000 and 2001–2002 waves of NHANES were combined into one sample, following NCHS recommendations (NCHS, 2013a). Measures were drawn from the following 1999–2000 and 2001–2002 NHANES survey and examination components: Demographics (DEMO), Physical Activity (PAQ), Physical Activity–Individual Activities (PAQIAF), Medical Conditions (MCQ), Diabetes (DIQ), Hospital Utilization & Access to Care (HUQ), and Body Measures (BMX; NCHS, 2016b).

Finally, our third sample consisted of combined data from the 2003–2004 and 2005–2006 waves of NHANES. In 2003, a new physical activity monitor component was added to NHANES. The primary aim of this component was to collect objective information on physical activity using accelerometers and, thus, eliminate the potential limitations of self-report interview data (e.g., difficulties in recall and quantification of periods of physical activity). Measures were drawn from the following 2003–2004 and 2005–2006 NHANES survey and examination components: DEMO, PAQ, PAQIAF, Physical Activity Monitor (PAXRAW), MCQ, DIQ, HUQ, and BMX (NCHS, 2016b).

The original data sets contained 41,104 observations (NHIS), 21,004 observations (1999–2002 NHANES), and 20,470 observations (2003–2006 NHANES). We excluded respondents who were ineligible for the mortality follow-up either because they were under 18 at the time of examination (NHIS:  $N = 14$ , 1999–2002 NHANES:  $N = 9,564$ , 2003–2006 NHANES:  $N = 9,288$ ) or because their records did not contain sufficient identifying information for NDI linkage (see NCHS, 2013b; NHIS:  $N = 330$ , 1999–2002 NHANES:  $N = 12$ , 2003–2006 NHANES:  $N = 12$ ). We additionally excluded 2,217 respondents from the 2003–2006 NHANES sample who had not been selected to undergo the physical activity monitor examination. The final NHIS sample consisted of 40,760 respondents, of whom 11,088 (27.2%) had died by 2011. The final 1999–2002 NHANES sample consisted of 11,428 respondents, of whom 2,017 (18%) had died by 2011. The final 2003–2006 NHANES sample consisted of 8,953 respondents, of whom 810 (9%) had died by 2011. In these nationally representative samples, each respondent is selected to represent a certain number of U.S. adults with similar characteristics; the weighted sample sizes are  $N = 86,812,447$  (NHIS),  $N = 205,796,070$  (1999–2002 NHANES), and  $N = 183,438,224$  (2003–2006 NHANES).

## Measures

**Mortality.** Mortality was measured as death from any cause between the respondent's interview date and December 31, 2011. Information on respondents' vital status was obtained from the NCHS 2011 linked mortality files (NCHS, 2016c), which link survey data to the 2011 National Death Index (NDI). Survival time was computed from the quarter (NHIS) or month (NHANES) of interview to the quarter (month) of death recorded in the NCHS

2011 linked mortality files. Individuals who were assumed alive (hence not matched to NDI data) were right-censored to the maximum time from interview until December 2011.

**Perceived physical activity relative to peers.** NHIS respondents were asked to evaluate their level of physical activity relative to other persons their age: "Would you say that you are physically more active, less active, or about as active as other persons your age?" Depending on their response, respondents were then asked if they were "a lot more or a little more", or "a lot less or a little less" physically active. These two items were combined into one measure of relative perceived physical activity (levels: a lot more active, a little more active, about as active, a little less active, a lot less active). NHANES respondents were asked: "Compared with most [men/women] your age, would you say that you are more active/less active/or about the same?", resulting in a three-level factor. For brevity, this measure will henceforth be referred to interchangeably as "perceived (physical) activity," or "perceived (physical) activity relative to peers/others."

**Covariates.** Following prior work (e.g., Keller et al., 2012; Sutin et al., 2015), covariates measuring demographic variables, health status, and health behavior were included in our models to account for known predictors of mortality and for individual characteristics that might influence physical activity perceptions. Measures of actual physical activity and fitness were included to examine whether perceived physical activity predicted mortality even when adjusting for actual physical activity. Table S1 in the supplemental online materials presents descriptive statistics for these variables in the NHIS and NHANES samples.

**Physical activity.** Respondents' actual levels of physical activity were assessed through a comprehensive self-report battery (NHIS, 1999–2002 NHANES) and accelerometry (2003–2006 NHANES). For brevity, these measures are henceforth referred to as "actual (physical) activity," with the caveat that while they are widely used and validated measures, they still may not perfectly capture actual activity levels because of self-report biases and measurement error.

**Actual physical activity (self-report).** In the 1990 NHIS and 1999–2002 NHANES, actual physical activity was determined following recommendations by the NCHS (2016a) and prior research (Stephens & Craig, 1989). Respondents indicated which of 24 (NHIS) or 48 (NHANES) physical activities they had done in the recent past (NHIS: past 14 days; NHANES: past 30 days). For each activity, respondents also reported frequency, duration, and intensity. Using metabolic equivalent of task (MET) ratings, average total energy expenditure in kilocalories per kilogram of body weight per day (kcal/kg/day) was computed. Participants were then classified as inactive ( $< 1.5$  kcal/kg/day), moderately active ( $1.5 \leq$  kcal/kg/day  $< 3.0$ ), or very active ( $\geq 3.0$  kcal/kg/day; see supplemental materials for further details).

**Actual physical activity (accelerometer).** In the 2003–2006 NHANES, participants wore an ActiGraph AM-7164 accelerometer for 7 days. The device was programmed to detect and record the magnitude of acceleration or "intensity" of movement over each 1-minute epoch. Accelerometer data was processed to determine physical activity intensities and compliance using a method developed by the National Cancer Institute (NCI, 2016) and used in prior research (e.g., Tucker, Welk, & Beyler, 2011). Consistent with standard procedures, respondents were considered compliant if they wore the monitor for at least 10 hr/day on at least 4 of the

7 days. Also following standard procedures, light activity was defined as activity counts per minute from 100 to 2,019, and moderate/vigorous activity was defined as counts per minute of 2,020 or higher. Participants' mean duration (minutes) of accumulated light activity and moderate/vigorous activity per day from all valid days were divided into sex-specific low, moderate, and high tertiles (Fishman et al., 2016; Wolff-Hughes, Fitzhugh, Bassett, & Churilla, 2015). Results were consistent when using these categorical measures or continuous measures of accelerometer-assessed activity (see supplemental materials).

**Amount of hard physical work required on job or in main daily activity.** In NHIS only, a measure assessed how much hard physical work was required on respondents' job, or if they did not work a job, in their main daily activity (1 = *a great deal* to 4 = *none*).

**Sociodemographic characteristics.** The following sociodemographic characteristics were included in the analysis: gender (male/female), age (top coded by the NCHS at 99 years in NHIS and 85 years in NHANES to reduce the privacy risk of disclosure), race/ethnicity (NHIS: White, Black, other; NHANES: non-Hispanic White, non-Hispanic Black, Hispanic/other), marital status (married/living with partner, divorced or separated, widowed, never married), education (NHIS: Some high school or less, high school diploma, some college, college graduate or more; NHANES: some high school or less, high school diploma, more than high school), urbanicity (NHIS only; urban vs. rural as defined by metropolitan statistical area status), employment (NHIS: employed, unemployed, out of labor force; NHANES: employed, looking for work, not working), annual household income, and access to appropriate source of medical care (see supplemental materials for further details).

#### **Health and health behavior factors.**

**Perceived health.** Respondents rated their general health on a 5-point scale (1 = *excellent*, 2 = *very good*, 3 = *good*, 4 = *fair*, 5 = *poor*).

**Disease burden.** A detailed medical history was used to calculate disease burden as the sum of 5 diagnoses in NHIS (hypertension, diabetes, heart condition, stroke, and high blood cholesterol) or 12 diagnoses in NHANES (heart attack, angina, coronary heart disease, congestive heart failure, high blood pressure, stroke, emphysema, chronic bronchitis, thyroid disease, liver condition, cancer or malignancy of any kind, and diabetes).

**Disability.** Respondents reported if they were limited in any major activity (such as working or doing housework) by any disability or long-term health problem (NHIS: unable to perform major activity, limited in kind or amount of major activity, limited in other activities, not limited; NHANES: yes, no).

**Mental health.** NHIS respondents rated the amount of stress experienced in the past year (a lot, a moderate amount, relatively little, and almost none). NHANES respondents indicated whether they had seen a mental health professional in the past 12 months.

**Illness bed days.** NHIS respondents indicated on how many days during the past 12 months illness or injury kept them in bed more than half of the day (none, 1–7 days, 8–30 days, 31–180 days, 181–365 days).

**Smoking.** Respondents were classified as current smokers (smoked more than 100 cigarettes in life and still smoked at time of survey), former smokers (smoked more than 100 cigarettes in life, but did not smoke anymore at time of survey), or never smokers (smoked fewer than 100 cigarettes in life).

**Body Mass Index (BMI).** BMI was calculated from height and weight. To account for the curvilinear relationship between BMI and mortality, BMI was coded into the standard categories (e.g., Sutin et al., 2015): underweight ( $BMI < 18.50 \text{ kg/m}^2$ ), normal weight ( $18.50 \text{ kg/m}^2 \leq BMI < 25 \text{ kg/m}^2$ ), overweight ( $25 \text{ kg/m}^2 \leq BMI < 30 \text{ kg/m}^2$ ), obese ( $30 \text{ kg/m}^2 \leq BMI < 40 \text{ kg/m}^2$ ), and morbidly obese ( $BMI \geq 40 \text{ kg/m}^2$ ).

## **Preliminary Data Processing**

**Imputation of missing data.** As several variables contained missing data because of item nonresponse, including complete observations only (i.e., complete-case analysis) entailed exclusion of 3,301 observations (12%) from NHIS, and 3,997 observations (45%) from 2003–2006 NHANES. If observations with missing values differed systematically from completely observed cases, exclusion could create bias and jeopardize representativeness of the sample (Gelman & Hill, 2006). Therefore, we performed multiple imputation by chained equations to impute missing values, using the R package “mice” (Van Buuren & Groothuis-Oudshoorn, 2011). For completeness, we repeated all analyses with complete-case data (i.e., removing observations with missing values). All results were consistent across imputed and complete-case data sets (see supplemental materials).

## **Statistical Analysis**

Cox proportional hazards regression was used to test whether perceived physical activity was associated with mortality risk. Time to event was defined as survival time in quarters (NHIS) or months (NHANES). Four progressively restrictive models were tested in each of the three samples. Model 1 tested the association between perceived activity and mortality, adjusting only for basic demographic characteristics (age, gender, race, and education). Model 2 adjusted for additional demographic characteristics (employment, income, marital status, access to medical care, and urbanicity). Model 3 additionally adjusted for actual physical activity (actual activity measured by self-report and accelerometer, activity on the job/main daily activity). If perceived activity was merely a proxy for or redundant with actual activity, it would not emerge as a significant predictor. However, based on the theorized mechanisms described above, we predicted that perceived levels of physical activity relative to others would be associated with statistically and clinically significant changes in mortality risk, even when adjusting for multiple measures of actual activity. Model 4 additionally included measures of health status (perceived general health, BMI, disease burden, disability, mental health, illness bed days, and smoking). This final model tested whether the association between perceived activity and mortality persisted after accounting for major clinical and behavioral risk factors that also predict mortality. All survival analyses were conducted using the “survey” package in R to account for the complex survey design (Lumley, 2004).

We ascertained that the proportional hazards assumption held (Stevenson, 2009). The scaled Schoenfeld residuals plotted against time were scattered around zero showing no visible trends, indicating that the proportional hazards assumption was not violated. Additionally, the Pearson product–moment correlations between the scaled Schoenfeld residuals and time were negligible (NHIS:



$|r|$ 's  $\leq .072$ , 1999–2002 NHANES:  $|r|$ 's  $\leq .045$ , 2003–2006 NHANES:  $|r|$ 's  $\leq .129$ ), and no practically significant departures from the null hypothesis of no correlation emerged.

**Results**

As hypothesized, perceived levels of exercise relative to others significantly predicted mortality risk across all three samples and all four model specifications (Tables 1–3). Compared with NHIS respondents who perceived themselves as *a lot more active* than others (reference group), those who perceived themselves as *a little more active*, *about as active*, or *a little less active* had a 17% (hazard ratio [HR] = 1.17, 95% confidence interval [CI, 1.09, 1.26],  $p < .001$ ), 26% (HR = 1.26, 95% CI [1.19, 1.33],  $p < .001$ ), or 48% (HR = 1.48, 95% CI [1.37, 1.60],  $p < .001$ ) higher mortality risk, respectively, adjusting for basic sociodemographic characteristics only (Model 1, Table 1). NHIS respondents who perceived themselves as *a lot less active* than others had a 100% higher mortality risk relative to the reference group (HR = 2.00, 95% CI [1.80, 2.22],  $p < .001$ ).

These associations were attenuated but remained significant when adjusting for additional covariates (Models 2–4, Table 1). In the full Model 4, NHIS respondents who perceived themselves as *a little more active* (HR = 1.08, 95% CI [1.01, 1.16],  $p = .036$ ) or *about as active* (HR = 1.08, 95% CI [1.02, 1.15],  $p = .012$ ) had an 8% higher mortality risk, relative to the reference group. Although the increase in mortality risk for those who perceived themselves as *a little less active* did not reach statistical significance (HR = 1.08, 95% CI [0.98, 1.18],  $p = .105$ ), respondents who perceived themselves as *a lot less active* had an 18% higher risk of mortality than the reference group (HR = 1.18, 95% CI [1.03, 1.35],  $p = .017$ ). That is, perceptions of physical activity relative to others were associated with statistically and clinically significant changes in mortality risk, even after controlling for

multiple measures of actual physical activity and fitness, sociodemographic characteristics, and health status.

This pattern was replicated in the 1999–2002 NHANES sample (see Table 2) and the 2003–2006 NHANES sample (see Table 3), which included an objective measure of physical activity based on accelerometer data. Adjusting for sociodemographic characteristics, physical activity, and health status (Model 4), respondents who perceived themselves as *about as active* as others had an up to 21% higher risk of death relative to those who perceived themselves as more active (1999–2002 NHANES: HR = 1.14, 95% CI [1.01, 1.30],  $p = .040$ ; 2003–2006 NHANES: HR = 1.21, 95% CI [0.98, 1.48],  $p = .071$ ). Finally, individuals who perceived themselves as *less active* than others had an up to 71% higher mortality risk (1999–2002 NHANES: HR = 1.71, 95% CI [1.41, 2.07],  $p < .001$ ; 2003–2006 NHANES: HR = 1.40, 95% CI [1.08, 1.81],  $p = .011$ ; see supplemental materials for a note on differences in effect sizes found in the samples from NHANES and NHIS).

**Discussion**

The present findings show that perceived physical activity—an important but often-overlooked variable—is associated with clinically and statistically significant changes in U.S. mortality rates. The less active individuals perceived themselves to be, as compared with other people their age, the more likely they were to die in the follow-up period. Most notably, individuals who perceived themselves as less active than other people their age had an up to 71% higher mortality risk than those who perceived themselves as more active. More important, this result held when controlling for actual amounts of activity (assessed through comprehensive self-report questionnaires and objective accelerometer data), sociodemographic variables, health status, and other health behaviors. This finding was replicated in three independent nationally repre-

Table 1  
Results of Cox Proportional Hazards Regression Testing the Association Between Perceived Physical Activity and Mortality in the 1990 NHIS Sample (N = 40,760, Weighted N = 86,812,447), With (Models 3 and 4) or Without (Models 1 and 2) Actual Activity as a Covariate

| Predictor  | Model 1           | Model 2           | Model 3           | Model 4           |
|--|-------------------|-------------------|-------------------|-------------------|
| <b>Physical activity</b>                           |                   |                   |                   |                   |
| Perceived activity relative to others              |                   |                   |                   |                   |
| A lot more active                                  | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   |
| A little more active                               | 1.17 [1.09, 1.26] | 1.15 [1.08, 1.24] | 1.14 [1.06, 1.22] | 1.08 [1.01, 1.16] |
| About as active                                    | 1.26 [1.19, 1.33] | 1.22 [1.16, 1.29] | 1.18 [1.11, 1.25] | 1.08 [1.02, 1.15] |
| A little less active                               | 1.48 [1.37, 1.60] | 1.40 [1.30, 1.51] | 1.33 [1.23, 1.43] | 1.08 [0.98, 1.18] |
| A lot less active                                  | 2.00 [1.80, 2.22] | 1.83 [1.65, 2.04] | 1.72 [1.54, 1.92] | 1.18 [1.03, 1.35] |
| Actual activity (self-report)                      |                   |                   |                   |                   |
| Very active  | —                 | —                 | 1.00 (baseline)   | 1.00 (baseline)   |
| Moderately active                                  | —                 | —                 | 1.02 [0.96, 1.10] | 1.02 [0.94, 1.10] |
| Inactive   | —                 | —                 | 1.10 [1.04, 1.16] | 1.08 [1.02, 1.14] |
| Little physical work on job/daily activity (cont.) | —                 | —                 | 1.05 [1.02, 1.07] | 1.03 [1.01, 1.06] |
| <b>Additional Covariates Included in Model</b>     |                   |                   |                   |                   |
| Full demographics                                  | No                | Yes               | Yes               | Yes               |
| Health status                                      | No                | No                | No                | Yes               |

Note. Table presents hazard ratios (HRs) with 95% confidence intervals in brackets. HRs greater than 1 indicate an increase in mortality risk relative to the baseline level, HRs smaller than 1 indicate a decrease in mortality risk. Four progressively restrictive models were tested. All models controlled for basic demographic characteristics (age, gender, race/ethnicity, education). Model 2 controlled for additional demographic characteristics (employment, income, marital status, access to medical care, urbanicity). Model 3 additionally controlled for actual physical activity. Model 4 additionally controlled for measures of health status (perceived health, BMI, disease burden, disability, stress, illness bed days, smoking). Full table presented in online supplemental materials.

Table 2

Results of Cox Proportional Hazards Regression Testing the Association Between Perceived Physical Activity and Mortality in the 1999–2002 NHANES Sample (N = 11,428, weighted N = 205,796,070), With (Models 3 and 4) or Without (Models 1 and 2) Actual Activity as a Covariate

| Predictor                             | Model 1           | Model 2           | Model 3           | Model 4           |
|---------------------------------------|-------------------|-------------------|-------------------|-------------------|
| Physical activity                     |                   |                   |                   |                   |
| Perceived activity relative to others |                   |                   |                   |                   |
| More active                           | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   |
| About as active                       | 1.34 [1.19, 1.50] | 1.32 [1.17, 1.48] | 1.23 [1.09, 1.40] | 1.14 [1.01, 1.30] |
| Less active                           | 2.94 [2.54, 3.39] | 2.72 [2.35, 3.16] | 2.43 [2.08, 2.83] | 1.71 [1.41, 2.07] |
| Actual activity (self-report)         |                   |                   |                   |                   |
| Very active                           | —                 | —                 | 1.00 (baseline)   | 1.00 (baseline)   |
| Moderately active                     | —                 | —                 | 1.15 [0.80, 1.64] | 1.11 [0.76, 1.63] |
| Inactive                              | —                 | —                 | 1.53 [1.26, 1.86] | 1.36 [1.11, 1.67] |
| Additional demographic covariates     | No                | Yes               | Yes               | Yes               |
| Health status and behavior covariates | No                | No                | No                | Yes               |

Note. Table presents hazard ratios (HRs) with 95% confidence intervals in brackets. HRs greater than 1 indicate an increase in mortality risk relative to the baseline level, HRs smaller than 1 indicate a decrease in mortality risk. Four progressively restrictive models were tested. All models controlled for basic demographic characteristics (age, gender, race/ethnicity, education). Model 2 controlled for additional demographic characteristics (employment, income, marital status, access to medical care). Model 3 additionally controlled for actual physical activity. Model 4 additionally controlled for measures of health status (perceived health, BMI, disease burden, disability, mental health, illness bed days, smoking). Full table presented in online supplemental materials.

sentative samples with a total sample size of 61,141 U.S. adults (weighted N = 476 million) and follow-up periods of up to 21 years.

This study is based on observational, cross-sectional survey data with a longitudinal mortality follow-up. Following standard practice in studies of population health surveys (e.g., Keller et al., 2012; Levy et al., 2002; Sutin et al., 2015), our statistical models adjusted for potential confounding variables at the level of the individual and household. In particular, we were able to adjust for many known predictors of mortality (including sociodemographic factors, health status, and health behaviors) while estimating the contribution of actual and perceived activity in one model. Some known predictors of mortality, such as diet and alcohol consump-

tion, were omitted because of limited availability across data sets, statistical modeling constraints because of sparsity, and for consistency with prior research (Keller et al., 2012; Levy et al., 2002; Sutin et al., 2015). The finding that perceived physical activity predicted mortality held across different model specifications varying the number of characteristics that were included as covariates. Although the current study does not permit conclusions about causal relationships, previous research demonstrates that experimentally changing perceived (but not actual) physical activity can cause physiological health improvements (Crum & Langer, 2007). Additionally, prior work discussed above provides evidence for potential behavioral, affective, and physiological mechanisms linking perceptions of health behaviors with health outcomes and

Table 3

Results of Cox Proportional Hazards Regression Testing the Association Between Perceived Physical Activity and Mortality in the 2003–2006 NHANES Sample (N = 8,953, Weighted N = 183,438,224), With (Models 3 and 4) or Without (Models 1 and 2) Actual Activity as a Covariate

| Predictor                                  | Model 1           | Model 2           | Model 3           | Model 4           |
|--|-------------------|-------------------|-------------------|-------------------|
| Physical activity                          |                   |                   |                   |                   |
| Perceived activity relative to others      |                   |                   |                   |                   |
| More active                                | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   | 1.00 (baseline)   |
| About as active                            | 1.43 [1.19, 1.74] | 1.42 [1.16, 1.73] | 1.30 [1.07, 1.59] | 1.21 [0.98, 1.48] |
| Less active                                | 3.02 [2.36, 3.87] | 2.66 [2.08, 3.40] | 2.18 [1.70, 2.80] | 1.40 [1.08, 1.81] |
| Actual activity (accelerometer)            |                   |                   |                   |                   |
| Moderate/vigorous activity (accelerometer) |                   |                   |                   |                   |
| High tertile                               | —                 | —                 | 1.00 (baseline)   | 1.00 (baseline)   |
| Moderate tertile                           | —                 | —                 | 1.22 [0.68, 2.16] | 1.23 [0.70, 2.16] |
| Low tertile                                | —                 | —                 | 2.11 [1.10, 4.04] | 1.98 [1.05, 3.72] |
| Light activity (accelerometer)             |                   |                   |                   |                   |
| High tertile                               | —                 | —                 | 1.00 (baseline)   | 1.00 (baseline)   |
| Moderate tertile                           | —                 | —                 | 1.07 [0.76, 1.50] | 1.06 [0.76, 1.47] |
| Low tertile                                | —                 | —                 | 1.55 [1.11, 2.17] | 1.43 [1.04, 1.97] |

Note. Table presents hazard ratios (HRs) with 95% confidence intervals in brackets. HRs greater than 1 indicate an increase in mortality risk relative to the baseline level, HRs smaller than 1 indicate a decrease in mortality risk. Four progressively restrictive models were tested. All models controlled for basic demographic characteristics (age, gender, race/ethnicity, education). Model 2 controlled for additional demographic characteristics (employment, income, marital status, access to medical care). Model 3 additionally controlled for actual physical activity. Model 4 additionally controlled for measures of health status (perceived health, BMI, disease burden, disability, mental health, illness bed days, smoking). Full table presented in online supplemental materials.

mortality. The current findings thus highlight the need for additional experimental work to establish causality and investigate the underlying mechanisms.

The issue of measurement of perceived and actual physical activity also merits some discussion. One argument might be that the measure of perceived activity predicted mortality simply because it was a better measure of actual activity. While some research suggests that single-item physical activity measures can be quite powerful (Wanner et al., 2014), in the present study this is highly unlikely as it would mean that a single-item measure captured actual physical activity more accurately than *both* a large battery of established self-report items created by health experts (that assesses a vast array of activities including walking, household chores, and sports), *and* an objective measure of physical activity based on accelerometer data (that addresses issues of recall and social desirability bias). Far more likely is the interpretation that although perceived activity is certainly informed by actual activity, it is not redundant with actual activity because it also incorporates social-psychological influences, such as the social reference groups to which individuals compare themselves. Indeed, the correlation between perceived and actual activity levels in our samples was low (NHIS:  $r = .32$ ), and even more revealing, cross-tabulating actual and perceived activity indicates that among inactive people, over 20% perceived themselves as more active than others, while under 30% perceived themselves as less active (see supplemental materials). Thus, our finding that perceived activity relative to others predicts mortality controlling for two validated measures of actual activity suggests that subjective perceptions about one's level of physical activity are a distinct and important factor to consider in addition to actual activity measures when explaining health outcomes and mortality.

Although much remains to be explored, this study offers some important theoretical contributions to health psychology and behavioral health. First, these findings contribute to a growing body of research suggesting that subjective perceptions are critical factors that may not only influence behavior and affect (e.g., Shakya et al., 2015; Suls et al., 1991; Trautwein et al., 2008), but also shape physiological health outcomes (e.g., Crum & Langer, 2007; Crum et al., 2013; Idler & Benyamini, 1997). Indeed, prior work demonstrates that perceptions about health behaviors, such as stress and aging, may work synergistically with actual health behaviors to increase the risk of premature mortality (Keller et al., 2012; Levy et al., 2002). We extend these insights to the physical activity domain. Second, these findings build upon a large empirical literature demonstrating the powerful role of social comparison in shaping individuals' perceptions about their physical ability (Trautwein et al., 2008) and health (Gibbons & Gerrard, 2013; Idler & Benyamini, 1997; Suls et al., 1991) and advances that literature by demonstrating that physical activity perceptions based on social comparison may play an important part in shaping the influence of one's physical activity on health and longevity.

This research also reveals some important practical implications. First, it falls in line with prior work to suggest that to accurately estimate the association of physical activity (and other behaviors) with health and longevity, it is necessary to measure actual behavior as well as perceptions about this behavior and determine their relative contributions. However, nationally representative health surveys, which are among the most important

sources of information about the state of and long-term trends in population health, do not appear to contain any measures directly assessing individuals' perceptions about their health behaviors. Therefore, in this study, we used a social comparison measure as proxy for perceived physical activity. In the future, population health surveys would greatly benefit from incorporating direct measures of individuals' perceptions of various health behaviors (exercise, diet, smoking, etc.) and of their expected risks and benefits. For example, subjective perceptions of the amount and adequacy of one's physical activity could be assessed using questions such as, "How much exercise do you get?" "Do you get a sufficient or insufficient amount of physical activity?" or "How beneficial or harmful is your level of physical activity for your health?"

Second, these findings suggest that health perceptions may be highly susceptible not only to social comparison, but also to other external sources of information such as recommendations communicated by health care professionals, public health campaigns, and official physical activity guidelines (see also Crum et al., 2011, 2013; Crum & Langer, 2007; Gibbons & Gerrard, 2013; Levy et al., 2002; Shakya et al., 2015; Suls et al., 1991; Trautwein et al., 2008). This insight is important for rethinking health interventions. Public health campaigns devised without an appreciation of perceptions may inadvertently instill or reinforce negative perceptions about individuals' lifestyles. Moreover, environmental changes to facilitate active living through strategic, but often implicit, nudges may not realize their full benefits if individuals are not aware that they are getting good exercise (Crum & Langer, 2007). However, positive perceptions alone are unlikely to promote health and might even have adverse effects if they discourage individuals from engaging in healthy behavior. Finding the right balance may be a challenge, but carefully crafted campaigns that promote behavior change while simultaneously instilling positive perceptions are likely to be the most effective. For example, campaigns urging individuals to meet recommended physical activity levels should also make them aware of the exercise that they are already getting as part of their jobs or everyday activities. Additionally, interventions could encourage individuals to choose their reference groups for social comparison wisely to provide them with healthy goals, but not unrealistically high standards. Such changes in perceptions can increase individuals' motivation to adopt a healthy lifestyle, buffer them from stress and negative affect, and unlock a host of physiological benefits.

To be clear, the finding that perceptions play a role in shaping health outcomes does not mean that behavior is unimportant. Physical activity continues to be a crucial determinant of health (Warburton et al., 2006). However, in the same way that medical researchers and doctors have grown to appreciate the power of perceptions in evaluating medical procedures and prescribing medications (Fässler, Meissner, Schneider, & Linde, 2010), researchers and policymakers should appreciate the power of perceptions in evaluating the effects of health behaviors and promoting behavior change. The determinants of health are manifold and cannot be reduced to any one factor—such as behavior—however important it may be. It is time that we acknowledge, explore, and harness the powerful influence of perceptions in fostering public health, well-being, and longevity.

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