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Activity Level as a Mortality Predictor in a Population Sample after Typical Underwriting Exclusions and Laboratory Scoring

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Objectives.— To quantify the effect of physical activity on the mortality rates of healthy individuals in a population sample, after controlling for other sources of mortality risk.

Background.— The widespread availability of activity monitors has spurred life insurance companies to consider incorporating such data into their underwriting practices. Studies have shown that sedentary lifestyles are associated with poor health outcomes and higher risks of death. The aim of this paper is to investigate how well certain measures of activity predict mortality when controlled for other known predictors of mortality including a multivariate laboratory based risk score.

Methods.— Data were obtained from the National Health and Nutrition Examination Survey (NHANES) for the years 1999 through 2014. Laboratory and biometric data were scored for mortality risk using a previously developed proprietary algorithm (CRL SmartScore). Data on activity were obtained from the NHANES questionnaires pertaining to activity. In a second analysis, data were obtained from pedometers worn for 1 week by NHANES participants (years 2003-2004, and 2005-2006 only). Before analysis, cases were selected based on commonly used life insurance underwriting criteria to remove from consideration those who have major health issues, which would ordinarily preclude an offer of life insurance.

Results.—In fully-adjusted Cox model which included survey-based MET*hours per day as a 3-level categorical variable, the moderate and minimal levels of activity were associated with hazard ratios of 1.15 (95% CI: 1.04-1.28) and 1.38 (95% CI: 1.23-1.56), respectively, when compared to the highest level of activity. When treated as a continuous variable, the fully adjusted model the HR for MET*hours per day was 0.91 (95% CI: 0.87-0.95). In fully adjusted models using pedometer data, the percentage of wear time spent sedentary was associated with mortality (HR: 1.19, 95% CI: 1.09-1.31), while average counts per minute were negatively associated with mortality (HR: 0.82, CI: 0.75-0.90).

Conclusions.— It is clear from these results that high proportions of sedentary time are associated with increased mortality, whether the sedentary time is quantified via questionnaire or pedometer. Because both laboratory scores and activity levels remain significant in Cox models where both are included, these factors are largely independent, indicating that they are measuring distinct influences on the risk of mortality.

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With the increasing availability of wearable devices to assess activity levels and the growing interest in developing less invasive underwriting requirements for life insurance products, carriers have been investigating if the data produced by wearable devices is, in fact a useful, reliable way to predict mortality. Further, if activity measurement is a valid mortality predictor, it is important to know how well an activity-based assessment compares with a fluid-based assessment.

The assessment of activity is intuitively appealing for risk assessment since it has been well established in the medical literature that sedentary lifestyles are associated with adverse health effects including mortality. This was first established in the medical literature by Morris et al[1] in the 1950s who studied the relative mortality of London bus drivers vs conductors. Over the intervening years, there have been a number of studies published examining the association between activity and health outcomes, and they have largely demonstrated that higher amounts of moderate activity and lower amounts of sedentary time are associated with lower rates of mortality as well as intermediate outcomes such as BMI, waist circumference and glucose tolerance. Most of these studies rely on self-report of activity, but a growing number use objective measurement of activity, especially pedometers worn for a period of time.

This study aims to assess the mortality risks of low activity using both self-reports and pedometers while controlling for other factors common to life risk assessment in an insurance setting.

METHODS

This study makes use of data from the National Health and Nutrition Examination Survey (NHANES)[2] data. This data is collected from in-home interviews and mobile examination centers, which gather data from a cross-section of American subjects who are chosen so as to represent the demographics of the American population. NHANES has been conducted in the US since the early 1960s and helps determine the overall prevalence of major diseases and risk factors. Subjects undergo extensive interviews, physical examination, blood and urine collection, and various other diagnostic and screening tests, which may change from period to period. In the 2003-2004 and the 2005-2006 period, eligible subjects were given pedometers to wear continuously for 1 week.

Data were collected on a total of 35,327 subjects from NHANES period between 1999 and 2013. These data included age, sex, household income, citizenship status, detailed health history, family history, laboratory tests (including lipids, glucose, hemoglobin A1c, liver function tests, serum proteins, renal function tests, urinalysis and serology for HIV and hepatitis). Vital status was assessed through a linked mortality file, which is also available for download. This mortality file uses the National Death Index and contains date of death as well as cause of death information based on death certificates. In order to account for reverse causation (imminently fatal conditions causing lack of physical activity), only deaths occurring after 2 years of exposure were counted. All deaths occurring prior to that time were censored on the date of death.

ACTIVITY ASSESSMENT

NHANES assesses activity via questionnaire. There are significant differences between the first 4 waves of NHANES and the more recent 4. The more recent 4 waves ask separately whether the individual performs any moderate or vigorous daily activity related to work/school, and any moderate or vigorous activity related to recreation. Each of these (moderate work-related, vigorous work-related, moderate recreational and vigorous recreational) are quantified in units of days per week and minutes per active day. The NHANES information recommends that these various levels of activity be assigned metabolic equivalents (METs);

4 METs for moderate activity, 8 METs for vigorous activity. Using these constants, the average MET*hours per day (MHD) were calculated as follows:

$$Average\ MET^{*}hrs\ per\ day\ (MHD) = \frac{\left[\frac{T_{vig}}{60}^{*}D_{vig}{}^{*}8 + \frac{T_{mod}}{60}^{*}D_{mod}{}^{*}4\right]}{7}$$

Where: D_{vig} = days per week of vigorous activity

T_{vig} = average minutes per day of vigorous activity on days where vigorous activity is performed.

D_{mod} = days per week of moderate activity

T_{mod} = average minutes per day of moderate activity on days where moderate activity is performed.

The questionnaires for the 4 earlier periods are different than the more recent periods. Participants were asked a single question about daily work/school activity. This question had 4 levels of response, and each was assigned an average level of METS consistent with the definitions supplied for the later surveys. Respondents could reply that they were largely sedentary (0 METS), that they stood or walked a lot but did not do much lifting (4 METS), that they frequently climbed stair or frequently lifted light loads (6 METS) or that they performed heavy lifting or other heavy physical labor (8 METS). For recreational activity, if respondents answered "yes" to questions regarding moderate or vigorous activity, they were asked to choose the activity from a fairly comprehensive list. Respondents could choose more than one, and each was quantified using days per week and minutes per day the activity was performed. This allowed a very comprehensive calculation of recreational MHD. The occupational activities in the older surveys were not quantified, so these values had to be imputed.

Imputation was done using information about the duration (hours per day) and frequency (days per week) of those who reported moderate or vigorous work activity in the more recent surveys. For instance, if a subject reported 'stand/walk' level of work activity, the mean and standard deviation for the duration and frequency of moderate activity was taken from the more recent surveys and a random draw was performed from a distribution with the same means and standard deviation. Since this could result in negative numbers, any negative draw was converted to zero. For those who reported 'heavy' work in the older survey, imputation was performed using mean and standard deviation values corresponding to the 'vigorous' level from the more recent surveys. For those reporting 'lift/carry' level of activity in the older surveys, the mean and standard deviation for the random draw distribution were taken as the midpoint of the values from 'moderate' and 'vigorous' in the more recent surveys.

This allowed calculation of total MHD for subjects from all periods. The distributions were somewhat different between the older and recent epochs (Figure 1), presumably because of the differing survey methods. For analysis, MHD was used in its raw form, but it was also categorized into 3 levels: minimally active (sedentary in both recreational and occupational categories – less than 1 MHD in each category), moderately active (up to 4 MHD recreationally with a sedentary job, or non-sedentary light work with no significant recreational activity), or active (everyone else). See Table 1 for the numbers and proportions of individuals meeting these definitions and summary statistics.

Pedometer data was processed using the *NHANESaccel*[3] package for the R statistical programming language. This effectively transforms the raw accelerometer data into useful variables. The variables used for analysis included the pedometer counts per minute, percentage sedentary time, and percentage of moderate/vigorous time – each are percentages of total pedometer wear time. It is important to note that 'counts' are not the same thing as steps.[4] Pedometer counts incorporate accelerometer data and are higher with greater intensity of movement. In this

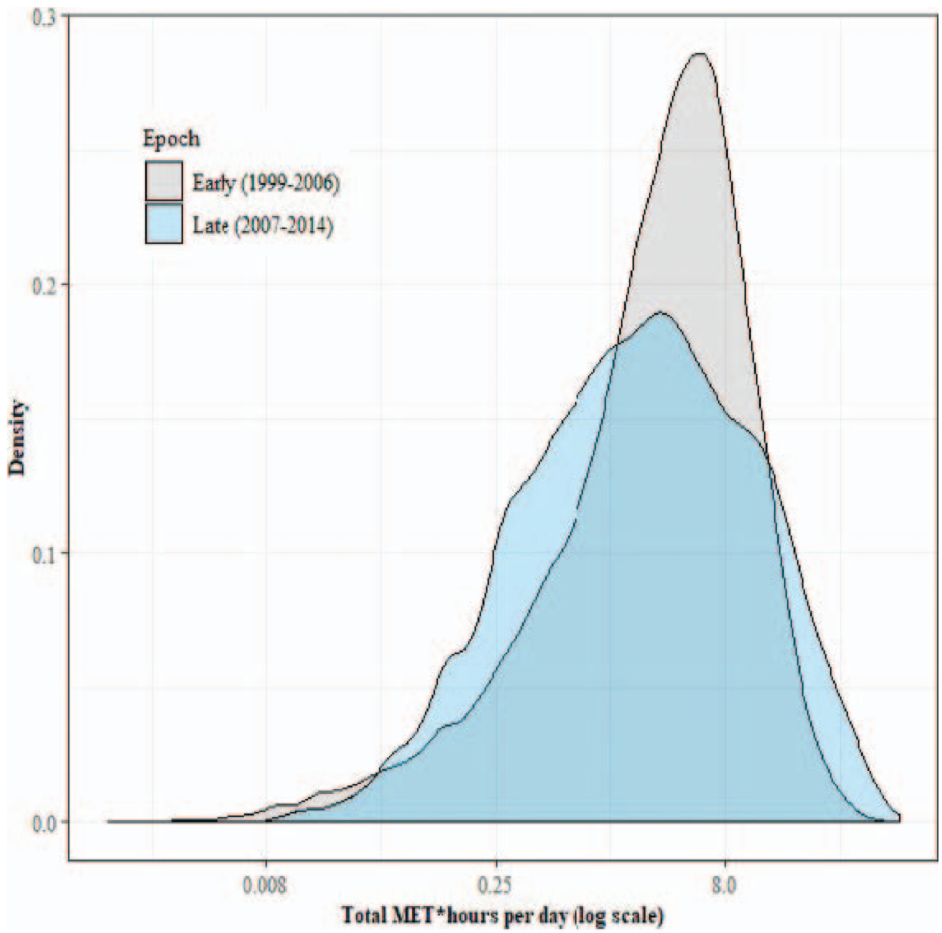

Figure 1. *Distribution of MET*hours per day by NHANES epoch.*

way a step while strolling is not treated the same as a step while sprinting. Pedometers were only worn while awake and not swimming or bathing. Certain exercise activities are not well captured by pedometers including cycling and weight training.

In the end, we have 4 different activity variables which can be analyzed: continuous MHD, categorized MHD, pedometer sedentary percentage, and average counts per minute of pedometer wear time (CPM).

UNDERWRITING EXCLUSIONS

There are significant differences between a general population and a typical population of life insurance applicants. In order to better approximate a population which would ordinarily apply, and potentially be accepted for life cover, exclusions were applied based on the following criteria: 1) Household income below $15,000 per year, 2) Age less than 18 years or older than 84 years, 3) Admission of more than 4 alcoholic drinks per day, 4) BMI $>$ 50 kg/m^2, 5) Blood pressure $>$190 mmHg systolic or $>$110 mmHg diastolic, 6) HIV positive by serology, 7) albumin less than 3 g/dl, 8) AST or GGT $>$ 200 mg/dl, 9) creatinine $>$ 2 mg/dl, 10) any history of CHF, stroke or emphysema, and 11) Any history of CAD, angina, or heart attack with onset prior to age 50. Additional exclusions were made for a history of cancer based on the cancer site. Those with any history of cancer of the bladder, brain, esophagus, gall bladder, larynx, liver, lung, mouth, nervous system, ovary, pancreas, soft tissues, stomach or an unknown site were excluded. Certain other

Table 1. Survey-Based Activity Distribution

Work Activity				
Recent surveys (2007-2014)	Vigorous	Moderate		
n(%) reporting	6024 (17)	12,153 (34.2)		
Hours per day, mean(sd)	2.99 (2.55)	2.53 (2.32)		
Days per week, mean(sd)	4.01 (1.81)	4.19 (1.80)		
Older surveys (1999-2006)	Sedentary	Stand/Walk	Lift/Climb	Heavy
n(%) reporting	6223 (24.9)	12,855 (51.3)	4229 (16.9)	1684 (6.7)
Recreational Activity	MHD mean (sd)			
Recent Surveys	2.40 (4.54)			
Older Surveys	3.66 (7.33)			
Total Activity	MHD mean (sd)			
Recent Surveys	8.18 (14.0)			
OlderSurveys	9.21 (10.1)			

cancers were excluded only if they occurred in certain age ranges or had occurred within a certain period in the past. See Table 3 for a full description of the cancer exclusions. See Table 2 for the number of individuals meeting each of the individual exclusion criteria. Note that individuals may meet more than one of these criteria, so the column totals from these tables is larger than the total number of exclusions.

Table 2. Exclusion Criterion

Exclusion Criterion	n
Household Income <\$15,000 per year	7947
Hemoglobin A1c > 9.0%	630
Admitted alcohol > 4 drinks per day	433
BMI > 50 kg/m^2	280
Systolic BP > 190	265
Diastolic BP > 110	59
HIV positive	100
Albumin < 3 g/dl	173
AST > 200 U/ml	29
GGT > 200 U/ml	259
Creatinine > 2 mg/dl	262
History of CHF	935
History of CAD before age 50	246
History of Angina before age 50	279
History of Heart Attack before age 50	342
History of Stroke	1077
History of Emphysema	610
Cancer history exclusions	945

After all exclusions, a total of 24,536 subjects, 69.4% of the original cohort, remained for evaluation.

SCORING

The CRL SmartScore algorithm was used to generate mortality scores for each subject. The CRL SmartScore is based on laboratory and physical measurements such as BMI, blood pressure, cholesterol, albumin, and urine protein, and has been previously validated as a mortality indicator.[5] Because SmartScore is centered at 0, any missing variables are simply given a SmartScore value of 0. The following variables are included in SmartScore but are not part of the NHANES data, and therefore, could not be utilized when generating scores: carbohydrate-deficient transferrin (CDT), carcinoembryonic antigen (CEA), NT-proBNP, blood alcohol, urine protein, urine protein:creatinine ratio, urine red blood cells, urine hemoglobin, and tests for illicit drugs. Scores are designed to reflect underwriting debits. For ease of analysis, values were converted to "tables" by simply dividing the debit value by 25. A total of 93 additional individuals were removed from analysis due to SmartScores of 500 of higher – after underwriting exclusions.

Table 3. Cancer Exclusions

Cancer Exclusions	n
Bladder, any	81
Blood, onset <5 years ago	3
Brain, any	13
Breast, onset before age 40 or < = 2 years ago	108
Cerivx, onset < = 1 year ago	20
Colon, onset before age 40 or < = 2 years ago	56
Esophgus, any	16
Gallbladder, any	1
Kidney, onset < = 2 years ago	13
Larynx, any	19
Leukemia, onset over age 20 or < = 5 years ago	28
Liver, any	24
Lung, any	84
Lymphoma, onset over age 50 or < = 5 years ago	38
Melanoma, onset before age 40 or < = 1 year ago	53
Mouth, any	21
Nervous system, any	1
Ovary, any	84
Pancreas, any	4
Rectum, onset before age 40 or < = 2 years ago	5
Skin (unknown type), onset before age 40 or < = 1 year ago	70
Soft Tissue, any	8
Stomach, any	26
Testicular, onset < = 1 year ago	2
Thyroid, onset < = 2 years ago	6
Uterus, onset < = 2 years ago	24
Other (unspecified type), any	144

Survival models were constructed using Cox proportional hazards. All survival models were controlled for age, sex, smoking status, and SmartScore value. Models with "full" adjustment were further controlled for income level, education level, citizenship status, use of medications for blood pressure and history of high cholesterol, coronary artery disease, angina, myocardial infarction, chronic bronchitis, liver disease and thyroid disease. For the purposes of the single-value hazard ratios displayed in the tables, continuous variables of interest were treated as linear. For the purposes of display and to evaluate for possible non-linear trends, these same variables were evaluated in the Cox models using restricted cubic splines with 4 knots. Because sedentary time and CPM were noted to be correlated with age, an age-corrected value was used in the Cox models. This value is simply the observed value plus the difference between the prediction of that value based on a linear, age-dependent model, and that predicted for a 50-year-old individual. The resulting values have no correlation with age.

All analyses were performed in R, version 3.5.1 "Feather Spray"[6] and included the following packages, tidyverse,[7] rms,[8] nhanesA,[9] and NHANESaccel.

RESULTS

The final data set, after all exclusions, consisted of 24,536 individuals with non-missing activity data, including 1963 deaths during an average of 10.38 years of follow-up. Of these, 5520 (22.5%) were minimally active, 6901 (28.1%) were moderately active and 12,115 (49.4%) were active. The baseline characteristics of the population, split by activity level, are displayed in Table 4.

Initial exploratory analysis demonstrated associations between activity and SmartScore (Figure 2). This stands to reason, since higher levels of physical activity are associated with lower levels of BMI, blood pressure, and total cholesterol, along with higher levels of HDL, all of which are components of SmartScore. Activity levels were also noted to be negatively correlated with age (Figure 3). This is also an expected observation since most of us slow down with advancing years.

In the partially-adjusted Cox model, which included MHD as a 3-level categorical variable, the moderate and minimal levels of activity were associated with hazard ratios of 1.19 (95% CI: 1.07-1.32) and 1.45 (95% CI: 1.29-1.56), respectively, when compared to the highest level of activity. In the fully adjusted model, the corresponding hazard ratios were 1.15 (95% CI: 1.04-1.28) and 1.38

Table 4. Baseline Characteristics of the Population, Split by Activity Level

	Active	Moderate	Minimal
n	12115	6901	5520
Age	41.18 (17.5)	45.5 (18.21)	47.56 (18.07)
% Male	58	41	38
Deaths	596	538	332
Death rate	4.92%	7.80%	6.01%
% Smokers	19	18	19
BMI (kg/m^2)	27.43 (5.53)	28.14 (5.91)	29.22 (6.6)
Systolic BP (mmHg)	121.28 (16.68)	122.75 (18.82)	122.88 (18.46)
Diastolic BP (mmHg)	69.9 (12.62)	69.88 (13.28)	70.21 (12.57)
Albumin (g/dl)	4.34 (0.35)	4.26 (0.36)	4.22 (0.34)
Cholesterol (mg/dl)	195.06 (41.24)	198.74 (41.51)	196.92 (41.6)
Creatinine (mg/dl)	0.86 (0.21)	0.81 (0.22)	0.82 (0.23)
Hemoglobin (g/dl)	14.56 (1.47)	14.14 (1.51)	13.97 (1.53)
SmartScore	48.97 (85.81)	64.48 (95.31)	75.33 (102.69)
Met*Hours/day	14.98 (13.39)	5.06 (5.31)	0.13 (0.27)

(95% CI: 1.23-1.56). In all cases, the hazard ratios for minimal vs active, and moderate vs active were statistically significant. In order to model MHD as a continuous variable, log transformation was used because of its skewed distribution. In the partially adjusted model, the HR per log unit increase of MHD was 0.90 (95% CI: 0.86-0.94), while in the fully adjusted model the HR was very similar at 0.91 (95% CI: 0.87-0.95).

In models using pedometer data, the percentage of wear time spent sedentary was associated with mortality after partial (HR: 1.14, 95% CI: 1.04-1.25 and full (HR: 1.19, 95% CI: 1.09-1.31) adjustment. Counts per minute were negative associated with mortality (HR: 0.83, 95% CI: 0.75-0.90), and this association was minimally affected by full adjustment (Table 5).

By using restricted cubic splines, it is possible to explore potential non-linear relationships between the continuous activity measures and mortality. As depicted in Figure 4, MET*hours per day, sedentary time and counts per minute show significant nonlinearity. Generally, sedentary time begins to affect mortality once it reaches approximately 60%. The mortality benefit of activity as measured by counts per minute is nearly maximized at 300 counts per minute, the median level. The benefit of activity as measured by survey-determined MET*hours per day is a nearly maximized at 2 log units, which is approximately 8 MET*hours per day. This is equivalent to approximately 1 hour of vigorous activity or 2 hours of moderate activity per day. Note, though, that any level of activity has a beneficial effect on mortality when measured this way. In Figure 4, there appears to be a modest increase in mortality risk at the very lowest proportions of sedentary time, but it should be noted that there is very little data in that tail, and that the error bars subtend the curve's global minimum, so the risk there is not likely different than the minimum.

In order to evaluate the possible age dependence of these findings, the data were divided by age younger or older than 50 years. For the survey data (MET*hours per day), the threshold effect was not evident in the younger group; higher levels of activity were beneficial across the range. In the pedometer data, counts per minute had no discernible effect on mortality in these younger individuals, though it should be noted that this restricted data set contained only 84 deaths. For the older group, the overall risk picture was

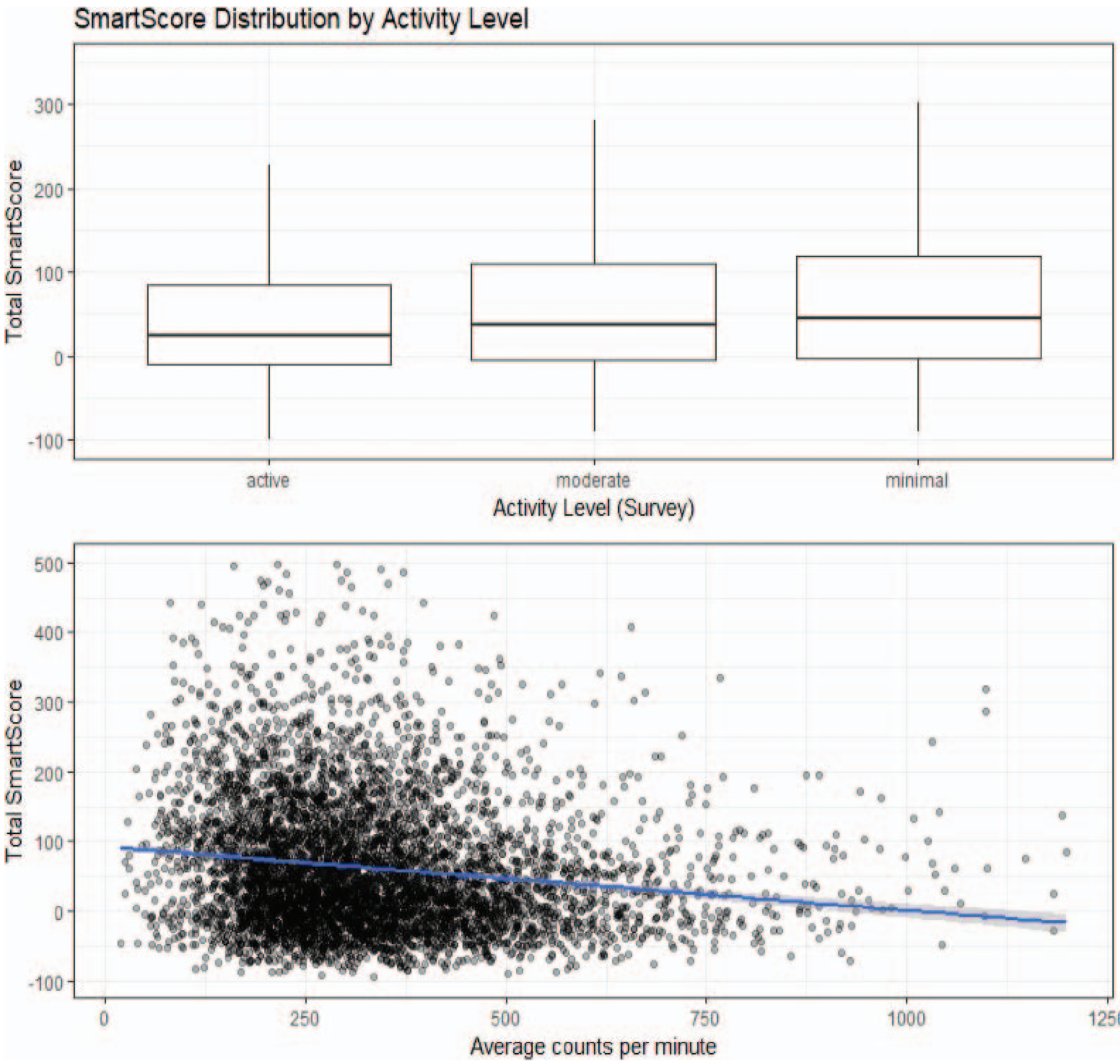

Figure 2. *Upper panel: Box-and-whisker plot of SmartScores by categorical activity level (all surveys). Lower panel: Scatter plot of SmartScore by continuous counts per minute (pedometer surveys only).*

not significantly different than that of the full data set – neither in the survey data nor the pedometer data.

In order to evaluate if laboratory-based risk assessment remains relevant when activity variables are included, reduced fully adjusted models were fit both with and without the activity variables. As Table 6 shows, the inclusion of the activity variable did not significantly alter the hazard ratios associated with SmartScore. Of the 4 activity measures, CPM produced the largest moderation of the SmartScore hazard ratio.

DISCUSSION

Several published studies have evaluated the relationship between activity as measured by pedometers or other types of activity monitors and mortality. Several of these studies have used the same NHANES data as in the present study, but did not attempt any type of digital underwriting, and did not include a laboratory-based mortality risk assessment as a covariate.

In 2017 Diaz et al,[10] published findings from pedometer measurements in the RE-

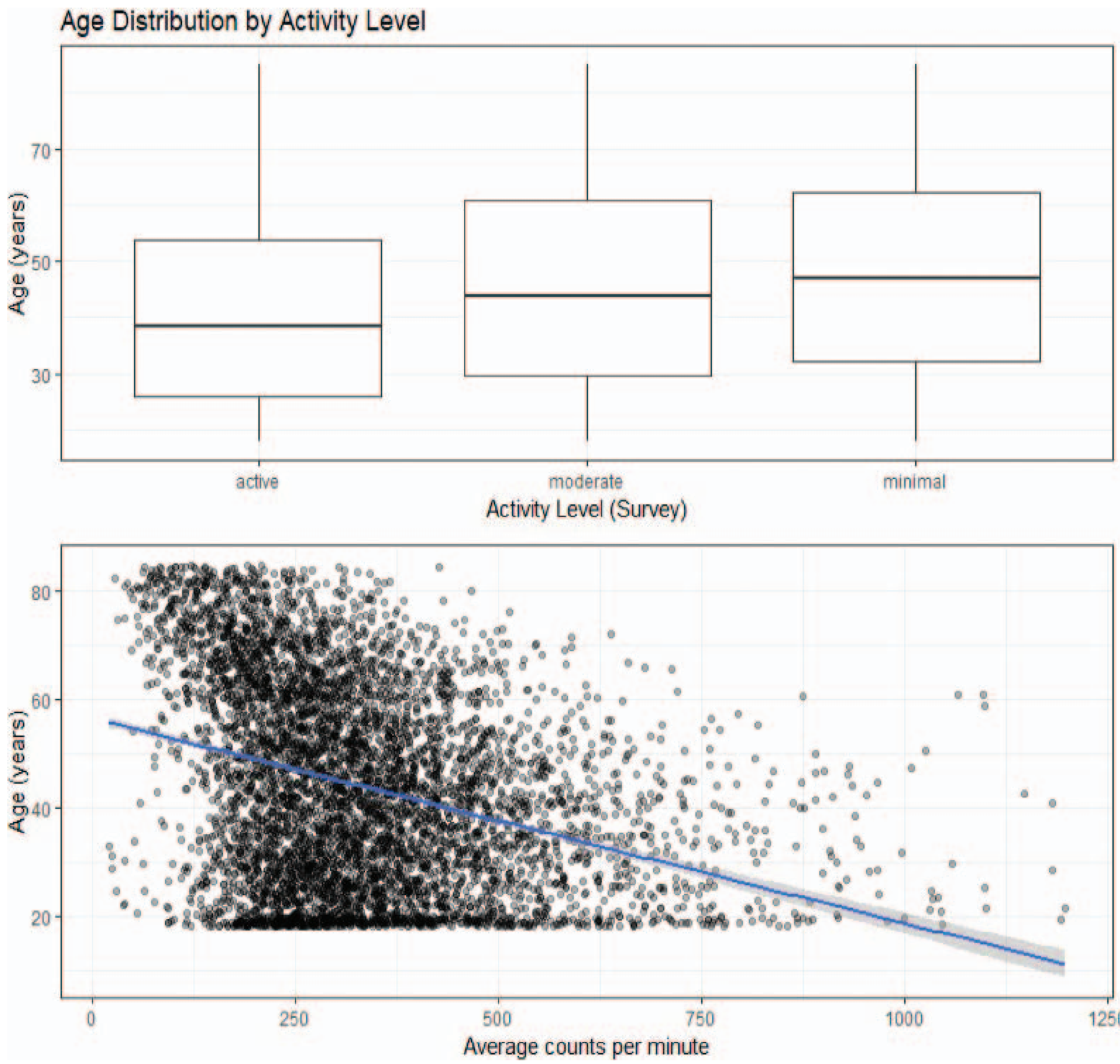

Figure 3. *Upper panel: Box-and-whisker plot of age by categorical activity level (all surveys). Lower panel: Scatter plot of age by continuous counts per minute (pedometer surveys only).*

GARDS study, a population-based study designed to evaluate disparities in stroke. This study included 7985 participants, who each wore a pedometer for 1 week. All participants were 45 years or older. Follow-up averaged 4 years and included 340 deaths. The primary finding was that the highest quartile of sedentary time was associated with mortality (HR: 2.63 (1.60-4.30) for the 4th vs 1st quartile), as were longer average duration of sitting (HR: 1.96 (1.31-2.93) for the 4th vs 1st quartile).

Schmid et al[11] evaluated the first NHANES cycle to include pedometer data. Follow up was fairly short (35 months) and included only 112 deaths. Sedentary time and moderate/vigorous activity were dichotomized at their medians (8.6 hours for sedentary time, 6.6 minutes for moderate/vigorous activity). Lower levels of moderate/vigorous activity were associated with a relative risk ratio of 3.30 (95% CI: 1.33-8.07). Higher levels of sedentary time produced a risk ratio of 2.03 (95% CI: 1.09-3.81). These two variables were evaluated for interaction, and none was discovered. The noted associations were largely unaffected by exclusions for various medical issues.

Table 5. Survival Model Results

	Survey		
	Categorical	Continuous	Pedometer
Number of Subjects	24,536	24,502	5,786
Number of Deaths	1,963	1,959	429
Average Follow-up time (yr)	10.38	10.38	10.64

Survival Model Hazard Ratios

	Adjustments	
	Partial*	Full**
Survey Categorical:		
Active	1 (ref)	1 (ref)
Moderate	1.19 (1.07-1.32)	1.15 (1.04-1.28)
Minimal	1.45 (1.29-1.63)	1.38 (1.23-1.56)
Survey, Continuous:		
MET*hours/Day (per log)	0.90 (0.86-0.94)	0.91 (0.87-0.95)
Pedometer:		
% sedentary time (per 10%)	1.14 (1.04-1.25)	1.19 (1.09-1.31)
Average Counts per Minute (per 100)	0.83 (0.75-0.91)	0.82 (0.75-0.90)

* Adjusted for age, sex, smoking and SmartScore.
** Additionally adjusted for education, income, citizenship and medical conditions.

A 2012 study by Koster et al[12] evaluated the NHANES data but again included only one cycle, with short follow up (2.8 years) and 145 deaths, with all participants being at least 50 years old. Very high mortality ratios were seen for the 3rd and 4th quartiles of sedentary time, but there may have been an element of reverse causation due to the short follow-up. Interestingly, this study did evaluate possible non-linearity using splines, and showed that the mortality risk associated with increasing sedentary proportions began at approximately 60%.

Table 6. SmartScore Hazard Ratios

Survey	
Without Activity	1.034
With Categorical	1.032
With MET*Hrs/Day	1.033
Pedometer	
Without Activity	1.064
With Sedentary %	1.056
With CPM	1.054

Hazard Ratios are per 25 points of SmartScore.

In 2016, Matthews et al[13] published findings from both pedometer cycles of NHANES, which included 700 deaths after an average of 6.6 years of follow up. In addition to confirming the risks of high levels of sedentary time and low levels of light and moderate/vigorous activity, this study demonstrated that highly active adults (those who were active at any level for more than 5.8 hours per day) were protected from the mortality effects of high levels of sedentary time. In other words, long sitting times can be countered by shorter periods of activity.

Evenson et al[14] evaluated the same data as Matthews using some different techniques. They found higher mortality for those with lower pedometer counts, and also showed that sedentary time lost its mortality association when controlled for light and moderate/vigorous activity, and a large variety of other

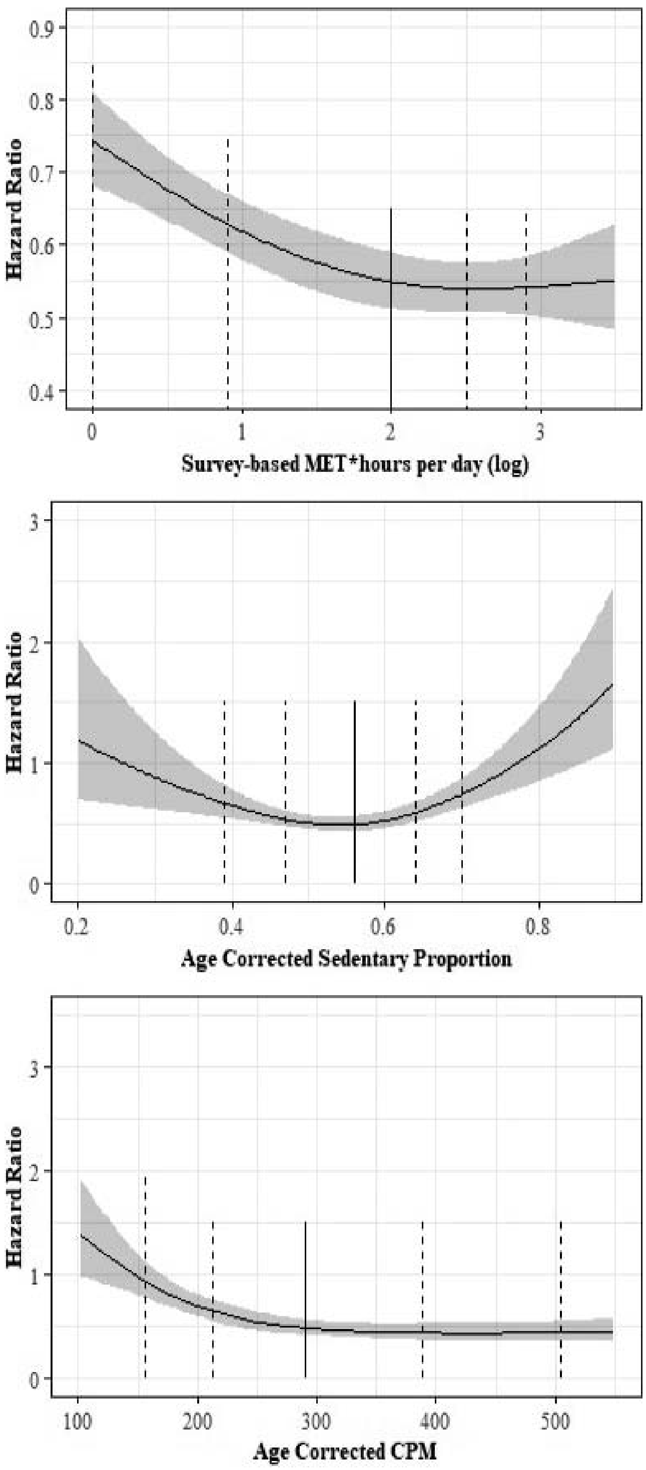

Figure 4. *Hazards associated with continuous activity variables in fully adjusted models. Solid vertical bars are at the median level of the activity variable. Dashed vertical lines are at the 10th, 25th, 75th, and 90th percentile (from left to right).*

mortality-associated variables. Notably, only deaths occurring after the second duration were counted in order to eliminate possible reverse causation. This left only 337 deaths in the cohort, and the fully adjusted model included at least 50 degrees of freedom, which casts doubt on the overall conclusions.

Finally, in 2016, Ekelund et al[15] published a meta-analysis with over 1 million aggregated study subjects and over 84,000 deaths. Activity was mainly measured through questionnaire. The primary finding was that higher sedentary time was associated with mortality, but not in those who are physically active (>35.5 MET*hours per week). The highest risk of being sedentary was found in those who exercise very little. Roughly translated this would suggest that exercising 1 hour per day at a moderate level would entitle one to long bouts of sedentary time without significant risk.

CONCLUSIONS

Overall, the present study supports the idea that higher levels of physical activity are associated with considerable protection against mortality, even after a virtual underwriting procedure, and after controlling for multiple demographic and medical variables, as well as a multivariate laboratory and biometric mortality score (SmartScore). In all tested models, the SmartScore variable remained significantly associated with mortality risk. Therefore, it is likely that laboratory/biometric measurements and activity levels are largely independent influences on mortality.

Insurers wishing to integrate some measure of activity into underwriting would, according to the present study, be justified. However, the collection of data similar to NHANES is not feasible. Simply asking applicants about their activity may not be reliable since it would be done in the setting of a transaction where price may depend on the answer. Also, asking applicants to wear a pedometer or other device for a week is not customer friendly and may also present the risk of falsification. Submission of pre-existing data from wearable activity monitors, heart monitors or GPS-enabled devices is more feasible, but the data contained therein differs from the data studies, including this one, have used. While the direction of the mortality effect would likely hold, the quantification of the effect likely would not.

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