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Research Article

Physical Inactivity and Health-Related Quality of Life as Predictors of Survival in US Adults: A Novel Use of Item-Response Theory

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Abstract

Background: Item-Response Theory (IRT) is a modern psychometric technique able to develop a true score measure of Health-Related Quality Of Life (HRQOL) from survey data. The purpose of this study was to investigate both Physical Inactivity (PIA) and HRQOL as predictors of survival, with the aid of IRT.

Methods: Data for this research came from the 2001-02 NHANES and its corresponding linked mortality file. PIA status was determined from survey questions regarding moderate and vigorous leisure-time physical activity. HRQOL was assessed by entering five perceived health variables into a single parameter IRT model. Cox proportional hazards regression was used to model the effects of PIA and HRQOL on survival time while controlling for confounding variables (age, sex, race and income).

Results: A total of 5,985 adults were included in this analysis with a mean person-year follow-up of 9.24 years and 965 deaths. Adjusted model showed a significant (p = .006) three-way (HRQOL×PIA×SEX) interaction, requiring a stratified analysis. Among females, those with poor HRQOL had shorter survival time (Hazard Ratio (HR) = 3.08, 95% CI: 1.24, 7.65) than those with good HRQOL. Physically inactive females showed shorter survival time (HR = 1.88, 95% CI: 1.24, 2.85) as compared to those who were not physically inactive. Since the two-way (HRQOL×PIA) interaction was significant (p = .004), the analysis for males was further stratified by PIA status. Among males who were physically inactive, those with poor HRQOL showed shorter survival time (HR = 2.39, 95% CI: 1.46, 3.90) than their counterparts with good HRQOL. Among males with poor HRQOL, those who were physically inactive showed shorter survival time (HR = 4.25, 95% CI: 2.30, 7.83) than their counterparts who were not physically inactive.

Conclusion: Results from this study support both HRQOL and PIA as predictors of survival time. Health promotion programs should include physical activity in adults with poor HRQOL.

Introduction

Physical inactivity (PIA) is defined as an amount of physical activity that falls short of given recommended guidelines [1]. PIA is considered a behavioral and modifiable risk factor for several chronic diseases as well as premature mortality [2]. Current U.S. reports and guidelines suggest limiting sedentary behavior and accumulating at least 150 minutes of moderate-intensity physical activity each week by all adults [3,4]. Given these recommendations, large percentages of the US population still do not meet these guidelines [5].

Health-Related Quality of Life (HRQOL) is a complex multidimensional trait that can include several different dimensions, such as physical, mental, social, emotional, pain, vitality, among others [6]. HRQOL is a measure of growing interest in public health research that is often used as an outcome variable [7,8] as well as a variable predictive of major health outcomes [9,10]. Furthermore, the vast number of different instruments used to measure HRQOL [11] can possibly confuse the HRQOL and health outcome relationship. Therefore, a need exists for a superior method for measuring HRQOL.

Item-Response Theory (IRT) is a modern psychometric technique and works differently from classical test theory in that it focuses on the item by examining the response of an individual at a specific ability level (i.e., HRQOL) and the characteristics of that item [12,13]. An IRT model that is only concerned with an item's difficulty level (b-parameter) and the individuals' ability (θ), is considered a 1-parameter model, and commonly called a Rasch measurement model [14,15]. The statistical fit of items to its construct (i.e., HRQOL) ensures a unidimensional trait and in turn provides evidence of construct validity. Once data are fit to an IRT model, model parameters can be used to convert raw scores to a common metric scale. This new measure is called an ability (θ) parameter and is a true score measure of the trait and so, IRT is able to develop a true score measure

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of HRQOL from survey data that contain several perceived health variables.

In review, both PIA and HRQOL can be considered important predictors of premature morbidity and mortality. However, the vast number of HRQOL instruments used in research may confuse the HRQOL and health relationship. Therefore, the purpose of this study was to investigate both PIA and HRQOL as predictors of survival, with the aid of an IRT-determined true score measure of HRQOL.

Methods

Participants and design

Data for this research came from National Health and Nutrition Examination Survey (NHANES) and linked mortality file for years corresponding to 2001-02 [16]. NHANES is a complex multi-stage sample of all noninstitutionalized US citizens. Mortality status of NHANES participants was assigned based on a National Death Index (NDI) matching procedure. To be eligible for the matching procedure, specific participant data was required (i.e., social security number, sex, date of birth, first name, last name). If adequate matching data were not available, participants were deemed ineligible for record linkage. After screening and matching, participant mortality status was compiled in a linkable mortality file provided by the National Center for Health Statistics (NCHS). For this study, the follow-up period ended December 31, 2011. A total of 5.985 participants who were 18+ years of age, answered all relevant survey questions, and who were eligible for mortality linkage were used in the analysis.

Measures

Two predictor variables were used in this study: PIA status (yes/no) and HRQOL. Physical activity data were self-reported by participants and PIA status was determined from the answers to two questions [17]. Vigorous physical activity was assessed using the following question: “Over the past 30 days, did you do any vigorous activities for at least 10 minutes that caused heavy sweating, or large increases in breathing or heart rate? Some examples are running, lap swimming, aerobics classes or fast bicycling.” Moderate physical activity was assessed using the following question: “Over the past 30 days, did you do moderate activities for at least 10 minutes that cause only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, and dancing.”Participants answering “no” to both questions were considered physically inactive.

HRQOL was assessed by entering four perceived health variables (general, physical, mental, activity) and one constructed index (healthy days) into a dichotomous single parameter IRT model [17]. The true ability score measure of HRQOL was then T-score transformed and dichotomized (good/poor) at the mean prior to analyses.

Finally, several demographic variables were used as covariates in the regression models. Demographic variables included age (yr.), sex (male/female), income (US $) and race (white/non-white).

Statistical analysis

The SAS SURVEYPHREG (Cox proportional hazards) procedure was used to examine the effects of PIA and HRQOL on survival time while controlling for confounding variables (age, sex, race, and income) [18]. All models were post-fit checked to ensure the proportional hazards assumption was met. SAS version 9.4 was used for all inferential analyses [19] and Winsteps for all IRT analyses [20].

Results

Table 1 contains results from both the IRT and classical analyses regarding the creation of the new HRQOL measure. Classical analyses results indicated a well-fitting unidimensional HRQOL construct, with moderately strong internal consistence reliability (KR20=.75) and 51.5% of explained variance from factor analysis. IRT results also indicated a well-fitting unidimensional construct, with all items and 82% of persons fitting the IRT model. Additionally, item separation (17.6) and item reliability (.99) were both well above acceptable cutoffs.

Table 2 contains the Hazard Ratios (HRs) and 95% Confidence Intervals (CIs) for mortality for HRQOL status and PIA status by sex. Among females, those with poor HRQOL had shorter survival time (HR=3.08, 95% CI: 1.24, 7.65) than those with good HRQOL. Physically inactive females also had shorter survival time (HR=1.88, 95% CI: 1.24, 2.85) as compared to those who were not physically inactive. Since the two-way (HRQOL×PIA) interaction was significant (p=.004), the analysis for males was further stratified by PIA status. Among males who were physically inactive, those with poor HRQOL had shorter survival time (HR=2.39, 95% CI: 1.46, 3.90) than their counterparts with good HRQOL. Among males with poor HRQOL, those who were physically inactive had shorter survival time (HR = 4.25, 95% CI: 2.30, 7.83) than their counterparts who were not physically inactive.

(Figures 1-4) display mean values of IRT-derived HRQOL with 95% CIs by survival status for the overall sample as well as across PIA status, sex, age and obesity status groups. Surviving adults had significantly (p<.001) greater HRQOL than non-surviving adults,

Table 1: New HRQOL scale properties from both classical and IRT approaches.

Statistics	Value
Descriptives	
No. of Items	5
Mean	0.86
Variance	0.005
IRT Analysis	
% Person Fit	82.1
% Item Fit	100
Item Separation	17.6
Item Reliability	0.99
r_{RM}	0.99
Item Logit Range	3.28
Classical Analysis	
KR_{20}	0.75
% of Variance	51.5
LFL	0.45

Note: r_{RM} is the correlation between raw HRQOL scores and IRT ability scores. KR20 is Cronbach alpha for dichotomous data. % variance is explained variance from factor analysis. LFL is the lowest factor loading from factor analysis.

Table 2: Hazards of all-cause mortality associated with Physical Inactivity (PIA) and Health-Related Quality Of Life (HRQOL).

	Crude		Adjusted		*t*
Grouping	**HR**	**95% CI**	**HR**	**95% CI**	***p***
Overall					
Poor HRQOL	2.72	1.99-3.72	2.87	1.11-7.42	
Physically Inactive	2.59	2.19-3.07	1.81	1.18-2.77	
HRQOL×PIA×Sex					0.006
Females					
Poor HRQOL	2.87	1.83-4.49	3.08	1.24-7.65	
Physically Inactive	3.08	2.38-3.98	1.88	1.24-2.85	
HRQOL×PIA					0.197
Males					
Poor HRQOL	2.55	1.84-3.55	0.71	0.41-1.20	
Physically Inactive	2.3	1.87-2.84	1.2	0.93-1.54	
HRQOL×PIA					0.004
Males Active					
Poor HRQOL	1.03	0.56-1.87	0.66	0.38-1.15	
Males Inactive					
Poor HRQOL	3.02	1.98-4.60	2.39	1.46-3.90	
Males Good HRQOL					
Physically Inactive	1.98	1.58-2.49	1.16	0.91-1.49	
Males Poor HRQOL					
Physically Inactive	5.78	3.04-10.98	4.25	2.30-7.83	

Note: Crude column shows unadjusted HRs for PIA and/or HRQOL in separate models. Adjusted column shows HRs adjusted for age, sex, race, and income. Cox regression was used for all models using PROC SURVEYPHREG to account for the complex sampling design. Reference group for Physically Inactive status is "Physically Active" with an HR=1.00.Reference group for Poor HRQOL status is "Good HRQOL" with an HR=1.00.

overall. Similarly, survivors had significantly greater HRQOL in both the inactive ($p<.001$) and active ($p=.004$) groups, however, active adults had greater HRQOL as compared to inactive adults. Surviving inactive males had significantly ($p<.001$) greater HRQOL as compared to inactive non-surviving males. Whereas surviving active females had significantly ($p=.006$) greater HRQOL as compared to active non-surviving females. Both PIA status groups saw significantly ($p<.05$) greater HRQOL in survivors among the older adults, however, younger adults only saw this significance in the inactive group. Finally, only the non-obese adults saw significantly ($p<.05$) greater HRQOL in survivors as compared to non-survivors, in both PIA status groups.

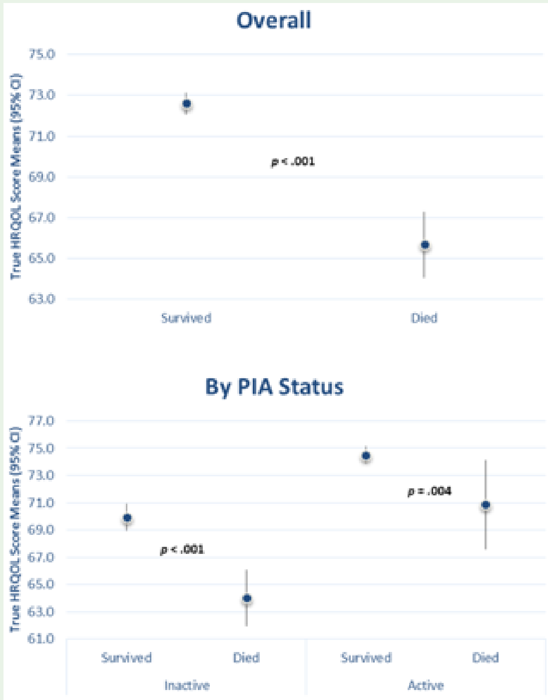

Figure 1: Comparison of IRT-derived HRQOL scores across survival status, overall and by PIA status.
Note: *p*-values are testing survival-specific mean differences adjusted for age.

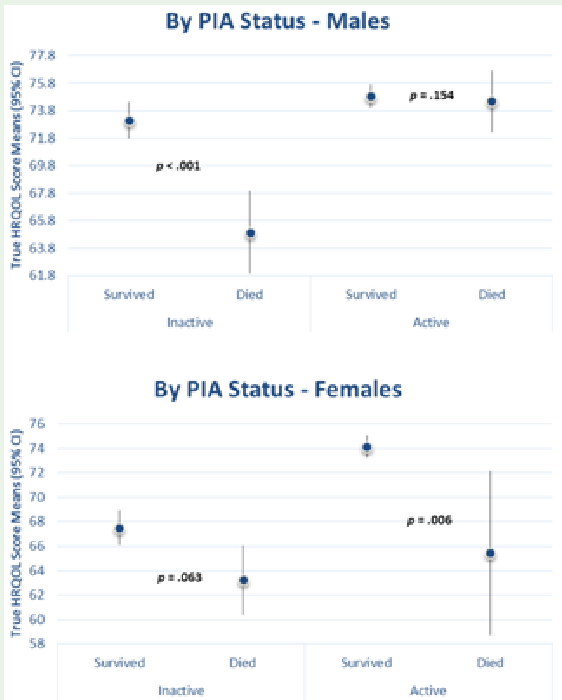

Figure 2: Comparison of IRT-derived HRQOL scores across survival status by PIA status: males and females.
Note: *p*-values are testing survival-specific mean differences adjusted for age.

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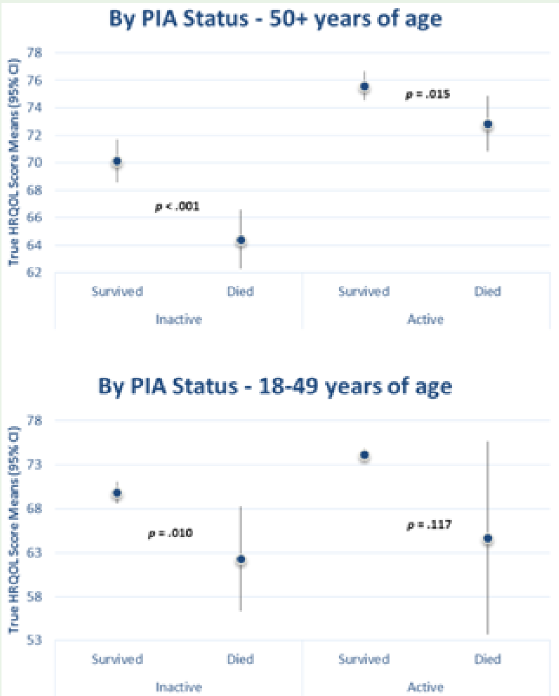

Figure 3: Comparison of IRT-derived HRQOL scores across survival status by PIA status: older adults and younger adults.
Note: *p*-values are testing survival-specific mean differences adjusted for age.

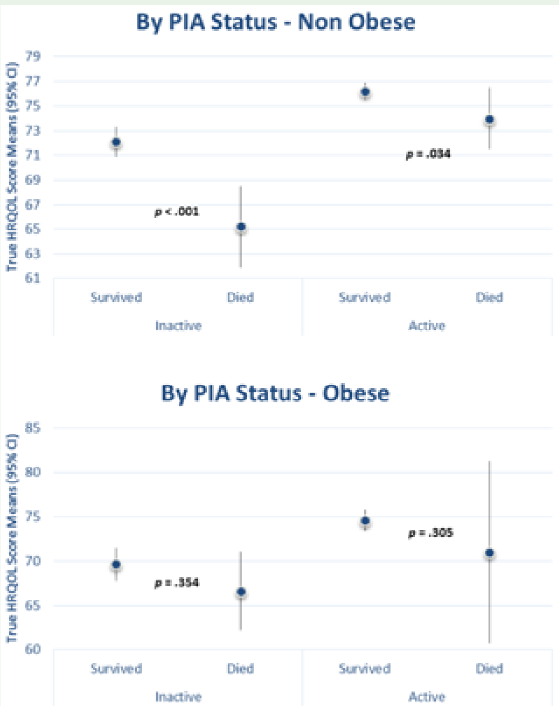

Figure 4: Comparison of IRT-derived HRQOL scores across survival status by PIA status: non-obese and obese.
Note: *p*-values are testing survival-specific mean differences adjusted for age.

Discussion

The purpose of this study was to use an IRT-developed HRQOL measure and use this measure, along with PIA, as predictors of survival in a representative sample of US adults. Initial results indicated that IRT can be used to develop and validate a new HRQOL measure from national survey data. These findings are consistent with other studies where IRT has been successfully applied to validate HRQOL measures among several different special populations [21-23].

Results of the survival analysis clearly showed that both PIA and HRQOL are predictive of survival time in adults. Moreover, specifically among males with poor HRQOL, those who were physically inactive had a substantially greater (over 4 times) risk of mortality, as compared to their more active counterparts. These findings may be explained by the fact that men may receive great benefit from physical activity despite have lower HRQOL. For example, males who suffer from chronic disease and as a result exhibit lower levels of HRQOL may in fact reap much benefit from being physically active. This hypothesis, however, is not corroborated in the literature. Therefore, further research is needed to better understand and explain the interaction between physical activity and poor HRQOL on all-cause mortality in men.

A major strength in this study is its use of modern psychometric theory (IRT) to develop and validate a new measure of HRQOL from survey data. Strength in this study is its use of a large representative survey of US adults. Thus, this study has the ability to generalize its findings to a larger population. However, this study does have limitations worth mentioning. One limitation by this study is its use of self-reported data for the assessment of PIA. Therefore, there may be some measurement error that cannot be accounted for in terms of categorizing individuals into these PIA status groups. A second limitation of this study is the fact that both physical activity and HRQOL may possibly have changed in some individuals after their baseline assessments. For example, some participants may have initially reported being physically inactive at baseline and then became physically active at a later time. Consequently, findings from this study may include an amount of bias that cannot be accounted for and so it should be interpreted with caution.

Conclusion

Results from this study support both HRQOL and PIA as predictors of survival time. Due to the strong moderating effects of PIA on the HRQOL and longevity relationship in males, physical activity should be promoted in programs that include men with poor HRQOL.

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