SEDENTARY BEHAVIOR AND PHYSICAL ACTIVITY: RISK FACTORS ASSOCIATED WITH MODERN LIFESTYLES

Anne-Marie Meyer

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Approved by

Advisor: Kelly R. Evenson
Reader: June Stevens
Reader: David Couper
Reader: Steve Marshall
Reader: Gerardo Heiss

ABSTRACT

Sedentary Behavior and Physical Activity: Risk Factors Associated with Modern Lifestyles

Anne-Marie Meyer

(Under the direction of Kelly R. Evenson)

This dissertation explores two diametrically opposed behavioral risk factors. The first risk factor, television watching, is the most prevalent leisure activity in the United States. The second, physical activity, is one of the most important modifiable risk factors for chronic disease.

The first aim was to examine the association of television watching with physical activity and diet in the Atherosclerosis Risk in Communities Study. Television exposure, physical activity, and dietary information were collected via self-report at baseline and six years later in 12,678 men and women ages 45 to 64 years at baseline. Participants who reported high television exposure were more likely to be inactive and have a poor dietary profile. These results persisted over the six years of follow-up, regardless of modeling strategy. Risks associated with sedentary behaviors, such as television watching, have been neglected in public health research. This work highlights the need for further research on measurement, determinants, and risks of sedentary behaviors.

A better understanding of behavioral risk factors such as physical activity requires continued research on current questionnaires and measurement tools used to quantify these behaviors. The test-retest reliability of the Women's Health Initiative physical activity questionnaire was examined in 1092 women as part of the second aim. Mild physical activity had lower test-retest reliability than moderate, vigorous, and walking physical activity, which were moderately to substantially reliable.

Walking is the most common leisure physical activity engaged in by adult women. The Women's Health Initiative, with its reliable and unique questionnaire offered an opportunity to examine the independent effects of walking intensity, frequency, and duration on risk of coronary heart disease. After a decade of follow-up, baseline intensity, frequency, and duration of walking were all associated with lower risk of coronary heart disease in 71, 502 women from 40 centers across the United States. The highest category of walking intensity was associated with a 60% reduction in risk relative to the lowest category. Weaker associations were observed for frequency and duration of walking. To untangle the effect of each walking component (i.e., intensity, frequency, and duration) from their contribution to energy expenditure, a control variable estimating recreational physical activity energy expenditure was introduced in the models. The addition of this control variable did not appreciably change the results. Strengths and limitations of this approach are highlighted.

This dissertation highlights several areas for future research in physical activity epidemiology. The first is a pressing need to better understand the impact of sedentary behaviors on health. The second is the need to develop better measurement tools for research and surveillance. Lastly, new epidemiologic methods need to be applied to help understand the specific health benefits from different types of physical activities or components of activity, such as frequency, intensity, and duration.

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LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
ANOVA	analysis of variance
ARIC	Atherosclerosis Risk in Communities Study
BMI	body mass index
CABG	coronary artery bypass graft
CDC	Centers for Disease Control and Prevention
CHD	coronary heart disease
CVD	cardiovascular disease
FFQ	food frequency questionnaire
HR	hazard ratio
ICC	intraclass correlation coefficient
IOM	Institute of Medicine
MJ/h	megajoules per hour
METs	metabolic equivalents of task
MD	Maryland
MN	Minnesota
MS	Mississippi
NC	North Carolina
NIH	National Institutes of Health
OR	odds ratio
PTCA	percutanerous transluminal coronary angioplasty
RR	relative risk
TV	television
US	United States
VCR	videocassette recorder
WHI	Women’s Health Initiative
95% CI	95% confidence interval

I. INTRODUCTION

Throughout the 20th century, changes in technology have drastically influenced human lives and behaviors. Human beings have become increasingly sedentary as machines, computers, and automation lessen the physical demands of living. While these same innovations help us live longer through advances in medicine, the risks of an inactive, sedentary lifestyle are not well understood.

Every day the average American adult spends approximately four to five hours watching television (Television At A Glance 2005), and yet the majority of the population does not spend enough time in moderate to vigorous physical activities to maintain health (MMWR 2004). As a result the population is experiencing an epidemic of obesity and other disorders associated with inactive lifestyles (Blair et al. 1999; Bouchard 1999; Colditz 1999; Katzmarzyk et al. 2003; Mack et al. 2003; Manson et al. 2004; Physical inactivity a leading cause of disease 2002).

While epidemiologists have continued to explore the effects of physical activity through observational cohort studies, it has been difficult to keep up with changes in computer and other "screen" technologies. Technological advances in television, video, internet and gaming increasingly encourage sedentary lifestyles. Only a handful of epidemiologic studies have examined the effects of sedentary behaviors, such as television watching, and risk of diabetes or obesity (Dunstan et al. 2004a; Fung et al. 2000; Hu et al. 2001; Hu et al. 2003; Kronenberg et al. 2000). Public health scientists are considering the necessity of new "sedentary behavior" health recommendations to complement the current physical activity recommendations (ACSM 2007).

Many groups have published physical activity health recommendations over the last thirty years (examples: ACSM 1994; ACSM Position Statement 1990 1990; ACSM 1998; ACSM 1978; Beunen et al. 1994; American Cancer Society 2006; IOM 2005; Fletcher et al. 1992; American Cancer Society Guidelines 1996; USDHHS 2004a; Surgeon General 1996b). But the optimal physical activity prescription regarding health and longevity is still not understood (ACSM 2002; Barinaga 1997; Kesaniemi et al. 2001). At the present time, there appears to be insufficient evidence on the relative importance of intensity, duration, and frequency of physical activity with regards to morbidity and mortality (Erlichman et al. 2002; Kesaniemi et al. 2001; Lee et al. 2001b).

This body of work explored two sides of the public health burden of our present-day lifestyles. First, we examined television watching as a marker of sedentary lifestyle and its association with the chronic disease risk factors of diet and physical activity. Second, we explored the relative contribution of the physical activity components (intensity, frequency and duration) to the risk of coronary heart disease morbidity and mortality.

II. SPECIFIC AIMS

Aim 1: Explore the Relationships between Television Watching, Physical Activity, and Diet.

Aim 1a: Describe the cross-sectional relationship of television watching with physical activity and diet (total calories, total fat, servings of fruits and vegetables, sweets, and salty snacks).

We hypothesize that individuals who report watching television “often” or “very often” will have lower levels of physical activity and fruit/vegetable consumption, as well as higher caloric, fat, sweets, and salty snack intake compared to individuals who watch television “never”, “seldom”, or “sometimes”.

Aim 1b: Examine the relationships of television watching with physical activity and diet (total calories, total fat, servings of fruits and vegetables, sweets, and salty snacks) measured six years later.

We hypothesize that people who watch television “often” or “very often” as baseline will have a stronger association with physical activity, fruit/vegetable consumption, caloric, fat, sweets, and salty snack intake assessed 6 year later than people who watch television “never”, “seldom”, or sometimes”.

Aim 2: To assess the test-retest reliability of a physical activity questionnaire and using this questionnaire to examine the independent effects of intensity, duration, and frequency of walking on coronary heart disease (CHD) morbidity and mortality.

Aim 2a: To assess the test-retest reliability of the Women's Health Initiative (WHI) physical activity questionnaire.

Aim 2b: To examine the independent effect that *intensity* of walking has on CHD morbidity and mortality.

We hypothesize that when controlling for volume of activity (recreational physical activity energy expenditure), participants who walk at a higher speed (intensity) will experience a lower risk of CHD morbidity and mortality than participants who walk at a lower intensity.

Aim 2c: To examine the independent effect that *frequency* of walking has on CHD morbidity and mortality.

We hypothesize that when controlling for volume of activity (recreational physical activity energy expenditure), participants who walk on most or all days of the week will experience a lower risk of CHD morbidity and mortality than participants who walk less frequently.

Aim 2d: To examine the independent effect that *duration* of walking has on CHD morbidity and mortality.

We hypothesize that when controlling for volume of activity (recreational physical activity energy expenditure), participants who take longer walks will experience a lower risk of CHD morbidity and mortality than participants who walk for shorter periods of time.

III. BACKGROUND AND SIGNIFICANCE

A. Epidemiology of Physical Activity, Physical Inactivity, and Sedentarism

An important first step in behavioral epidemiology is to identify clear and consistent definitions and measures. For example, the terms physical *inactivity*, physical *activity,* and physical *fitness* are often used interchangeably, as are the terms physical inactivity and "sedentary". Physical *activity*, physical *inactivity*, and sedentary behavior (sedentarism) have become increasingly important risk factors. The definitions and measurement of these risk factors have been evolving over the past decade (ACSM 2007). This evolution has occurred because of increasing interest in studying these three behaviors independently. This dissertation examines all three of these risk behaviors: sedentarism as a risk factor for physical *inactivity*, and physical *activity* as a risk factor for cardiovascular disease.

Of the three behaviors, "physical activity" has the clearest definition: any bodily movement produced by skeletal muscle that results in energy expenditure (Caspersen et al. 1985). The definition of "physical inactivity" is not consistent, but is often defined as limited participation in, or the absence of, activities demanding at least three metabolic equivalents of task (METs) above resting metabolism (Ezzati et al. 2002). Physical inactivity will be defined as such for the purposes of this research. "Sedentarism" or a term for sedentary behaviors has not yet identified by any definition in the epidemiologic literature but will be defined here as spending extended amounts of time in sedentary (requiring one MET or less) pursuits or behaviors.

Physical inactivity is one of the most prevalent chronic disease risk factors. Over the past decade, between 25-30% of American adults have consistently been defined as inactive (MMWR 2004). According to a Healthy People 2010 progress report, 38% of adults engaged in no leisure time physical activity (USDHHS 2004). At the other end of the spectrum, age adjusted data for physical activity shows that only one-third of adults aged 18 years and older engaged regularly in moderate physical activity (i.e., 30+ minutes of moderate activity at least 5 times a week) and only 23% engaged in vigorous physical activity (20+ minutes on at least 3 occasions per week) (MMWR 2004). This prevalence has not changed significantly over the past decade (USDHHS 2004a). This provides evidence that the vast majority of the American public is inactive or insufficiently active. The high prevalence of sedentary activities and low prevalence of adequate physical activity have both been documented as important risk factors which directly affect health (Surgeon General 1996b).

How physical activity, inactivity, or sedentarism affect health is not well understood. All three may potentially have independent effects on health (Ching et al. 1996; Coakley et al. 1998; Dunstan et al. 2007; Dunstan et al. 2005; Fung et al. 2000; Fung et al. 2001; Hamilton 2007; Hamilton et al. 2004; Healy 2007a; Healy 2007b; Hu et al. 2001; Hu et al. 2003 ; Jakes et al. 2003; Kronenberg et al. 2000; Martinez-Gonzalez et al. 1999; Salmon et al. 2000; Zderic 2007). It is probable that distinct physiologic and metabolic consequences exist for each behavior and that these consequences differentially effect health. It is also possible that other population attributes or personal behaviors vary in regards to effect or association with each risk factor (e.g., age, gender, race/ethnicity, education, occupation/employment, geography, marital status, perceived health, neighborhood/environmental factors, psychosocial variables) (Allison 1996; Buckworth et al. 2004; Caspersen et al. 2000; Evenson et al. 2002a; Eyler et al. 2003; King et al. 2000). One step toward untangling this puzzle is to examine the degree to which these behaviors are associated with one another. Although it appears to be a contradiction, it is possible for a person to be both "active" and "sedentary". For example, an individual may engage in a single sports activity for 30-60 minutes every day thereby meeting many of the physical activity recommendations, but spends the rest of the day sitting. Understanding the differences and health effects of these behaviors requires both clear, concise definitions, and specific, valid measurement tools.

B. Television Watching as a Marker for Sedentary Behavior

A better understanding of the differences between physical activity and sedentary behaviors is complicated by the absence of a tool for measuring sedentary activities. However, in the absence of a validated tool, television watching become a useful estimate for sedentary time (Bertrais et al. 2005; Dunstan et al. 2005; Dunstan et al. 2004a; Dunstan et al. 2004b; Ford et al. 2005; Gao et al. 2007; Kronenberg et al. 2000; Li et al. 2007). While hours of television watching or other measure of screen time may not be adequate for quantifying all sedentary behavior, it has become an important starting point.

In the past half century, watching television has become the most popular leisure activity in the United States (US). A survey of US households by Nielsen Media Research, showed that the average household reported 8 hours and 25 minutes of television watching per day

(Television At A Glance 2005). According to that survey, adult women watched on average 5.6 hours per day, while men watched an average 4.7 hours per day (Television At A Glance 2005). Ninety-nine percent of homes owned a color television, 80% had 2 or more, and 85% of these homes received wired cable or alternate delivery service (e.g., satellite) (Television At A Glance 2005). A separate organization, The Annenberg Public Policy Foundation, also found that 98% of households had at least one television (average 2.4-2.8 per household), 97% owned a VCR, and almost 50% had all four types of "media hardware" which included a television, VCR, video games, and personal computer (Annenberg Public Policy Center 2000). The Annenberg report also found that more families had an Internet subscription than a newspaper subscription.

The amount of leisure time available to American adults averages only 3-4 hours per day, after working, travel, and chores are accomplished (Bouchard 1999). As a result, the vast majority, if not all, of a person's discretionary time is typically spent being sedentary (Bouchard 1999; Television At A Glance 2005). Therefore, very few opportunities remain for more physically active pursuits and hobbies. This sedentary lifestyle may have a direct effect on the energy balance of the population. Indeed, the steady increase in number of televisions and hours of watching in the last 10 to 20 years seems to parallel the increase in obesity (Hu et al. 2003).

Although watching television is such a prevalent behavior, it is surprising that few studies have examined it, or its associations, to other risk factors like physical activity or diet. Most scientific publications have excluded the association between television watching and activity, because both "exposures" are independently associated with the outcomes under study (e.g., diabetes, weight gain, energy expenditure, etc).

1. Television and its Associations with Physical Activity and Diet

Few studies have reported an association between television watching and physical activity. Both the Men's Health Professionals (Fung et al. 2000) and Nurses Health Studies (Hu et al. 2003) found low correlations between watching television and physical activity (-0.05 and -0.03 respectively). A study conducted among Pima Indians also reported similarly low Spearman correlations between watching television and past year physical activity (-0.11 in men, -0.10 in women) (FitzGerald et al. 1997). The most recent and in-depth examination of television watching in the Australian Diabetes cohort has also found weak associations with physical activity (-0.04) (Dunstan et al. 2004a).

Compared to physical activity, more research has occurred on television watching and dietary behaviors. The Men's Health Professional Cohort and Nurses Health Study are the largest longitudinal cohorts to examine diet and television (Fung et al. 2000; Hu et al. 2001; Hu et al. 2003). Both men and women with high television watching were more likely to smoke, drink alcohol, and have more energy dense diets that were higher in total and saturated fats. They also ate more red and processed meat, french fries, refined grain, snacks, sweets or desserts, and had a lower intake of fish, fruits, vegetables, and whole grains (Fung et al. 2000; Hu et al. 2001; Hu et al. 2003).

Studies examining obesity have also provided evidence of an association between television watching and diet. One such a study to find an association with diet, but not activity, suggested that energy intake associated with television watching may be a more powerful mechanism for weight gain than physical activity (Jeffery et al. 1998). Using a study that observed over 1,000 men and women for one year, they found no significant associations between television and exercise. However, for every additional hour of television viewing per day, the women in the study consumed an additional 50-136 kcal/day (Jeffery & French 1998).

Although the behaviors appear related, the small number of studies on diet and television do not provide any information on the temporality of the two behaviors. Hypothesized mechanisms through which television viewing is associated with energy intake are not well understood. Science has not adequately explained whether television watching cues eating behavior or if eating encourages television viewing?

One hypothesized mechanism involves time of day. “Primetime” television hours overlap with the evening meal period. This time conflict may encourage people to consume their meal or snack in front of the television to avoid missing the news or a television program. Breakfast may also be a meal consumed while watching the morning news or weather. A study by Gore et al (Gore et al. 2003), conducted in overweight women, found that the women ate 46% of their meals (~ 9.1 meals per week) in front of the television. However, the content (calories, percent fat, etc) of these meals was not significantly different than meals not eaten in front of the television.

A similar study of college students, showed that on days when participants ate with the television on, they consumed approximately one additional meal compared to days when they ate with the television off (Stroebele et al. 2004). Meals during television watching may have been smaller in size, but resulted in a net increase of energy intake (Stroebele & de Castro 2004). Their study also found that the total amount eaten was also related to the time spent with the television on. Additionally, on days when television and eating were combined, participants exercised less and watched almost twice as much television compared to days when they did not eat with the television on.

Perhaps watching television does not influence the timing or content of a “main meal” (breakfast, lunch or dinner) but may increase the frequency and/or quantity of snacking. The Gore et al. (Gore et al. 2003) study, which found no association between meals and television, reported significant associations with snacking and television exposure. Their results suggest that snacking while watching television is associated with increased overall caloric intake and calories from fat (Gore et al. 2003). A previous study from the 1980’s also found that the number people snacked as frequently during primetime television views as eating breakfast, lunch, and dinner combined (Gerbner et al. 1982).

Stimulus control may also play a role in energy intake when men and women eat meals in front of the television. When a meal or snack is consumed while watching television, the satiety response may be dulled or ignored resulting in continued eating. The college students who were examined in Stroebele et al. (Stroebele & de Castro 2004) study indicated less hunger before the meals they consumed eaten while watching television. This introduces an important question: How does watching television encourage a person to eat when he or she may not be particularly hungry?

One logical explanation for this paradox is advertising. Television viewing may directly cue eating behaviors due to the high proportion of targeted food advertising. People may respond to this stimulus by heading to the kitchen or pantry for the types of sweet and salty foods heavily advertised during programming breaks or featured during the show. Food advertisements on television tend to be for higher-energy dense foods, with more fat, sodium, and sugar (Byrd-Bredbenner et al. 2000; French et al. 2001). French et al (French et al. 2001) estimated that during 15 hours of television exposure a week, approximately 90 minutes of that time is commercial advertising and this advertising is heavily geared toward confectionaries, snacks, prepared convenience foods, fast foods, and soft drinks. In 1988, Story et al (Story et al. 1990) conducted an analysis of food messages during primetime television hours (shows and advertisements) and found that for every 30 minutes of programming, approximately five food references were made. Sixty percent of these foods references were low nutrient beverages and sweets, and 35% of the commercials aired promoted specific foods, with fast food restaurant commercials occurring the most frequently. Although there is a clear and consistent pattern of unhealthy foods marketed on television, there has been very little exploration of its impact on physical activity and diet.

C. Physical Activity and its Evolution as a Health Risk Factor

Although the health benefits of activity have been recognized for centuries, the modern evidence for a relationship between activity and mortality began with a handful of studies conducted by Drs. Jeremy Morris (Morris et al. 1958) and Ralph Paffenbarger (Paffenbarger et al. 1978). These early research endeavors found evidence that vigorous sports or active occupations provided a cardioprotective lifestyle (Erlichman et al. 2002). These studies, combined with the increasing literature in exercise science, supported a vigorous threshold to cardiovascular benefits. Together these fields of science laid a foundation for the future health recommendations regarding activity and fitness (Blair 2005).

One of the first physical activity recommendations was published in 1978 by the American College of Sports Medicine (ACSM) and outlined what has become known as the

F.I.T. principle (Frequency, Intensity, Time) (ACSM 1978). This recommendation focused on the development and maintenance of cardiorespiratory fitness for health and encouraged vigorous exercise at least three times per week performed as a continuous bout of at least ≥20 minutes.

As interest in physical activity increased, measurement and methods improved. Scientists soon realized that many of the earlier studies were limited in their assessment of physical activity. Two meta-analyses on the effect of physical activity on CHD concluded that conflicting results in the literature may be a result of study quality or insufficient differences between the levels of active and inactive populations (Berlin & Colditz 1990; Powell et al. 1987). Another weakness identified by these studies was that previous studies had dichotomized the population into active/inactive groups based on a single job description or sport participation question(s).

By the early 1990's an effort was made to draw more distinctive differences between the definitions for exercise, physical fitness, and physical activity. As a result, awareness was generated concerning their differences and public health significance of each measure. Population studies also began to move away from the focus on performance related exercise and began to examine lifestyle activities.

Soon after, the American Heart Association identified physical inactivity as a primary risk factor for cardiovascular disease (Fletcher et al. 1992). By 1995, evidence for moderate-intensity and modest amounts of activity was enough for the ACSM and Centers for Disease Control and Prevention (CDC) to publish a joint recommendation for health (Pate et al. 1995). This widely accepted guideline recommended that adults accumulate 30 minutes or more of at least moderate activity on most or all days of the week (Pate et al. 1995). The recommendation also highlighted the importance of total amount (dose) of activity over the specific manner in which it is performed.

However, the scientific community was not in complete agreement with its conclusions and there was a great deal of discussion surrounding the new recommendations (Barinaga 1997). Advocates of vigorous exercise countered that many of the studies supporting moderate levels of activity were based on physical fitness research (Barinaga 1997). They argued that studies based on cardiorespiratory fitness should not influence physical activity recommendations because cardiorespiratory fitness is more genetically determined than activity and influenced by other personal attributes (Barinaga 1997). It was also suggested that much of the impetus for changing the guidelines was not based on solid evidence but rather finding a more palatable, encouraging message for an increasingly inactive population (Barinaga 1997). The previous recommendations advocating vigorous, sustained activity was deemed a difficult prescription and seen as a barrier (Barinaga 1997; Lee & Skerrett 2001b).

To add to the controversy, in 2002 the Institute of Medicine (IOM) released a separate report that recommended 60 minutes of accumulated activity performed every day (IOM 2005). The difference between the IOM and ACSM/CDC recommendations generated an even greater degree of controversy and confusion; especially with regard to general health benefits versus weight gain (ACSM 2002). However, the IOM recommendation was focused more so on energy balance or weight stability and not as much on general health benefits.

Additionally, most of the previous recommendations do not contain information on the components of total activity: intensity, frequency, or duration (Barinaga 1997; Haskell 1996; Kesaniemi et al. 2001). This has been an important shortcoming in the literature used to craft recommendations that are specific with regard to activity prescription. The central criticism is that these studies focus solely on total volume (defined as total energy expended) of activity. These epidemiologic studies examined specific domains of activity (i.e., sport/exercise, transportation, lifestyle, or occupation) and then examined the volume of energy expenditure associated with morbidity and mortality.

1. Physical Activity Volume, and Health

Most epidemiologic studies report that a moderate *volume* of activity is sufficient to produce health benefits regardless of type, intensity, frequency, or duration. Health benefits are achieved as long as a moderate volume of total energy is expended, between 800 and 1500 kcal of energy per week (Blair et al. 1989; Lee & Skerrett 2001b; Pate et al. 1995; Surgeon General 1996a). Although many studies agree that this volume will result in cardioprotective health benefits, many studies report a dose-response or linear relationship between volume and risk of cardiovascular disease (CVD) morbidity and mortality (Berlin & Colditz 1990; Katzmarzyk et al. 2003; Kesaniemi et al. 2001; Oguma et al. 2004). This translates into “more is better”. What most studies do not describe is the optimal dose or prescription of activity (defined as intensity, duration, and frequency) for achieving health benefits.

In 2000, an international symposium was held to discuss many of the scientific issues concerning physical activity dose-response and health (Kesaniemi et al. 2001). International experts gathered to examine the evidence to date, and better define the relationship between physical activity and health. At the 2000 symposium, Blair et al (Blair et al. 2001) reviewed 67 studies on physical activity and health or cardiorespiratory fitness and health. A goal of their review was to identify which of the two measurements, cardiorespiratory fitness or physical activity, was more important in achieving health benefits. They found 49 studies describing a dose-response between physical activity and general health and nine studies were found examining cardiorespiratory fitness and health. Among the studies which used physical activity as the main exposure, different dose-response patterns were observed. However, these differences in the dose-response patterns may have been influenced by the diverse methods of measuring activity (number of categories, etc) (Blair et al. 2001). Of the nine studies using cardiorespiratory fitness as an exposure, all appeared to show a strong, inverse, dose-response gradient. In the few studies which compared both exposures (physical activity vs. fitness), a threshold for benefits was observed with physical activity, while a steeper gradient was observed for physical fitness. The study authors concluded that future studies should not focus on the differences of any health benefits between physical activity and physical fitness, but rather they reported that more work remains to better define the shape of the curve between activity and the different health benefits, especially in terms of optimal duration and intensity (Blair et al. 2001).

Oja et al (Oja 2001) reviewed the dose-response between total volume of activity and it's effect on health and/or cardoirespiratory fitness published in observational and experimental studies since 1990. This review differed from the previous review by Blair et al (Blair et al. 2001) because it used cardiorespiratory fitness as an outcome (rather than an exposure) and focused on total volume of activity and the subsequent health or fitness response. Nineteen observational studies were included in this review. The authors concluded that when viewed collectively these observational studies indicate that health benefits are highly associated with the total volume of activity. In fact they suggested that the benefits were proportional to the total volume of activity performed.

In contrast, the 15 experimental studies with assigned activity prescriptions (11 were randomized control trials), did not seem to show the same relationship between volume of exercise and health benefit. The lack of a relationship observed between volume of activity and health may be because very few of these studies were designed to study health outcomes. As a result they were underpowered or unable to detect small effects. The authors also concluded that an "urgent need" exists for future research to identify the volume of activity and key elements of physical activity dose associated with health outcomes.

A separate review from the same symposium as (Blair et al. 2001) and (Oja 2001) examined the effect of either physical activity or fitness on all-cause mortality and considered 44 papers spanning over thirty years of research (1966-2000) (Lee & Skerrett 2001b). Thirty-four of the papers reported a significant relationship between the volume of physical activity and all-cause mortality. However, a threshold effect with no additional benefit at the highest levels of activity was reported in five of the studies. More recently, studies have been pooled in a meta-analysis to examine physical activity and mortality (Katzmarzyk et al. 2003). Thirty-one studies provided over fifty separate analyses and produced a variance-based measure of risk that translated into 20% increase in risk for inactive individuals compared to their more active peers (relative risk [RR]=0.80, 95% confidence interval [CI] 0.78-0.82, in studies controlling for measure of adiposity). The authors of the meta-analysis concluded that the elevated risk of all-cause mortality associated with inactivity was independent of adiposity, age, gender, and that adequate evidence existed for an inverse dose-response between activity and mortality.

In longitudinal studies a consistent, inverse dose-response relationship has been reported between physical activity volume and cardiovascular disease. This has been observed with physical activity and morbidity and mortality from CVD and/or CHD. Kohl et al (Kohl 2001) published a review for the 2000 symposium concentrating on studies which performed a dose-response assessment of physical activity. They identified five major cohorts and eight scientific articles which specifically assessed the dose-response relationship between CVD and physical activity. Two of the eight studies provided no evidence of a dose-response, while five exhibited a convincing dose-response relationship. From 31 publications on CHD, 20 provided support for a dose-response (Kohl 2001). Eight found no association, while a handful of others presented a threshold effect, or a U-shaped relationship. A second epidemiologic review of the literature on CHD and activity, published near the same time, reached a similar conclusion (Wannamethee et al. 2001). Wannamethee and colleagues (Wannamethee & Shaper 2001) found that although a linear dose-response relationship exists, once a higher level of activity or intensity is reached, risk might actually increase. In fact, elevated risk of CHD was associated with increased vigorous activity in individuals with established risk factors or clinical disease (Wannamethee & Shaper 2001; Wannamethee et al. 2000). This was also one the few reviews that examined the effect of intensity as one of the three physical activity components: intensity, frequency, and duration.

2. Physical Activity: Intensity, Frequency, and Duration

Scientists define and assess physical activity as a product of its individual components: intensity, frequency, and duration. These components are how activity is often measured and prescribed. The recommendations from both the ACSM/CDC and IOM are specific in regard to the components, although the scientific evidence regarding the individual contribution of each component is unclear.

Though information is readily available concerning benefits or risk of physical activity, little is know about defined doses of activity and resulting health response (Kesaniemi et al. 2001). Specifically, scientists at the expert symposium in 2000 were unable to assess the impact of the individual components of activity apart from their contribution to total volume. A review published one year later found that the symposium *"merely sought to establish the effects (risks and benefits) of regular physical activity - rather than the more precise measurement of the most effective dose (frequency, duration, intensity and total volume)"* (page #269)(Erlichman et al. 2002). The dearth of literature on the components of physical activity leaves many unanswered questions, including the relative effect each component has on morbidity and mortality. Only a small number of population-based experimental trials have examined the effect of physical activity components on health outcomes or risk. There are even fewer observational studies.

One of the most challenging methodological issues complicating the debate is the difficulty in untangling the effect of each component from the resulting energy expenditure (volume) (Hardman 2001; Kesaniemi et al. 2001; Lee & Skerrett 2001b; Shephard 2001). Many of the scientific articles that examine the effect of physical activity components neglected to control for total volume of activity (Hardman 2001; Kesaniemi et al. 2001; Lee & Skerrett 2001b; Shephard 2001). This is important because an individual who engages in activities that are frequent, of long duration, or vigorous intensity, will expend more total energy than another who engages in activity of moderate intensity, infrequent, or short duration. Therefore, until energy expenditure is considered, it is difficult to know if the observed health effects in more active individuals are an artifact of greater total energy expenditure or a result of the higher intensity, additional frequency, or longer duration.

This situation is analogous to nutritional epidemiology when a "relative" measure of diet or nutrient composition is examined independently of total caloric intake. For example, fat or saturated fat is associated with increased risk for obesity and chronic disease above and beyond their contribution to total energy intake. Fat as a nutrient also contributes to more kilocalories of energy intake relative to other nutrients (carbohydrate, protein, etc). In order to examine the biological meaning or impact of fat, researchers must control for total energy intake (Hu et al. 1999b; Willet 1998). There are a number of nutritional epidemiologic methods developed for this purpose including "nutrient density" methods, "energy partition methods and "residual' methods (Hu et al. 1999b; Willet 1998), although many of these methods are not without limitations or controversy (Mackerras 1996; Wacholder et al. 1994).

The first step to untangling these effects in physical activity epidemiology is to collect the separate components (intensity, frequency, duration) so that each one is assessed independently, but contributes to a summary variable of volume (e.g., energy expenditure as METs or kilocalories). Second, to control for volume of activity, an estimate of energy expended from all activities must be matched for or controlled in the analysis. This is achieved in laboratory studies by directly estimating the caloric energy expenditure or "work" required in specific activities. Usually energy expenditure is measured in laboratory studies through the composition of each individual's respiration while performing an activity (gas analysis). However, this method is not possible to integrate into epidemiologic studies, so other ways to estimate the volume of work or activity performed must be calculated.

The most common method of assessing total energy expenditure in epidemiologic studies is by using the intensity of an activity, and applying a constant metabolic energy requirement or MET value to that activity. This constant is estimated from a published list of the energy costs of activities performed at different intensities (Ainsworth et al. 1993; Ainsworth et al. 2000). The constant metabolic rate (energy requirement) can then be combined with a measure of time and converted in to METs per unit time. Although it varies slightly by individual, METs can also be translated into caloric expenditure which can also be used as a summary measure to estimate volume of activity.

Translating total energy expenditure into METs or calories for an exposure variable is common in physical activity studies. However, attempting to control for it as a covariate to examine components has not been used. At this time, there are no published studies on epidemiologic data that attempted controlling for total energy as a covariate to examine the relative contribution of all three activity components. There have been a handful of studies that tried to examine individual component effects by stratifying by volume or restricting the population.

i. Intensity

More than any other component of physical activity, intensity (how hard the activity is to perform) has been the most critically examined. It is clear from the literature that there are beneficial effects of physical activity, regardless of the intensity at which it is performed. But there is little evidence in the epidemiologic literature that suggests vigorous activity provides a unique protective or negative effect beyond its contribution to total energy expenditure.

The public health recommendations have changed dramatically regarding the vigor at which activity must be performed to obtain health benefits. The 1978 recommendation (ACSM 1978) called for vigorously performed activity or activities which result in sweating or significantly increased respiration. More recently, the recommendations have become broader and encourages activities of more moderate intensity (Barinaga 1997; Pate et al. 1995). There has been controversy surrounding both the moderate and vigorous recommendations as well as the science behind each message (Barinaga 1997).

The first part of the controversy pertaining to the vigorous recommendation is that a vigorous requirement is perceived as a barrier. Secondly, experts have not fully elucidated the scientific evidence for health benefits from intense activity, over and above the contribution to volume of energy expenditure. Although some have suggested that intensity and volume may work together to produce an additive effect on health (Shephard 2001).

Experts at the 2000 symposium found moderate to vigorous exercise positively influenced many physiological end-points including blood lipids, lipoproteins, and overweight or obesity, but that high intensity provided no benefit to blood pressure (Kesaniemi et al. 2001). They found insufficient evidence to establish a relationship between intensity and coagulation and hemostatic factors (Kesaniemi et al. 2001). Other studies have shown benefits of higher intensity physical activity on a number of risk factors including resting energy expenditure (Hunter et al. 1998), acute changes in hormone or clotting mechanisms (Shephard 1997), insulin sensitivity (Shephard 1997), triglycerides (Fletcher 1999), immune function (Shephard 1997), aerobic capacity (Rognmo et al. 2004), and atherosclerotic plaque regression (Fletcher 1999).

When examining later endpoints like mortality, the reviewers of the previously referenced meta-analysis of activity and mortality (Katzmarzyk et al. 2003) concluded that there was insufficient evidence to indicate whether or not vigorous activity was associated with additional risk attenuation over and above moderate activity. But they also concluded that high intensity activity performed for shorter amounts of time might have a different health effect than moderately intense activity for longer periods of time (Katzmarzyk et al. 2003). In their review paper which also examined mortality, Drs. Lee and Skerrett (Lee & Skerrett 2001b) presented only four studies which examined intensity of activity while attempting to control for activity of other intensities (attempt to control for volume). Results from three of those studies indicated that only vigorous activity was associated with lower all-cause mortality rates. A few studies have attempted to control for volume when examining intensity of activity and health effects by stratifying. In two studies of men (Harvard alumni, Caerphilly study) stratified by total physical activity, only vigorous activities remained associated with risk of CHD or mortality (Lee et al. 2000a; Lee et al. 2003; Sesso et al. 2000; Yu et al. 2003). In the Men's Health Professionals Study, average exercise intensity was significantly associated with risk even after accounting for total activity (Tanasescu et al. 2002). Researchers also examined the same cohort with regard to diabetes risk and found that walking pace was independently associated with risk for diabetes after considering time spent walking (Hu et al. 2001).

The results in women have been more mixed. The Women's Health Study did not find that walking pace was associated with lower risk of CHD (Lee et al. 2001a). Although the authors associated vigorous activities with lower risk, the study provided evidence that light and moderate activities conferred similar benefits. Dr. Manson and colleagues (Manson et al. 2002; Manson et al. 1999) found the opposite in two other populations of women. In both the Nurses Health and WHI walking pace (an indicator of intensity) was significantly associated with coronary events.

More recently, a review comparing the cardiovascular risk benefits of vigorous versus moderate activity concluded that *"the preponderance of evidence favors more cardioprotective benefits from vigorous than from moderate intensity exercise"* (page 145)(Swain et al. 2006). This summary examined both epidemiologic cohort studies and clinical trial evidence. The authors concluded that the epidemiologic evidence pointed toward a greater reduction in risk of CHD associated with vigorous intensity versus moderate intensity activity. The public health recommendation regarding intensity of activity can be very contentious. The preponderance of evidence seems to suggest activities performed at a vigorous intensity are more beneficial than moderate. However, the majority of the epidemiologic literature examining this topic has failed to explore the independent health effects of the physical activity components while controlling for volume of activity.

ii. Duration

Another difference between the two recent public health recommendations, ACSM/CDC (Pate et al. 1995) and IOM (IOM 2005), was in duration of activity. While the ACSM/CDC advocates 30 minutes or more of moderate to vigorous activity on most days, the IOM has recommended twice that amount (60 minutes). Activities of longer duration contribute more toward energy expenditure or volume, but it is unclear if sustained activity provides any health benefits beyond the contribution to volume.

The 2000 symposium (Lee & Skerrett 2001b) found only two studies (Lee et al. 2000b; Leon et al. 1987) which examined duration in regards to CHD while controlling for total volume activity. Both studies did not find an independent effect of duration once scientists accounted for volume. The authors concluded that as long as the total energy expenditure was equal, longer sessions of exercise did not confer additional benefit (Lee et al. 2000b). Other studies which attempted to address duration did not control for volume and therefore findings reflected the association between volume of activity and events (Lee & Skerrett 2001b).

A recent randomized control trial of activity on insulin sensitivity was conducted in 154 sedentary, obese adults and comparing three differing prescriptions based on volume and intensity (Houmard et al. 2004). After six months, the authors found that although all exercise groups improved insulin sensitivity, the total duration was a more important factor for increasing insulin sensitivity (vs. frequency and intensity). The optimal duration to perform activity has clearly not been clarified in the literature. In order to assess this component in an unbiased manner the volume of activity must be controlled for.

iii. Frequency

The issue of frequency, or fractionalization (activity performed in intermittent bouts), has received even less attention than either intensity or duration, and very few studies have examined the associated health effects. An important question to answer is whether one continuous session of exercise has similar physiologic effects compared to several shorter sessions if the same total duration is accumulated, and intensity is held constant.

Dr. Hardman attempted to review this issue for the 2000 symposium and found inconclusive evidence concerning the frequency of activity bouts and health effects (Hardman 2001). A small number of randomized trials indicated if total duration and intensity are equal; several short exercise sessions per day are equal in regards to improvement in cardiorespiratory fitness (measured as oxygen consumption or VO_2) compared to one long exercise session.

In the Harvard Alumni Study, Lee et al (Lee et al. 2004) examined people who engage in high volumes of activity, but during infrequent bouts. They identified these people as "weekend warriors" and defined them as individuals who expend enough energy for health benefits (>1000 kcal/week), but during only one or two days per week. Comparing these people to both their sedentary and more regularly active peers (people who were active on more than 2 days/week), they found that the weekend warriors (who were not at risk of disease) had a lower risk of mortality than their sedentary peers. When compared to regularly active men, the weekend warriors had slightly elevated risk. In subjects at high risk for disease, weekend warriors experienced much higher risk, which led the authors to hypothesize that perhaps the physiologic benefits are different. This analysis however did not control for volume of activity or examine other patterns or frequencies of activity.

The current ACSM/CDC recommendations supports breaking up physical activity into smaller "bouts" performed more frequently. However, there is no conclusive literature regarding frequency of activity bouts and the resulting health effects. When activity volume is held constant, we do not know if one longer bout elicits the same effect as numerous shorter bouts.

D. Conclusion

There is emerging evidence that physical activity, physical inactivity, and sedentarism have different influences on health. Examining both the combined and independent effects of these risk factors on health is increasingly important for future public health recommendations.

The influence of television watching, as a marker of sedentary activity has never been evaluated with regard to diet and physical activity in a prospective cohort of adults. The Atherosclerosis Risk in Communities (ARIC) Study provides an excellent opportunity to do this. ARIC is a population-based cohort study designed to investigate the etiology and natural history of atherosclerosis. This cohort has been followed up annually and physical examinations have been repeated at approximately three year intervals. Adults from four communities in the US provided baseline information in 1986-1989, and six years later, on many behavioral risk factors including television watching and the outcomes of diet and physical activity and were subsequently followed.

Physical activity is an undisputed risk factor for morbidity and mortality, however the optimal physical activity prescription is not well defined. The recent controversy surrounding the IOM and ACSM/CDC guidelines highlights the importance of this issue (Barinaga 1997). At this time, there is no published study on epidemiologic data that attempted to control for energy expended as a covariate to examine the relative contribution of each prescriptive component (intensity, duration, and frequency). The Women's Health Initiative (WHI) provides a unique opportunity to examine the three components of physical activity. The questionnaire developed for this study was designed specifically for women and ascertains information on each component of activity separately. WHI is likely the largest and most ethnically diverse cohort to examine women's health to date. Over 90,000 women from forty centers across the US have been followed for almost ten years. An extensive baseline survey, yearly contact with the participants, and detailed morbidity and mortality information supply detailed information on the variables that will help answer the specific aims of this proposal.

IV. METHODS

A. Introduction

The objectives of this dissertation were to examine the behavioral consequences of modern day lifestyles. The two exposures under study, television watching (sedentarism) and physical activity, are diametrically opposed behaviors and risk factors. Therefore, the methods for this dissertation required several different approaches. Data for the first aim were extracted from the ARIC study to examine the associations of television watching with physical activity and diet. Data for the second aim required two different datasets. The first dataset, the Measurement and Precision Study from the WHI, was used to examine the test-rest reliability of the WHI physical activity questionnaire. The second dataset for this aim was derived from women enrolled in the Observational Cohort of the WHI. This group of women was used to explore the independent associations of intensity, frequency, and duration of walking with CHD morbidity and mortality. For each aim, we describe the study population first, followed by the variable measures, and lastly, details of the analysis.

B. Aim 1 Analyses from the ARIC Study

The ARIC study was designed to investigate the etiology and natural history of atherosclerosis in middle-aged adults. Four communities in the US were chosen: Washington County, Maryland; suburbs of Minneapolis, Minnesota; Jackson, Mississippi;

and Forsyth County, North Carolina. Between 1986 and 1989, a probability sample of men and women ages 45-64 years were recruited to joint the study. From this sample 15,792 participants completed the first visit. Recruitment rates were lowest in Jackson, Mississippi (46%) and between 65-67% for the remaining three sites. At the baseline visit, participants underwent a physical examination and testing to provide information on cardiovascular risk factors. All participants were also interviewed by trained personnel about their past medical history, educational attainment, family income, as well as usual diet and physical activity. Each year, participants received a telephone call to ascertain their health status. Approximately every three years the clinic visits, which include physical exams and interviews, were repeated.

1. ARIC-Baecke Physical Activity Questionnaire

The Baecke questionnaire was designed by Dutch researchers to assess long-term patterns of habitual physical activity (Baecke et al. 1982). The questionnaire was intended to better distinguish between different dimensions of physical activity. The original questionnaire consisted of 29 items concerning five components/domains: occupation, movement, sport, leisure time activities (excluding sport), and sleeping habits. After completing detailed analyses, the Dutch questionnaire was narrowed into three indices or domains: leisure, sport, and work. These three indices are included in the ARIC-Baecke questionnaire. However, the ARIC-Baecke questionnaire had minor modifications made to the work and sport indices for the purposes of the ARIC Study. These modifications are described by index. The ARIC-Baecke questionnaire was also designed to be interview administered. Participants completed the questionnaire at baseline enrollment and at the third clinic visit (1993-1995).

Leisure Index

The leisure index comprised questions regarding participation in the following activities: watching television, walking, biking, and transportation activity (minutes spent walking or biking to and from work or shopping). The derived leisure index was not used in the analysis of the first aim because it included the main exposure (television). The television watching question in the leisure index asked, “During your leisure time do you watch television?” It allowed for five responses, never, seldom, sometimes, often and very often. The answers were ranked on an ordinal scale from 1 (low) to 5 (high) and this single-item variable was used as the main exposure.

The leisure index also included questions on walking, biking, and non-motorized transport. These were used separately as outcomes of interest where appropriate. All of the questions were based on an ordinal scale from the responses never, seldom, sometimes, often, and very often (coded 1 to 5). The transportation question was also broken into ordinal categories based on categories of time (< 5 minutes/week, 5-<15 minutes/week, 15-<30 minutes/week, 30-<45 minutes/week, or ≥45 minutes/week).

Sport Index

The sport index was determined from four component questions. There are three close-ended questions which asked participants how often they engage in sports or exercise, how they compare their leisure activity level to their peers, and how often they sweat. These questions were also based on an ordinal scale from 1 (low) to 5 (high).

The fourth question allows the participant to report up to four sports or activities. The participants recall how many hours per week and months per year they engage in each of the four possible sports or activities. Each activity is assigned an intensity value estimated from the compendium of physical activities (Ainsworth et al. 2000). Lastly, a summed value is assigned to each activity, by multiplying intensity, duration (hours per week), and frequency (months per year). Intensity is measured by megajoules per hour (MJ/h) and defined as low, moderate, or high (0.76 MJ/h, 1.26 MJ/h, 1.76 MJ/h) (Richardson et al. 1995). Duration is measured in hours per week from less than 1 hour to 4 or more hours per week (0.5 hr/wk, 1.5, 2.5, 3.5, 4.5). Frequency is measured by the proportion of the year each activity is performed from less than one month to more than 10 months per year (0.04 month/yearr, 0.17, 0.42, 0.67, 0.92). The ARIC-Baecke questionnaire differs from the original questionnaire in regards to number of activities reported (original=2, ARIC=4). All of the questions (4 activities plus 3 ordinal questions) are summed together to create a final index which ranges from 1 to 5, with each item contributing between 0 to 1 point or weighting each item equally.

Work Index

Most modifications to the questionnaire involved the assessment of occupational activity. The original Baecke consisted of one item, while the ARIC-Baecke work activity score contains eight items. The first seven questions measure frequency of sitting, standing, walking, lifting, sweating at work, fatigue after work, and comparison of work activity to peers. These use an ordinal scale coded from the following responses, never, seldom, sometimes, often, very often (1-5). A final (eighth) item ranks the reported occupation into low, medium or high activity levels (value of 1, 3, or 5) based on industrial hygiene codes and the scoring of two exercise physiologists. The final work index is calculated by weighting each question equally, with a range from 1 to 5.

Reliability and Validity

The reliability and validity of the Baecke questionnaire has not been tested in the ARIC population. However, reliability and validity from other populations have been reported in approximately 16 other studies and are detailed in Appendix A**.** In terms of reliability, test-retest correlations for total activity combined from all three indices ranges from 0.65 to 0.93 and for the leisure index (which includes television watching) correlations range between 0.70 to 0.80. The sport index has reported correlations indicating test-retest reliability between 0.79 to 0.93 and the work index between 0.74 and 0.95.

Modest associations have been observed between the Baecke questionnaire and other physical activity measures in a number of studies. Comparative tools used against the Baecke include aerobic capacity/maximal oxygen consumption, accelerometers, physical activity diaries, and doubly labeled water. Of the separate indexes, the sports index correlations were more strongly associated with aerobic capacity (r=0.50-0.70) than the leisure or work index (leisure r=0.26-0.57, work r=0.11-0.23). Three different types of accelerometers were also used to examine validity of the Baecke physical activity questionnaire (Cauley et al. 1987; Gretbeck et al. 1990; Jacobs et al. 1993; Mahoney et al. 1990; Miller et al. 1994; Philippaerts et al. 2001; Pols et al. 1995; Rauh et al. 1992; Richardson et al. 1995). When compared with accelerometery, the validity of the tool varied significantly across studies. A number of studies compared the Baecke against activity diaries ranging from multiple 24-hour recalls, three day histories, or even a four week diary (Jacobs et al. 1993; Pols et al. 1995; Voorrips et al. 1991). Comparing the Baecke to physical activity diaries resulted in moderate to high correlations with the separate indexes (correlations with sport index r= 0.40- 0.70, with leisure index r= 0.30-0.40). The last validation method used for the Baecke physical activity questionnaire was against doubly labeled water (Philippaerts et al. 1999). Of all questionnaires examined in the Philippaerts study, the Baecke had the highest agreement compared with the doubly labeled water, and an overall Pearson's correlation for physical activity level of r=0.69 (sport index r=0.55, leisure index r=0.22, work index r=0.52).

i. Television: Exposure Measurement and Ancillary Data

Television watching has become an important marker for sedentary behavior. The Baecke questionnaire includes one question on television watching as part of the leisure index. The question is categorized on an ordinal scale and taken directly from the questionnaire. Participants identified their television exposure as never, seldom, sometimes, often, or very often.

The validity of the Baecke single-item television watching question is unknown. Lacking this information, we sought a population in which we could compare a more detailed measure of self-reported television watching with the Baecke question. An ancillary dataset was found which used both the Baecke questionnaire and a continuous measure of television watching (Hulens et al. 2003). This data comes from a walking study involving patients, hospital employees, and family or friends of employees at the University Hospital Gasthuisberg in Leuven, Belgium. Participants were female, between 18 and 65 years of age, and not suffering severe or symptomatic diseases (including, hypertension, dislipidemia, type II diabetes, orthopedic pain, or cardiopulmonary disease). The Baecke physical activity questionnaire and hours each day spent watching television were both recorded by self-report.

To quantify the agreement between the two television questions, we examined the distribution of the two variables and then categorized each question into three levels. The Baecke categories were collapsed by combining never-seldom into one category, sometimes into the second, and often-very often into the third. The question on continuous hours of watching television was then categorized by tertiles. When we compared the categorized questions together the resulting chi-square statistic (nonzero correlation) was 92.3 ($p<0.0001$), showing a high level of agreement between the two television measures (see Appendix B).

ii. Physical Activity: Outcome Measurement

The main physical activity outcomes in the first aim were the sport and work indices. The leisure index could not be utilized because of overlap with the main exposure (television). However, the remaining leisure activity questions concerning walking, biking, and non-motorized transport were included as outcomes or covariates of interest. Participants were also dichotomized as active or inactive based on whether or not they engaged in “regular physical activity”. This was defined as participation in at least one hour per week of activity for 10 or more months of the year. Inactivity was identified by a lack of regular physical activity (defined as less than one hour per week of activity 10 months or more of the year).

2. ARIC Food Frequency Questionnaire – Dietary Outcomes

Usual dietary information was collected at baseline (1986-1989) and at the third clinic visit (1993-1995) using a semi-quantitative dietary questionnaire. The ARIC food frequency questionnaire (FFQ) contains 66 items and is based on the original Willett 61-item FFQ (Willett et al. 1985). It also deviates from the original 61-item FFQ, because it is interview-administered to improve accuracy and completeness. The ARIC FFQ is organized into seven sections; 1) dairy, 2) fruit, 3) vegetables, 4) meats and fish, 5) sweets and baked goods, 6) miscellaneous, carbohydrates, fried foods, and 6) beverages.

Interviewers asked the participants, "In the last year how often, on average, did you consume ______." Nine responses were available for each food item ranging from "almost never" to "more than 6 times per day". Each response was assigned a weight to transform it into servings per day. Daily intake of nutrients was computed at the Channing Laboratory, Harvard Medical School, by multiplying daily servings of each item with the corresponding nutrient content for each food item (Shimakawa et al. 1994).

Dietary questionnaires, such as the ARIC-FFQ, are often used to estimate the association between specific nutrients and disease or disease etiology (Subar et al. 2001b). Because this analysis was not intended to explore disease etiology, but rather the association between two risk factors, we focused primarily on absolute values of dietary composition. Other measures of interest were nutrient estimates of total kilocalories and total grams of fat. These variables were also derived by the Channing Laboratory, Harvard Medical School (Shimakawa et al. 1994). All dietary outcomes were examined continuously, but because this food frequency questionnaire was designed to rank individuals into levels of intake, the outcomes were also categorized into tertiles or other appropriate categorization. Details on variable creation are outlined in Appendix C.

Validity and Reliability

Validity of the ARIC FFQ among cohort participants has not been assessed. However, the original 61-item FFQ has been validated and is a well-recognized dietary tool (Willett et al. 1985). Percent agreement between dietary records and the FFQ on ranking subjects in the lowest two quintiles of calorie-adjusted intake was 79%, with a 77% agreement between the highest two quintiles.

The reliability of the nutrients assessed by the ARIC FFQ has been estimated among both white and African American ARIC study participants (Stevens et al. 1996). The median reliability coefficients (unadjusted, using regression techniques) were 0.48 and 0.63 for white women and men respectively, and 0.45 and 0.50 in black women and men respectively.

i. Covariates

A number of covariates were selected for analysis based on known and suspected relationships with the exposure and outcomes. Because there is very sparse evidence about the relationship of our main exposure (television watching) with other variables, the list of potential covariates began broadly and narrowed as the analyses progressed. Information from the univariate and bivariate analysis helped guide this process. Selected covariates and their methods of collection are described in detail in the analysis plan.

3. Analysis Plan - Aim 1

The association of television watching with physical activity or diet (aim 1a) was answered using a cross-sectional design. The second part of this aim (Aim 1b) addressed the prospective associations between television watching with physical activity or diet by using a longitudinal design. The central difference between the cross-sectional and longitudinal analyses is that the outcome measures were taken from the third clinic visit. The main exposure and other covariate information were taken from baseline values.

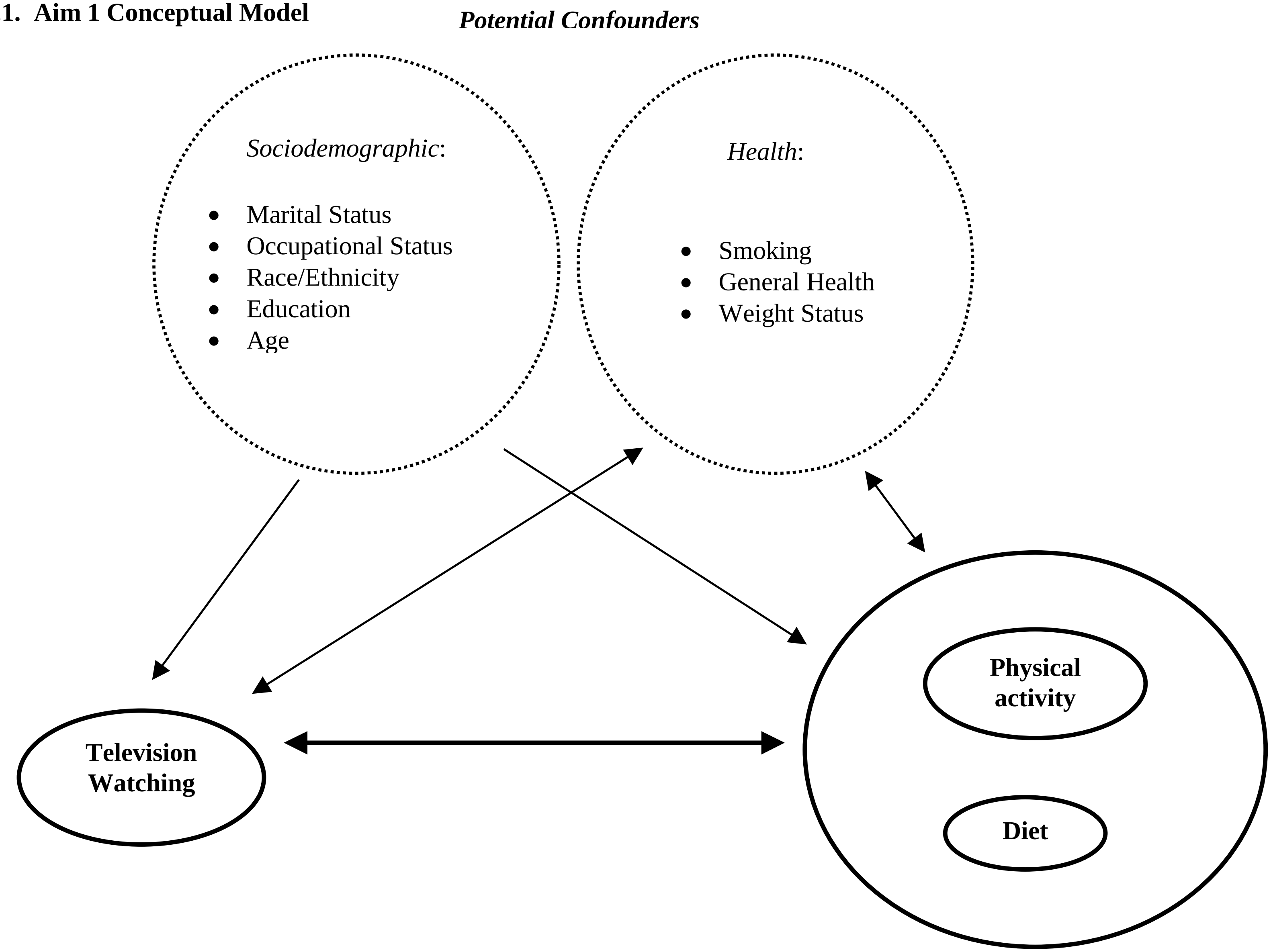
Data reduction

Any individual who did not answer the question on television watching at the baseline visit was excluded from all analyses. Individuals who were missing information on television watching at the third clinic visit were included for the baseline cross-sectional analysis but excluded from longitudinal analyses. For both cross-sectional and longitudinal analyses, any participant who selected a racial group other than white or African American was excluded because of small sample size. Additionally, African Americans from the Washington County, MD and Minneapolis, MN sites were also excluded because the small samples make the control of race by site difficult.

Covariates

A number of variables were considered as potential confounders of the relationship between television watching and diet or physical activity. These variables were decided on *a priori* and included both socio-demographic and health related variables. The conceptual model helped guide decision-making regarding the covariates (Figure 4.1).

Figure 4.1. Aim 1 Conceptual Model



All sociodemographic variables were self-reported at baseline. Because racial groups other than African American and white were excluded, race was dichotomized as white or African American. Race was also combined with the study center from which the participant was recruited. This gave us a race by site variable that is organized into five categories (Forsyth County African American; Forsyth County white; Washington County white; Minneapolis white; and Jackson African American). Education was also self-reported and organized into categories (<high school, high school, >high school). Occupational information was reported at each visit and was estimated with two variables. The first occupational variable describes whether or not the participant is currently employed; the second describes the type of employment which was categorized.

A number of health measures were also collected. At each visit smoking status was obtained during interviews and defined categorically as current, former, or never smoker. A subjective general health question was also asked at each visit and ranked the participants health as excellent, good, fair, or poor. Anthropometric measurements were obtained at each clinic visit and included weight and height body mass index. Body mass index, weight in kilograms by height in meters squared, can be used as an indication of body habitus. It was categorized into underweight (<18.5 kg/m^2), normal (18.5 to <25 kg/m^2), overweight (25 to <30 kg/m^2) and obese (≥ 30 kg/m^2) (WHO 1995).

i. Univariate Analysis

<u>Aim 1a: Cross-sectional</u>

Initial analysis described the frequency and distribution of television watching with each outcome. Television watching was described first, as a categorical variable using the original

5- level Likert scale and second, categorized into three levels: low, medium, and high exposure. Participants who watched television “never” or “seldom” were identified as low exposure. Participants who reported “sometimes” watching were categorized into the medium exposure group, and participants watching “often” or “very often” were assigned to the high exposure category. The choice to categorize television watching into these groups was guided by information from the average hours reported by Nielsen Media Research and the ancillary data (Television At A Glance 2005) (Appendix B). Nielsen Media Research, the television ratings company collects data on television viewing audiences, reported that the average television exposure for men and women over 18 years of age was between four and six hours per day (Nielsen Media Research 2006; Television At A Glance 2005). The ancillary data from Belgium also indicated that the mean television hours in the “often” and “very often” categories of the Baecke (high exposure) were around four and five respectively (Appendix B). For the purposes of this study, individuals assigned to “low” exposure represented people who were exposed to television at a level less than what is considered normal or average.

ii. Bivariate Analysis

Aim 1a: Cross-sectional

The crude associations between television watching at baseline and each of the outcomes at baseline were examined using contingency tables and the appropriate measures of association (e.g., Mantel Haenszel, etc). Covariates of interest were also examined separately with the exposure and each outcome of interest. This information helped identify meaningful cut-points for categorical variables.

Aim 1b: Longitudinal

Because we had already examined the associations between television watching and the covariates, only crude associations between covariates and values of the outcome at the third clinic visit were explored for this analysis. There were no significant differences between the cross-sectional and longitudinal bivariate analyses.

iii. Multivariable Analysis

Aim 1a: Cross-sectional

Linear (continuous outcomes) and logistic (categorical) regression analyses were used to estimate the cross-sectional associations between our main exposure and each outcome. Linear models provided an estimate of the means for each outcome by level of television exposure. Models were also explored using television watching exposure as a five-level Likert variable, as well as a three level categorical variable (low, medium, high).

Multivariable analysis included variables for the different covariates and confounders of interest. Categorical variables were included as indicator variables. Additional models included controlling for the 'opposite' outcomes. For example, dietary outcomes were examined with and without controlling for physical activity. Because the Willett FFQ has been shown to be more valid with energy adjustment, dietary outcomes were explored in models simultaneously adjusted for total calories (Subar et al. 2001b).

Aim 1b: Longitudinal

For the second objective, linear and logistic regression were also used to estimate the measure of six-year association, or risk between television watching and each outcome at the third clinic visit. Models were run with the same television exposure variables as the cross-sectional analysis.

The only significant difference between the cross-sectional and longitudinal analyses was the outcome variable and interpretation of the beta parameter. In the longitudinal analyses each parameter estimate represents increasing *risk* (estimated by odds ratio in logistic model) of the outcome at the third clinic visit (rather than prevalence). Additionally, the outcomes at baseline were included in the longitudinal model which was advantageous in helping to address temporality of the exposure and outcome relationship.

Multivariable Linear Regression

Multivariable linear regression was performed for both cross-sectional and longitudinal analysis. The continuous outcomes in each model followed the same general formula:

$$y = \alpha + \beta_1 X_1 + \gamma_k V_k + e$$

where the parameter β_1 indicates the coefficient of the main exposure, the parameter γ_k indicates the coefficient of all covariates or potential confounders. A number of models were run and each separate model had a unique intercept and regression parameters.

For example, a model of the association between television watching and the number of servings of fruits and vegetables was:

Prevalence (servings fruits and vegetables) = $\alpha + \beta_1$(television) + $\gamma_k V_k + e$

where :

α = servings per day of fruits and vegetables in participants with all referent levels of the independent variables

β_1 = the estimated average increase in servings per day of fruits and vegetables with an increase in television exposure, while all other covariates are at referent levels

γ_k = represents the coefficients of all potential covariates or confounders

Multivariable Logistic Regression

For dichotomous outcomes, each model followed the same general formula:

$$\ln[p/(1-p)] = \alpha + \beta_1 E_1 + \gamma_k V_k$$

where the parameter β_1 indicates the coefficient of the main exposure, the parameter γ_k indicates the coefficient of potential confounders. A number of models were explored and each separate model had a unique intercept and regression parameters. Outcomes were dichotomized whenever possible. For example, a model of the association between television and the physical activity outcome (dichotomized) was:

$$\ln[P(\text{inactivity} \mid \text{television})] = \alpha + \beta_1(\text{television}) + \gamma_k V_k$$

where:

α = intercept, background log odds of being inactive for all referent levels of the covariates

β_1 = expected increase in the log odds of inactivity associated with an increase in television exposure when all other covariates are fixed

γ_k = represents the coefficients of all potential covariates or confounders

Assessment of Confounding

The bivariate analyses helped guide assessment for confounding with an *a priori* list of important covariates. In order for a variable to be a confounder it must be associated with both the exposure of interest (television) and the outcome of interest (diet or physical activity). This variable may not be causal intermediate and lie on the pathway between exposure and outcome.

A covariate was considered a potential confounder if there was 1) evidence from the literature, 2) relationship in the conceptual model, or 3) indicated by the bivariate analysis. To test for the impact of the potential confounder between exposure and outcome, each model was analyzed with and without the potential confounder. When comparing the beta coefficients of the main exposure between the crude and adjusted models, meaningful differences of 10% or more indicated that the additional covariate was a confounder.

Additional Models

Because retirement was previously associated with change in leisure time activities, additional modeling explored these relationships while controlling for retirement status. The participants were stratified by retirement status (e.g., fully-retired, partially-retired, retired during follow-up).

C. Aim 2 Analyses from the WHI Study

The second aim consists of two distinct parts. The first part assessed the test-rest reliability of the WHI physical activity questionnaire. For this aim we used the

Observational Study's Measurement and Precision Study. The second part of this aim examined the independent effect of intensity, frequency, and duration of walking on CHD morbidity and mortality. The entire WHI observation cohort sample was included as in the second part of this analysis.

The WHI is a multicenter study involving over 161,000 postmenopausal women aged 50-79 years at baseline and living throughout the United States. The WHI is largely comprised of three different studies: 1) clinical trial, 2) observational cohort, and 3) community prevention study. For the purposes of this dissertation, only data from the Measurement and Precision Study and the observational cohort were examined.

The WHI observational cohort was designed to examine major causes of illness and death in postmenopausal women and to be ethnically and racially diverse. Between 1994 and 1998, over 93,000 women were enrolled at one of 40 clinic centers across the United States. Women were recruited largely through mass mailings. One priority of recruitment was to enroll a large number of minority women. To achieve this goal, ten centers were chosen as minority recruitment sites with an average of 40% minority enrollment (Hays et al. 2003).

Observational study participants were primarily women who were ineligible or unwilling to enter the clinical trial, although some were recruited directly into the study. Eligibility for enrollment into the OS included the intention to reside in the area for at least three years and free from any major medical condition which would impact survival within three years of study entry, as well as no reported mental illness, dementia, alcoholism, or drug dependency. Consent was obtained through materials approved by institutional review boards at each center.

At the first screening or clinic visit, demographic, medical history, and risk exposure data from the participants were collected by standardized questionnaires. During the clinic visit, physical and clinical measurements (anthropometrics, blood pressure, etc) were recorded by certified staff members. Prospective exposure data and medical histories were obtained annually through mailed questionnaires.

Measurement and Precision Study Participants

A sample of women enrolled in the observational study were recruited to participate in a substudy to assess the reliability of the self-administered questionnaires. Between October 1996 and June 1997, a predefined number of the participants were randomly selected and invited to join the reliability study. Women were stratified by center, age, and ethnicity. Recruitment continued until 1,000 women had completed the study. Each clinic was randomly assigned to repeat a group of four of the original eight questionnaires. This meant that approximately 500 women repeated each questionnaire, including the physical activity questionnaire. The women repeated the questionnaire on average three months apart (range 8-15 weeks).

1. Measurement of Physical Activity

In 1996, a special meeting was held under a combined National Institutes of Health (NIH)/CDC WHI funding initiative to discuss issues related to measuring physical activity in women. One conclusion from the meeting was that current physical activity questionnaires were not specific to the activities performed by women, especially midlife, older, or minority women (Masse et al. 1998). One reason was because many of the physical activity questionnaires used in epidemiologic studies were primarily developed for white men. These questionnaires often emphasize male-oriented activities and use words like “leisure”, “free”, or “spare” time, which are difficult to operationalize for many women (Henderson et al. 2003; Masse et al. 1998; Tudor-Locke et al. 2003). Women are often engaged in a large number of diverse activities and perform them simultaneously or intermittently which makes measurement challenging (Tudor-Locke et al. 2001). It is therefore very important to identify instruments that are sensitive to the lifestyle and patterns of activity in women, but are also culturally relevant and user-friendly (Masse et al. 1998; Sternfeld et al. 1999).

The WHI investigators adapted a well-known physical activity questionnaire into one that was designed to better capture the activity level of the WHI population; postmenopausal women, aged 50-79 years (Siscovick, personal communication, 2006). To date, at least nine WHI studies have published findings using this physical activity questionnaire (Chlebowski et al. 2004; Evenson et al. 2002b; Hsia et al. 2004; Hsia et al. 2005; Manson et al. 2002; McTiernan et al. 2003; Shikany et al. 2003; Vogt et al. 2002; Wassertheil-Smoller et al. 2004). The questionnaire was self-administered at enrollment (1994-98) and ascertains information on usual activity. Full details of the questionnaire and its coding are included in Appendix D**.**

The physical activity information was organized into vigorous, moderate, mild, walking, household, and yard activity. Self-report of recreational activity was stratified by intensity, and included questions on frequency and duration. Household activity included hours per week of heavy indoor household chores, as well as the number of months and hours per week of yardwork. Since walking is such an important activity for this age group, participants also reported frequency, usual pace, and usual duration of walking outside the home.

Most activity measures from the WHI questionnaire can be quantified continuously as energy expenditure using the different summary variables (by type of activity: vigorous, moderate, mild and walking) or as total recreational energy expenditure (Manson et al. 2002). These variables have been quantified in MET-hours per week to estimate energy expenditure. The estimated MET level for each activity is based on the intensity from the physical activity compendium (Ainsworth et al. 2000).

Vigorous Physical Activity

To assess vigorous, or strenuous, physical activity participants were asked (excluding walking) to think about how often each week participated in "strenuous or very hard exercise (you work up a sweat an your heart beats fast.) [f]or example, aerobics, aerobic dancing, jogging, tennis, swimming laps". Reponses were collected using two questions on the components of frequency and duration. The first response quantifying frequency had five possible categories ranging from none to five or more days per week. Duration was collected by asking "[h]ow long do you usually exercise like this at one time" and has four possible categories (<20 minutes to 1 hour or more).

Vigorous activity exposure can be used as total time per week spent engaging in vigorous physical activity (minutes) or with a summary variable estimating energy expenditure from vigorous activities (MET-hours per week). To create the summary variable for vigorous activity the three physical activity components (intensity, duration, frequency) were multiplied together to estimate total energy expenditure. The components of frequency and duration are assigned from the previously described questions and intensity was assumed to be a constant value of 7.0 METs.

Summary estimate vigorous physical activity = [Frequency of activity per week * minutes per session * 7.0 kcal/kg*hour] / (60 min/hour)

<u>Moderate Physical Activity</u>

To assess moderate physical activity participants were asked (excluding walking) to think about how often each week participated in “moderate exercise (not exhausting), [f]or example, biking outdoors, using an exercise machine, calisthenics, easy swimming, popular or folk dancing”. Similar to vigorous physical activity, the moderate activity exposure was quantified from two questions on frequency, and duration with the same responses available for each component.

Moderate activity can also be used as total time per week spent engaging in moderate physical activity (minutes) or as a summary variable estimating energy expenditure (MET-hours per week). The summary variable for moderate activity was calculated by applying the same method used for vigorous activity. The components of frequency and duration were directly applied from the two questionnaire items and intensity is assumed to be a constant value of 5.0 METs.

Summary estimate moderate physical activity = [Frequency of activity per week * minutes per session * 5.0 METs] / (60 min/hour)

Mild Physical Activity

To assess mild physical activity participants were asked (excluding walking) to think about how often each week they participated in "mild exercise [f]or example, slow dancing, bowling, golf". Like moderate and vigorous physical activity, mild activity is quantified from two questions on frequency, and duration with the same responses available under each component.

The summary variable for mild activity is calculated by applying the same method as before. The components of frequency and duration were directly estimated from the two questions and intensity is assumed to be a constant value of 3.0 kcal/kg/hr.

Summary estimate mild physical activity = [Frequency of activity per week * minutes per session * 3.0 METs] / (60 min/hour)

Walking Physical Activity

The questionnaire included three questions about the participants walking activity. The first question asked participants to "[t]hink about walking you do outside of the home", and how often they walked "more than 10 minutes without stopping". This question, quantifying frequency, had five responses ranging from rarely or never, to seven or more times per week. The last two walking questions asked about typical duration (usual minutes walked), and usual intensity, or speed walked. Four categories from <20 minutes to 1 hour or more were included for duration, and five for intensity from casual strolling (<2 mph) to very fast (>4 mph).

Summary estimate walking = [(walks per week)*(minutes per walk)* (MET for intensity)] / (60 min/hr)

Household and Sedentary Activity

A number of daily activities that also contribute to total activity, such as household chores and gardening, were assessed in two separate questions. The first question asked the participants to estimate "how many hours each week do you usually spend doing heavy (strenuous) indoor household chores such as scrubbing floors, sweeping or vacuuming?". Five responses were offered from less than one hour, to greater than ten hours. This question was used to estimate total hours per week of heavy indoor chores, or by applying a constant estimate of energy expenditure can be used to estimate total energy expenditure (MET-hours per week) from heavy indoor chores.

The second question had two parts, and to answer it the women first had to estimate "how may months during the year to do you usually do things in the yard, such as mowing, raking, gardening or shoveling snow?" The second part to this question then asked the women, "when you do these things in the yard, how many hours each week do you do them?". Responses to the first question had five categories from less than 1 month to more than 10 months. Responses to the second question also had five categories, from less than 1 hour to more than 10 hours each week. Similar to indoor chores these two questions were combined to estimate total hours per week of yard work and when multiplied by a similar constant can estimate total energy expenditure (MET-hours per week) from yard work.

Two separate questions collected information on the amount of time "during a usual day and night" that the women spent sitting (including eating, driving, watching television) and lying down (including sleeping, watching television). Both questions had eight responses available from less than four hours to 16 hours or more.

The summary measures from the questionnaire can be combined in several ways to estimate whether or not a person meets the current physical activity recommendations of 30 minutes or more of moderate physical activity on most days of the week (Pate et al. 1995; Surgeon General 1996b). One way is to dichotomize participants using the cut-point of 150 minutes per week of moderate to vigorous physical activity. A second way is to use total MET-hours week, where the recommendations correspond to between 7.5 and 15.0 MET-hours per week. Lastly, an estimate of kilocalories burned per week can also be estimated, where a cut-point of 1000 kilocalories per week is approximately meeting the recommendations.

Reliability and Validity

The WHI physical activity questionnaire has not yet been fully explored with regard to reliability or validity. Aime2a examined the test-retest reliability of the questionnaire.

2. CHD Morbidity and Mortality

The outcomes for the second part of this aim were newly diagnosed, or incident CHD events. These events were defined as definite or probable myocardial infarction (MI) and incident coronary revascularization procedures. Elements used to help define the CHD events included all available electrocardiograms, cardiac enzyme and /or troponin levels, medical history, and death certificate. Using these elements, an algorithm was created at the WHI coordinating center to categorize MI events as either “definite “ or “probable”. Revascularization procedures consisted of percutanerous transluminal coronary angioplasty (PTCA), or coronary artery bypass graft (CABG), and were confirmed with medical record abstraction.

Each outcome was identified from annual follow-up questionnaires, or event reports (participant or third party) and confirmed by a review of medical records. Participants were contacted annually and completed a standardized questionnaire either self-completed, over the phone, or in-person during an interview. Medical records (discharge and relevant diagnostic/lab tests) were collected for each event.

Excluded from the analysis were other definitions of CHD, such as angina pectoris. Symptoms or events such as angina pectoris can be subjective depending on the severity of symptoms or the perception of individual and treating physician. They are more prone to misclassification than harder endpoints (which are diagnostically verified).

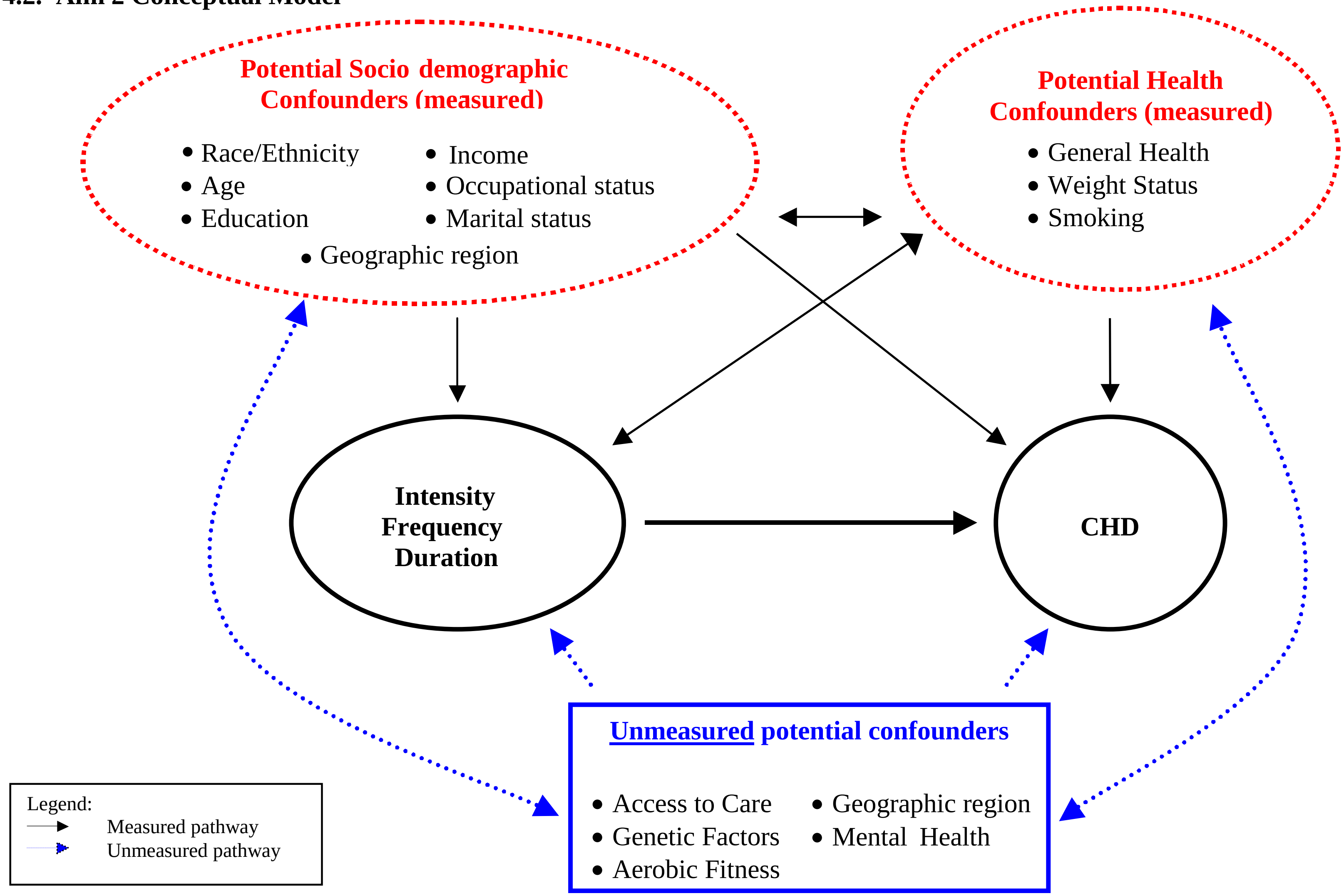
Reliability and Validity of Outcomes Measurement

Adjudication of events occurred at two levels. First, the local Clinical Center physician reviewed the documents and assigned a diagnosis (Curb et al. 2003). Second, events were centrally reviewed at the Clinical Coordinating Center (Curb et al. 2003). All Clinical Center staff responsible for outcomes were centrally trained on case documentation (Curb et al. 2003). Regional conference calls and a national workshop were conducted for re-training and problem solving. The adjudicators overseeing the event documentation completed a formal training and conferred together throughout the follow-up period. This training reviewed the study protocol, policies, and procedures. Agreement between self-report of events and local adjudicator diagnosis was generally good, for example myocardial infarction had a 70% confirmation rate (Curb et al. 2003). Good agreement between local and central adjudication was also reported for all outcomes used.

Covariates

A number of covariates were selected for the analysis based on known and suspected relationships with the exposure and outcomes. The conceptual model developed for aims 2b-2d helped identify important confounders of interest (see **Figure 4.2**). Available covariates and their methods of data collection are described in the analysis plan.

Figure 4.2. Aim 2 Conceptual Model



3. Analysis Plan - Aim 2

For aim 2a we examined the test-retest reliability of the WHI physical activity questionnaire. Data from the Measurement and Precision Study were analyzed for this aim. Aims 2b-2d explored the independent risks of CHD associated with walking intensity, duration, and frequency. We attempted to respond to shortcomings identified from the literature on this topic using appropriate statistical methods. Specifically, we examined each component independently while adjusting for recreational physical activity energy expenditure, through energy adjustment.

Data Reduction

Women who were missing physical activity data, or information on important confounders, were excluded from the analysis. Additionally, women who were eligible for enrollment but reported poor general health or ambulatory difficulties at baseline were excluded from the analysis. In post-hoc analyses an "early mortality exclusion" was also applied, where we excluded women who died within the first year of follow-up.

Covariates

Body mass index was collected during the baseline clinic visit and categorized into underweight, normal, overweight, and obese. All demographic variables were self-reported by the participants at baseline and obtained using standardized questionnaires. Participants could self-identify a single race or ethnicity from six possible categories: American Indian, Asian/Pacific Islander, Black, Hispanic, White, or Unknown. Family income was also reported and categorized into six levels from <$10,000 per year to >$75,000. Occupation was categorized into four broad types: managerial/professional, technical/sales/administration, service/labor and homemaker. Smoking was defined as current, former, or never smoker. Marital status was self-reported and categorized into currently married or in a marriage-like relationship, divorced or separated, widowed, and never married. Education was divided into four categories including less than high school, high school/GED, some college, and college degree. Region of the country the participant lived in was also used as a covariate and defined as northeast, south, midwest, and west. Lastly, a single question asked participants to report their perceived health status by asking "[I]n general, would you say your health is excellent, very good, good, fair, or poor?"

i. Aim 2a. Test-Retest Reliability of the WHI Physical Activity Questionnaire

The first objective of the WHI analysis was to examine the reliability of the individual items and summary physical activity variables using the Measurement and Precision Study. The first assessment involved all continuous variables, and summary estimates of energy expenditure. To explore these continuous variables, we used the intraclass correlation coefficient (ICC) from an analysis of variance (ANOVA) model. Secondly, kappa statistics or weighted kappa statistics were calculated for categorical variables. These categorical questions were directly taken from the questionnaire, or created by categorizing the summary variables.

Many of the summary variables for physical activity were quantified in continuous MET-hours per week of energy expenditure. The estimated metabolic energy required for each activity (or MET level) was derived from the intensity of the reported activity and the compendium of physical activities (Ainsworth et al. 2000). The summary variables of physical activity have been used as important confounders or covariates in WHI analyses (Chlebowski et al. 2004; Hsia et al. 2005). Each item from the questionnaire was analyzed independently, including the individual components (intensity, duration, frequency) which derive the summary variables. We also explored differences in reliability by race/ethnicity, age, time between test and retest, and level of physical activity.

ii. Aim 2b-2d. Walking Intensity, Frequency, Duration, and Risk of CHD

Before embarking on the aims for the second part of aim 2, descriptive and univariate analyses were performed on the entire observational cohort. Information gathered during this step helped to categorize various exposure levels. Bivariate associations were examined between the exposures (components of walking), the outcome (CHD), and covariates of interest.

In the second step of the analysis, the associations between walking and its components were explored using Kaplan-Meier curves. Kaplan-Meier curves were produced for stratified analyses and the unadjusted categorical estimates. Multivariable models were then created using Cox Proportional Hazards Regression to estimate hazard ratios and control for important covariates. The first of these multivariate model examined the relationship between total METs from walking and risk of CHD. We then applied similar Cox models to estimate the separate associations of each individual walking component and risk of CHD.

We explored two modeling strategies to adjust for physical activity energy expenditure. In the first approach, we assessed each walking component (i.e., intensity, frequency, duration) separately in a standard multivariable model. These models included a continuous term for recreational physical activity energy expenditure to control for volume of activity.

Because of the correlations between our exposure (or component) and the recreational energy expenditure variable, we further explored an alternative model using the “nutrient” residual method common in nutritional epidemiology. This method is often applied when an effect of a specific nutrient requires adjustment for total caloric intake (Willet 1998). To do this, we created a “residual” by regressing each activity component (intensity, frequency, duration) as the dependent variable in separate models with total physical activity energy expenditure as the independent variable (Willet 1998). This provided a component estimate that was “energy-adjusted” and uncorrelated with physical activity energy expenditure. We then used this “residualized” (or energy adjusted) component as our main exposure in the Cox model.

Proportional hazards assumptions were tested by examining the plots of the log - log survival curves for each covariate. The data were also fit with an exposure by time interaction term and tested in the model. In this data, we determined the proportional hazards assumption was not violated and the interaction term was dropped from the models. Data were right-censored and survival time was defined as time from baseline questionnaire until date of death or confirmed event or until the end of the study period (September 12, 2005). The appropriate statistical correction (Efron approximation) was used to account for tied events.

Separate models were used for each component or exposure. In each model the component was quantified as multiple categorical variables using indicator coding. The lowest level of physical activity was used as the reference category in each model. An important aspect of the modeling strategy was the control of recreational physical activity energy expenditure. In order to successfully isolate the independent effect of each walking component, recreational physical activity energy expenditure must be controlled for to prevent confounding.

All other covariates were taken from baseline and categorized at meaningful cut-points using information from the univariate analysis. All covariates were considered time-independent, and were modeled using indicator or dummy variables. Additionally, use of indicator variables helps to relax the assumption that effects are linear in the log hazard.

Each model followed the same general formula:

$$\text{Log Hazard } h(t) = h_o(t) + e^{\beta_k X_k + \gamma_k V_k}$$

Where the parameter β_k indicates the coefficient for the walking exposure and the parameter γ indicates the coefficient for potential confounders. For example:

$$\text{Log Hazard (CHD)} = h_o(t) + e^{\beta 1(\text{walking}) + \beta 2(\text{recreational energy expenditure}) + \gamma k V k}$$

<u>Aim 2b – Intensity</u>

Aim 2b examined the "intensity" of walking, measured by the speed or pace at which the walk was performed. In order to establish the independent effect of the component, two variables were included in the standard multivariable model. The first variable was the estimate of walking intensity. This was collected from the specific question "[w]hat is your usual speed?" and had four possible responses (casual strolling to very fast). We explored using the exposure as a continuous variable, as well as using indicator variables for each level of intensity. The second variable in the model was the "control" variable that estimated total recreational physical activity energy expenditure (MET-hours/week). Both variables were simultaneously entered into the model.

Using the residual approach to energy adjustment only one walking term was included in the model. The "residualized" value of the walking intensity was the main exposure of interest. Because this variable was already "energy adjusted", a second term for physical activity energy expenditure was not required.

Standard Multivariable Model

Log Hazard (CHD) = $h_o(t)$ + $e^{\beta 1(\text{walking intensity}) + \beta 2\ (\text{recreational physical activity energy expenditure}) + \gamma k V k}$

Where:

$h_o(t)$ = the baseline hazard for CHD as a function of time

β_1 = the log hazard for CHD associated with increasing walking intensity when controlled for volume of recreational physical activity and all potential covariates

β_2 = the log hazard for CHD associated with a one-unit increase in recreational physical activity energy expenditure after controlling for walking intensity and all potential covariates.

Residual Model

Log Hazard (CHD) = $h_o(t)$ + $e^{\beta 1(\text{residual of intensity}) + \gamma k V k}$

Where:

$h_o(t)$ = the baseline hazard for CHD as a function of time

β_1 = the log hazard for CHD associated with increasing the residual of walking intensity (or increase in walking intensity that is unexplained by energy expenditure), when controlled for all potential covariates

Aim 2c- Frequency

Aim 2c examined the relative importance of frequency of walking. The strategies for this model were almost the same as Aim 2b, but instead of intensity the first variable term was frequency. This was estimated from the specific question "[h]ow often each week (7 days) do you usually do the exercises below? (none to 5 days or more)". The second variable term was recreational physical activity energy expenditure. Interpretation of the model and beta parameters were the same as those in Aim 2b.

Aim 2d– Duration

Aim 2d examined the importance of the duration of the walk. The strategies for this model were the same as Aim 2b and 2c, but instead of intensity, or frequency the first variable term was the duration variable. This was estimated from the specific question "[h]ow long do you usually exercise like this at one time" and had four possible responses (<20 minutes to 1 hour or more). The second variable term in the model was recreational physical activity energy expenditure. Interpretation of the model and beta parameters was the same as those in the intensity example.

D. Strengths and Limitations

1. ARIC Limitations and Strengths

Limitations

One shortcoming in the ARIC proposal is the imperfect measure of television watching. At this time there is no objective way to measure television viewing in adults. Instead, we used a single, categorical question of television watching to estimate our main exposure. Because the exposure was self-reported and not validated, we are unsure if participants have adequately quantified their television watching. This may lead to exposure misclassification which could affect the results of the study.

There are several factors limiting the outcomes examined in this proposal. First, the validity and reliability of the Baecke physical activity questionnaire has never been examined within the ARIC cohort. Even when one attempts to quantify error in a physical activity questionnaire, there is no agreement on the gold standard for a validation study. However, questionnaires like the Baecke are capable of describing a number of domains of activity, including light activities. The Baecke physical activity questionnaire has also shown consistent performance over the last two decades in several populations (Appendix A).

Second, dietary food frequency data is also subject to misclassification (Byers 2001). This limitation is unavoidable until better tools for measuring diet are developed. Dietary outcome tools must be accurate in the field, yet cannot overly burden the participant. Food frequency questionnaires are one of the best instruments for gathering information on dietary behaviors in large cohort studies (Subar et al. 2001b). A popular questionnaire for this purpose is the Willett FFQ used in ARIC. Researchers have used it in a number of populations and quantified its measurement properties multiple times (Eck et al. 1996; Subar et al. 2001b). We attempted to minimize the amount of misclassification by applying the appropriate analysis (ranking, quartiles) (Michels et al. 2005).

Misclassification may also occur through other types of information bias, namely, recall and reporting bias. Recall bias occurs when participants inaccurately recall or remember their activity. Some types of activity are more difficult to remember, especially activities of light or moderate intensity, and activities that are unplanned or performed simultaneously. Reporting bias may occur if a person has certain perceptions, beliefs, or judgments about activity and, as a result, these feelings can influence their responses.

Lastly, the ARIC population is by no means representative of the adult population residing in the United States. Most large cohorts, including ARIC lose participants during follow-up. The participants who remain in the study population may not be representative of the entire study. Therefore any associations must be carefully applied outside of the existing sample.

<u>Strengths</u>

Television watching is the most prevalent and popular leisure activity for Americans, yet the associations of television watching with other behavioral risk factors are unknown. There have been a limited number of publications examining television behavior in adults. The ARIC portion of this proposal is the first analysis of television watching behavior and its associations with diet and physical activity in a large population-based cohort. Results from this study can help generate further hypotheses and will hopefully call attention to the importance of sedentary activity as an independent risk factor.

Although our television measure may be imperfect, not all physical activity questionnaires have the ability to single out television or sedentary behaviors. The ARIC Study represents a unique opportunity to do this using a well-quantified physical activity tool. We also found ancillary data which helped guide exposure categorization. The sample size available for this analysis was quite large and we had adequate power to detect potential associations.

2. WHI Limitations and Strengths

Limitations

Physical activity assessment in epidemiologic research presents several challenges. It is difficult to implement objective monitoring of physical activity in large cohort studies. Self-report questionnaires remain a cost-effective way of assessing usual activity in studies such as the WHI. However, these questionnaires often result in imperfect assessment of physical activity and are associated with recall and reporting biases.

Although the authors of the WHI questionnaire tailored it for this particular population, the measurement error in the tool has not yet been quantified. Aim 2a measured one potential source of error by examining test-retest reliability of the questionnaire. However, no measure of validity is available which can assess the accuracy of the questionnaire compared to a gold standard. This remains a limitation of the data and is addressed in the discussions of the resulting papers.

Another shortcoming of the WHI physical activity questionnaire tool is that it underestimates the activity of women who exercise twice per day at the same intensity. Women were asked how many “days per week” they exercised at a certain intensity, and how long each session lasted. When asked in this way, the questionnaire allows for only one session per day, at each intensity. As a result, the women who exercise more than once a day (other than walking) have their total activity underestimated. While this limitation is unavoidable, we do not feel that the results were significantly affected for two reasons. First, walking is the most popular activity in this population and was assessed such that it is unlikely to be underestimated (number of walks per week). Secondly, the proportion of women who exercised more than once a day, at either vigorous, or moderate intensity was very small. Even though the total volume of recreational physical activity may be underestimated, it is unlikely that women are misclassified regarding their activity levels. Any woman reporting consistent daily activity was identified as highly active regardless of this underestimation.

This study attempted to push forward methods for control of energy expenditure while examining the relative contributions of walking intensity, frequency, and duration. However, controlling for energy expenditure in physical activity research has rarely been attempted. Several limitations must be considered. First, any estimate of energy expenditure available in this data is not a true estimate of “total volume”. Several domains of physical activity are not captured by this questionnaire (e.g., occupational, child/elder care, transportation, etc). Second, individual variation in energy expenditure can be significant and is not estimated in the data. Lastly, the components of walking and any control variable of energy expenditure are not mutually exclusive.

Regarding the outcome used for this study, we minimized potential errors or limitations by using clear, objective endpoints. Many studies of physical activity and CHD use a broad definition of events. By restricting our event definition to definite or probable myocardial infarction (MI) and revascularization, we eliminate some of the potential misclassification. The adjudication procedures from the WHI coordinating center also helps to avoid outcome misclassification. Several sources of records were used to verify each event and adjudication occurred at multiple levels. We anticipate that the number of misclassified events were minimal and non-differential with regards to exposure. Therefore, it is unlikely this limitation significantly affects the results of the study.

Another limitation of assessing the effect of any physical activity, such as walking, on events is known as “reverse causation”. This bias arises when participants experience undetected or underlying illness and/or disabilities which lowers their physical activity level and negatively influences morbidity or mortality. We attempted to address this issue in a three ways. First, we excluded participants who reported that they were in “poor” general health, and controlled for other important health confounders (e.g., general health, smoking). Second, we excluded women who reported difficulty walking one block. Lastly, we explored additional analyses controlling for physical and mental functioning. We cannot however control for the inability or improper control of confounders.

The WHI was designed to study the lifestyles of post-menopausal women residing in the US. However, many of the women who took part in the observational cohort were either ineligible or unwilling to participate in the clinical trial (Langer et al. 2003). As such, they are not representative of the target population.

Strengths

The WHI study is quite possibly the most influential cohort of the past decade. Two very positive aspects of the study design are its size and diversity, both of which are strengths. Another strength is the quality and quantity of CHD events available for analysis. Although regrettable, the numbers of CHD events are quite large and lend adequate power to the analyses. The large minority population included in the study is another beneficial characteristic of this study.

The physical activity questionnaire was tailored for the purposes of this cohort. Although this was not a specific goal, it was designed in an optimal way to assess the intensity, frequency, and duration of walking. This was is the first study to examine all three components of walking and disease risk in the same cohort of individuals. The analyses and methods from this dissertation respond directly to limitations outlined at the 2000 Ontario, Canada symposium (Blair et al. 2001; Erlichman et al. 2002; Hardman 2001; Kesaniemi et al. 2001; Kohl 2001; Lee & Skerrett 2001b; Oja 2001)

E. IRB/ Human Subjects

Approval for this project was obtained through the Institutional Review Board of the University of North Carolina School of Public Health. No additional contact was made with study participants. All analyses were secondary data analysis. The ARIC and WHI study coordinators at each clinic site obtained approval for data collection.

V. Television Watching, Physical Activity, and Diet: The Atherosclerosis Risk in Communities (ARIC) Study

A. ABSTRACT

Purpose Television watching is the most common leisure activity in the US. Few studies of adults have described the relationship between television watching and health behaviors, such as physical activity and diet. **Methods** Extant data from the Atherosclerosis Risk in Communities Study were used to assess the association of television watching with physical activity and diet among 12,678 adults at baseline (1986-89) and six years later. Dietary intake and physical activity were collected using validated questionnaires. Adults were categorized into high television watching exposure (often or very often, n=4712), medium exposure (sometimes n=5932), or low exposure (never or seldom, n=2095). Multivariable linear and logistic regression models were used to examine the associations between television watching, physical activity, and diet. Models were adjusted for gender, age, race-center, smoking, education, health status, and body mass index. **Results** Relative to participants who watched television never or seldom, those with high television exposure were more likely to be inactive and consume fewer fruits and vegetables. High television exposure was also associated with higher fat and energy intake and greater servings of salty snacks, sweets, and sweetened drinks. **Conclusions** These results support the hypothesis that time spent watching television is associated with deleterious effects on physical activity and dietary behaviors.

B. INTRODUCTION

Over the last half century, television watching has become the most popular leisure activity in the United States (Robinson et al. 2005a; Robinson et al. 2005b). American adults watch an average of four to five hours of television each day (Television At A Glance 2005). The increase in the hours of television watched in the United States has paralleled the increase in obesity over the last two decades (Hu et al. 2003; Nielsen Media Research 2006). Despite the prevalence of this sedentary behavior, there has been little research on the relationship between television watching, physical activity, and dietary behaviors in adults.

A handful of cross-sectional studies have reported low, unadjusted correlations (-0.03 to -0.11) between television watching and physical activity (Dunstan et al. 2004a; FitzGerald et al. 1997; Hu et al. 2001; Hu et al. 2003). A more recent study using pedometers to measure physical activity found a negative association between daily television watching and number of steps per day (Bennett et al. 2006). Although few studies have studied television and physical activity, the relationship between television watching and diet has been more frequently examined. In both the Nurses Health and Men's Health Professional cohort studies, higher television exposure was cross-sectionally associated with smoking, drinking alcohol, diets higher in saturated fats, greater servings of red and processed meat, french fries, refined grain, snacks, sweets or desserts, and fewer servings of fish, fruit, vegetables, and whole grains (Hu et al. 2001; Hu et al. 2003). Neither of these cohort studies examined the relationships prospectively.

We know of only two prospective studies of adults that examined the association of television exposure with diet and physical activity. A small study conducted over one year found no significant associations between television and exercise in both men and women, but observed a small increase in energy intake among the women (Jeffery & French 1998). Among the participants of the 1958 British Cohort study, television exposure in adolescence and young adulthood (ages, 11, 16 and 32) was not correlated with subsequent physical activity (ages 33 – 42) and had low to moderate correlations with diet (Parsons et al. 2006). The British study did not control for important confounding factors such as race, age, education, weight, or health status.

Because of the dearth of information on the relationships between television exposure, physical activity, and diet, we used a large cohort of adults to explore these associations. More specifically, we examined the associations of television exposure with three domains of physical activity: sport, leisure, and work. We also examined the associations of television with dietary choices including total energy intake, amount of dietary fat, saturated fat, and number of servings of fruits and vegetables, sweets, salty snacks, and sweetened beverages. These relationships were explored cross-sectionally and prospectively (over six years) in the Atherosclerosis Risk in Communities (ARIC) cohort of African American and white men and women aged 45 to 64 years at baseline.

C. MATERIALS AND METHODS

Study population

The ARIC study was designed to study risk factors for cardiovascular disease, morbidity, and mortality. Participants are from four US communities: Washington County, Maryland; northwest suburbs of Minneapolis, Minnesota; Jackson, Mississippi; and Forsyth County, North Carolina. A probability sample of 16,000 men and women ages 45-64 years was recruited from these sites, from which 15,792 adults completed the first clinic visit. Between 1986 and 1989, participants underwent a baseline clinic visit with a physical examination and testing to provide information on cardiovascular risk factors. All participants were also interviewed by trained personnel about their medical history, educational attainment, health status, usual diet, and physical activity. Clinic visits were repeated at approximately three-year intervals. Further details on the ARIC cohort are available elsewhere (Atherosclerosis Risk in Communities Investigators 1989; Jackson et al. 1996).

In order to examine the associations between television, diet, and physical activity, we excluded participants who did not answer the television question at baseline (n=32) or were missing important covariates (n=83). Additionally, in order to control for the effect of race and center, individuals other than white or African American and all non-white participants from Minneapolis and Washington were excluded (n=103). Excluded from the prospective analysis were those individuals who died (n=722) or did not return to the third clinic visit (n=2,125), as well as those missing information on dietary and physical activity outcomes at the third clinic visit (n=49). Final sample sizes were 15,574 for the cross-sectional analysis and 12,678 for the prospective analysis, the latter referred to as "the cohort".

Television and physical activity measurement

The Baecke physical activity questionnaire was designed to study habitual physical activity and distinguish between different dimensions of physical activity using semi-continuous indices of sport, leisure, and work (Baecke et al. 1982). The questionnaire was interviewer administered at the baseline clinic visit (1986-1989) and at the third clinic visit (1993-1995). The questionnaire included an item on television watching as part of the leisure-time physical activity index. This subjective question of television exposure asked: "During your leisure time do you watch television?" and allowed five responses: never, seldom, sometimes, often, and very often. The answers were ranked on an ordinal scale from 1 (low) to 5 (high). From this ordinal scale, television watching was collapsed into three exposure levels: low (never/seldom), medium (sometimes), and high (often/very often). Because television watching is a component question of the leisure index, the remaining three questions on leisure activity were analyzed separately. These items included information on walking and biking. Two of these questions were ordinally scaled from the five responses (never, seldom, sometimes, often, and very often). The third question asked about minutes spent walking or biking to and from work or shopping, and respondents could answer < 5 minutes/week, 5-<15 minutes/week, 15-<30 minutes/week, 30-<45 minutes/week, or ≥45 minutes/week.

Sport and work physical activity were assessed with semi-continuous indices created from individual component questions. The sport index was derived from three close-ended questions (exercise/sport participation, sweating during leisure activities, and a subjective comparison of activity level based on peers), and open-ended questions that allowed participants to report up to four physical activities (including frequency, duration, and intensity of each activity). The work physical activity index comprised seven ordinally scaled questions on the frequency of sitting, standing, walking, lifting, sweating, fatigue after work, and comparison of work activity to peers. A final eighth work activity item ranked the participant's main occupation, based on industrial hygiene codes. Participants were also dichotomized into two groups as active or inactive (Evenson et al. 1999; Pereira et al. 1999). Using the reported activities from the sport index, active was defined as regular physical activity or participation in at least one hour per week of activity for 10 or more months of the year. Inactive was identified by less than one hour per week and/or less than 10 months per year.

The reliability and validity of the Baecke questionnaire have been examined in both European and American populations. Test-retest reliability correlations of total physical activity combined from the three indices range from 0.65 to 0.93 (Jacobs et al. 1993; Pols et al. 1995). Reliability correlations for the individual indices are as follows: the leisure index correlations (which include television) between r=0.60 and 0.80, sport index correlations between r=0.79 and 0.93, and work index correlations between r=0.74 and 0.95 (Baecke et al. 1982; Jacobs et al. 1993; Philippaerts et al. 2001). Relative validity of the Baecke has been assessed comparing it to physical activity diaries, maximum oxygen consumption, accelerometers, and doubly-labeled water (Cauley et al. 1987; Gretbeck & Montoye 1990; Jacobs et al. 1993; Mahoney & Freedson 1990; Miller et al. 1994; Philippaerts et al. 2001; Pols et al. 1995; Rauh et al. 1992; Richardson et al. 1995). In a doubly-labeled water study of three physical activity questionnaires, the Baecke had the highest agreement for total physical activity (Pearson's r=0.69) (Philippaerts et al. 1999).

Diet measurement

Usual dietary intake was collected at baseline and at the third clinic visit, using a semi-quantitative, interviewer-administered food frequency questionnaire. The ARIC food frequency questionnaire (FFQ) contains 66-items and was based on the original Willett 61-item FFQ (Willett et al. 1985). The ARIC FFQ is organized into seven sections; 1) dairy, 2) fruit, 3) vegetables, 4) meats and fish, 5) sweets and baked goods, 6) miscellaneous, carbohydrates, fried foods, and 7) beverages. Interviewers asked participants; "In the last year how often, on average, did you consume ______?" Nine responses were available for each food item ranging from "almost never" to "more than 6 times per day". Each response was assigned a weight to estimate servings per day and daily intake of nutrients (Shimakawa et al. 1994). Using the standard serving sizes from the FFQ, daily servings of each food item were calculated and summed to create food groups. Dietary outcomes were categorized into the following food groups: fruit, vegetables, fruit and vegetables combined, salty snacks, sweets, and sweetened drinks (Houston et al. 2005). Total caloric intake, total fat, percent saturated fat, and estimated nutrient values were calculated at the Channing Laboratory, Harvard Medical School.

The original Willett FFQ has been validated in a number of populations and is a well-recognized dietary tool with validity correlations between 0.35 and 0. 74 (Eck et al. 1996; Subar et al. 2001b; Willett et al. 1985). The reliability of the ARIC FFQ has been estimated among both white and African Americans participants in the ARIC study (Stevens et al.

1996). Median reliability coefficients were 0.48 and 0.63 for white women and men, respectively and 0.45 and 0.50 in black women and men, respectively.

Measurement of other study variables

At baseline, participants reported cigarette smoking (current, former, never) and years of education (<high school, high school, some college, or higher). A subjective general health question was included at each visit whereby the participants ranked their health as excellent, good, fair, or poor. Anthropometric measurements were also obtained at the clinic and included weight and height, which were used to calculate body mass index (BMI) (weight in kilograms divided by height in meters squared). Four weight status groups were formed using BMI: underweight (<18.5 kg/m^2), normal weight (18.5-<25 kg/m^2), overweight (25-<30 kg/m^2), and obese ($\geq$30 kg/m^2) (WHO 1995).

Statistical Analysis

The associations of baseline television watching with baseline and six-year physical activity and diet activity were modeled using multivariable linear regression. Using these models, we estimated the adjusted mean of each dependent variable at the three levels of television exposure (low, medium, high). Using low television exposure as a referent, logistic regression was used to estimate the odds of being below the median for positive outcomes (e.g., physical activity) and above the median for negative outcomes (e.g., total energy intake) with increasing television exposure category. All statistical models included the following covariates: age, race-center, gender, BMI, education, smoking, and general health status, coded as indicator variables. Separately, we estimated the effect of adding total caloric intake as a covariate to models examining physical activity as the dependent variable, and adding the sport index as a covariate to models examining dietary dependent variables. This further adjustment had no meaningful effect on the results and these variables were dropped from the final models.

To assess the temporal association of television watching with physical activity and diet over the six years of follow-up, we included the outcome at baseline in all prospective models for a further "baseline-adjusted" prospective model. The latter adjusts for the cross-sectional associations at baseline between television and our outcomes of interest. All statistical measures of effect and 95% confidence intervals were computed using SAS V9.1 (Cary, NC).

D. RESULTS

At baseline, participants were predominately white (73%) and most (76%) reported completing a high school education (**Table 4.1**). While the majority of the sample (67%) was overweight or obese, approximately 80% reported good or excellent health. Less than one-third of the participants were current smokers. More than one-third of the sample reported watching television "often" or "very often" (**Table 4.2**). The majority of the study population (>60%) was inactive at both time points. In the prospective cohort (n=12,678), the median number of servings of fruits and vegetables over the six years increased from 3.8 to 4.1 servings per day, while the servings of salty snacks, sweets and sweetened beverages remained relatively constant (data not shown). Total energy intake and total fat both declined for the cohort, and sport activity increased slightly.

Data were available for 15,574 participants at baseline and 12,678 six years later. Participants who did not return for the third clinic visit (n=2,125), or died (n=722) during follow-up, were more likely to watch television “often” or “very often” at baseline than individuals who remained in the study (42% vs. 33% respectively). They were also significantly ($p<0.001$) more likely to have a lower sport index (2.31 vs. 2.46), work index (2.10 vs. 2.20), and consume fewer fruits (1.90 vs. 2.03 servings), and salty snacks (0.35 vs. 0.41).

Table 4.1. Selected baseline covariates from the ARIC cohort, n=15,574

	Frequency	%
Age in years:		
45-49	3558	22.9
50-59	7851	50.4
>=60	4165	26.7
BMI:		
Underweight	142	0.9
Normal	5014	32.2
Overweight	6122	39.3
Obese	4296	27.6
Race:		
White	11423	73.4
African American	4151	26.7
Gender:		
Male	6977	44.8
Female	8597	55.2
Center:		
Jackson, MS	3671	23.6
Washington County, MD	3954	25.4
NW suburbs of Minneapolis, MN	3959	25.4
Forsyth County, NC	3990	25.6
General Health Status:		
Excellent	5170	33.2
Good	7285	46.8
Fair	2588	16.6
Poor	531	3.4
Education:		
Less than high school (HS)	3693	23.7
At least HS education, but less than college	6354	40.8
College education or higher	5527	35.5
Smoking Status:		
Current	4072	26.2
Former	5023	32.3
Never	6479	41.6

Table 4.2. Description of television watching, physical activity, and dietary outcomes at baseline and six years later

	Baseline n=15,574			Follow- up n=12,678		
	Median	**Range**	**Missing**	**Median**	**Range**	**Missing**
Sport activity index	2.3	1.0 - 5.0	37	2.5	1.0 - 5.0	51
Work activity index among workers*	2.6	1.0 - 4.9	4289*	2.6	1.0 - 5.0	5860*
Total caloric intake (kcal)	1530	500 - 4192	337	1494	504 - 4181	398
Total fat (grams)	55.4	5.4 - 235.1	337	50.9	6.7 - 228	398
Percent kcal from total fat (%)	33.1	5.9 - 62.6	337	31.3	6.4 - 61.8	398
Percent kcal from saturated fat (%)	12.0	1.3 - 29.0	337	11.3	1.6 - 27.7	398
Fruit & vegetables combined (servings per day)	3.7	0 - 53	42	4.1	0 - 69	56
Salty snacks (servings per day)	0.21	0 - 6.5	28	0.21	0 - 8.5	49
Sweets (servings per day)	1.0	0 - 27.4	30	1.0	0 - 37	51
Sweetened drinks (servings per day)	0.1	0 - 11	28	0.1	0 - 12	47
	Frequency	**%**	**Missing**	**Frequency**	**%**	**Missing**
Television:						
Never	296	1.9		255	2.0	
Seldom	2582	16.6		1825	14.4	
Sometimes	7293	46.8	0	5912	46.6	0
Often	4133	26.5		3735	29.5	
Very often	1270	8.2		951	7.5	
Physical Activity:						
Inactive	10681	68.7	37	8019	63.5	51
Active	4856	31.3		4608	36.5	
Leisure walking:						
Never or seldom	4591	29.5	0	3032	23.9	
Sometimes	7539	48.4		6221	49.0	1
Often or very often	3444	22.1		3424	27.0	

* Among those who worked outside of the home (full or part-time n=7912)

servings), and more sweetened drinks (0.65 vs. 0.54 servings), at baseline, than those who remained in the analysis. They were more likely to smoke (40% vs. 23%), report poor health status (8% vs. 2%), and have less than a high school education (39% vs. 20%).

Cross-sectional association with television watching

At baseline, watching television "often" or "very often" (high exposure) and "sometimes" (medium exposure) was associated with a 40% and 20% greater odds of being inactive (respectively) compared to watching television "never" or "seldom" (Table 4.3). High television exposure was also associated with a 50% greater odds of being below the median of the sport index, but was not associated with the work index. When comparing medium to low exposure, an almost two-fold greater odds was seen in walking during leisure time. High television exposure was also associated with less walking and biking during leisure and for transportation. Television exposure exhibited a graded relationship between unhealthy dietary choices and higher television exposure (Table 4.3). High television exposure was associated with an approximate 20 to 30% greater odds of being above the median for servings of salty snacks, sweets, and sweetened drinks, total fat, and percent of calories from fat and saturated fat, and below the median for fruit and vegetable servings.

Considering the difference in the adjusted means between the exposures from the linear models, we found that those with high television exposure participated in less sport activity than people who were exposed to medium or low amounts of television. There was no apparent relationship between television exposure and physical activity from the work index (**Figure 4.1**).

Examining diet, we found that participants who reported high television exposure ate more servings per day of salty snacks (0.07, 95% CI 0.04, 0.09), sweets (0.16, 95% CI 0.10, 0.22), sweetened drinks (0.11, 95% CI 0.07, 0.15), percent of calories from fat (0.78, 95% CI 1.09, 0.47), and percent of calories from saturated fat (0.27, 95% CI 0.47, 0.13) than people who reported low television exposure (**Figures 4.2-4.4**). Those with high exposure also consumed almost one-half serving fewer fruits and vegetables per day (-0.41, 95% CI -0.52, -0.30) (**Figure 4.2**).

Table 4.3. Odds ratios and 95% confidence intervals for the association of physical activity and diet with television exposure at baseline n=15,574

	Medium television exposure		High television exposure	
	OR	**95% CI**	**OR**	**95% CI**
Inactive	1.20	1.09, 1.31	1.40	1.26, 1.55
Sport index [†]	1.15	1.05, 1.27	1.50	1.36, 1.66
Work index[†]	1.03	0.93, 1.15	1.05	0.94, 1.18
Leisure walking[§*]	1.96	1.78, 2.17	1.60	1.44, 1.78
Leisure biking[§]	1.38	1.12, 1.71	1.29	1.02, 1.62
Leisure minutes of walking and biking for transportation[§]	1.04	0.93, 1.17	1.37	1.21, 1.56
Leisure sweating	1.43	1.27, 1.61	1.22	1.08, 1.38
Fruit & vegetable servings[†]	1.18	1.08, 1.29	1.36	1.24, 1.50
Salty snack servings[‡]	1.19	1.09, 1.30	1.37	1.24, 1.51
Sweet servings[‡]	1.12	1.03, 1.22	1.26	1.15, 1.38
Sweetened drink servings[‡]	1.17	1.07, 1.28	1.29	1.17, 1.42
Total calories[‡]	0.93	0.85, 1.01	1.05	0.95, 1.15
Total fat[‡]	1.02	0.93, 1.11	1.16	1.05, 1.27
Percent kcal from fat[‡]	1.14	1.04, 1.25	1.22	1.11, 1.34
Percent kcal from saturated fat[‡]	1.10	1.01, 1.20	1.17	1.06, 1.28

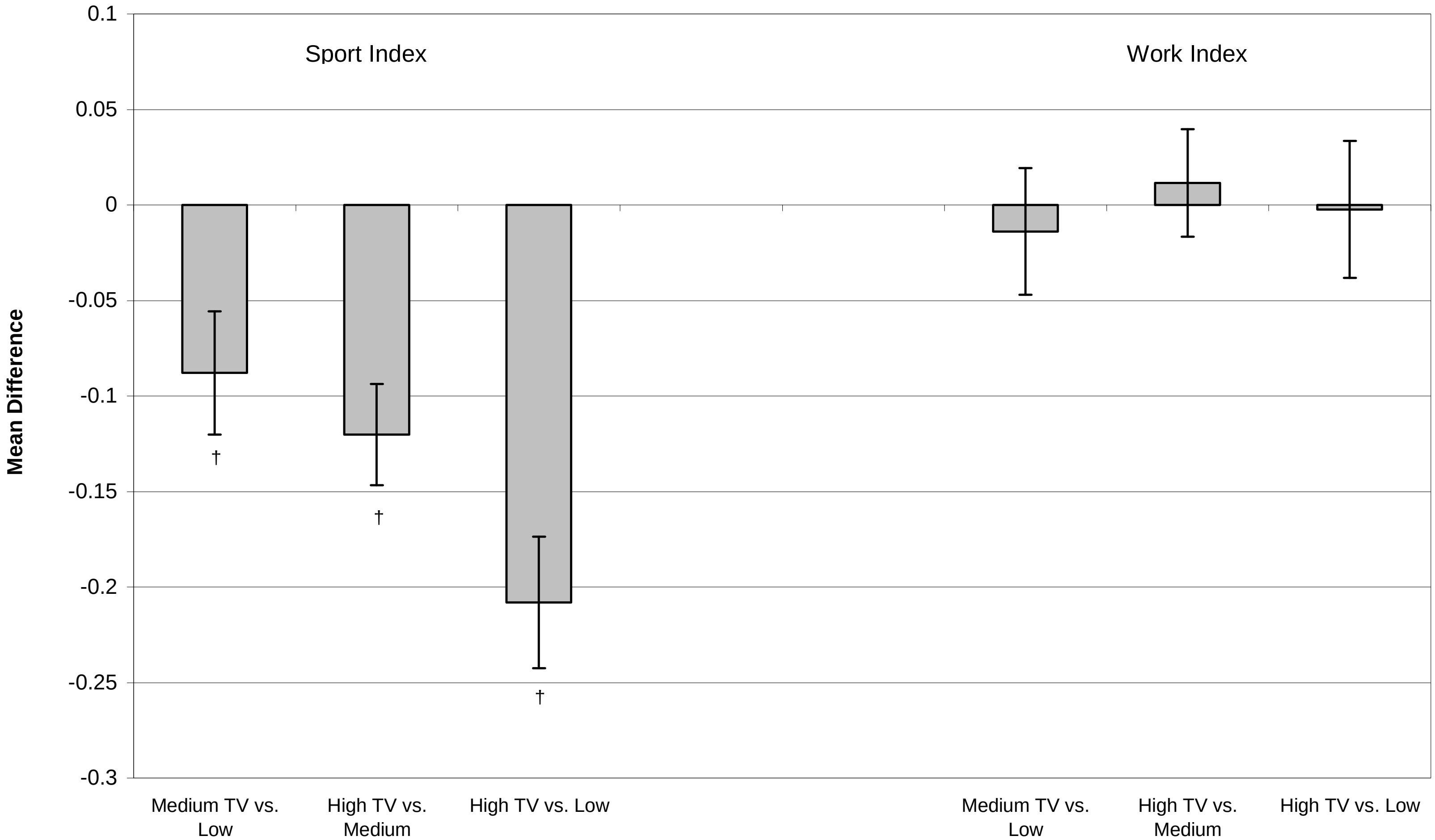
Models adjusted for age, BMI, gender, education, health status, smoking, and race - center

[†] At or below median

[‡] At or above median

[§] Never, seldom, sometimes vs. often, very often

Figure 4.1. Adjusted mean differences and 95% confidence intervals in physical activity by television exposure at baseline n=(15,574)

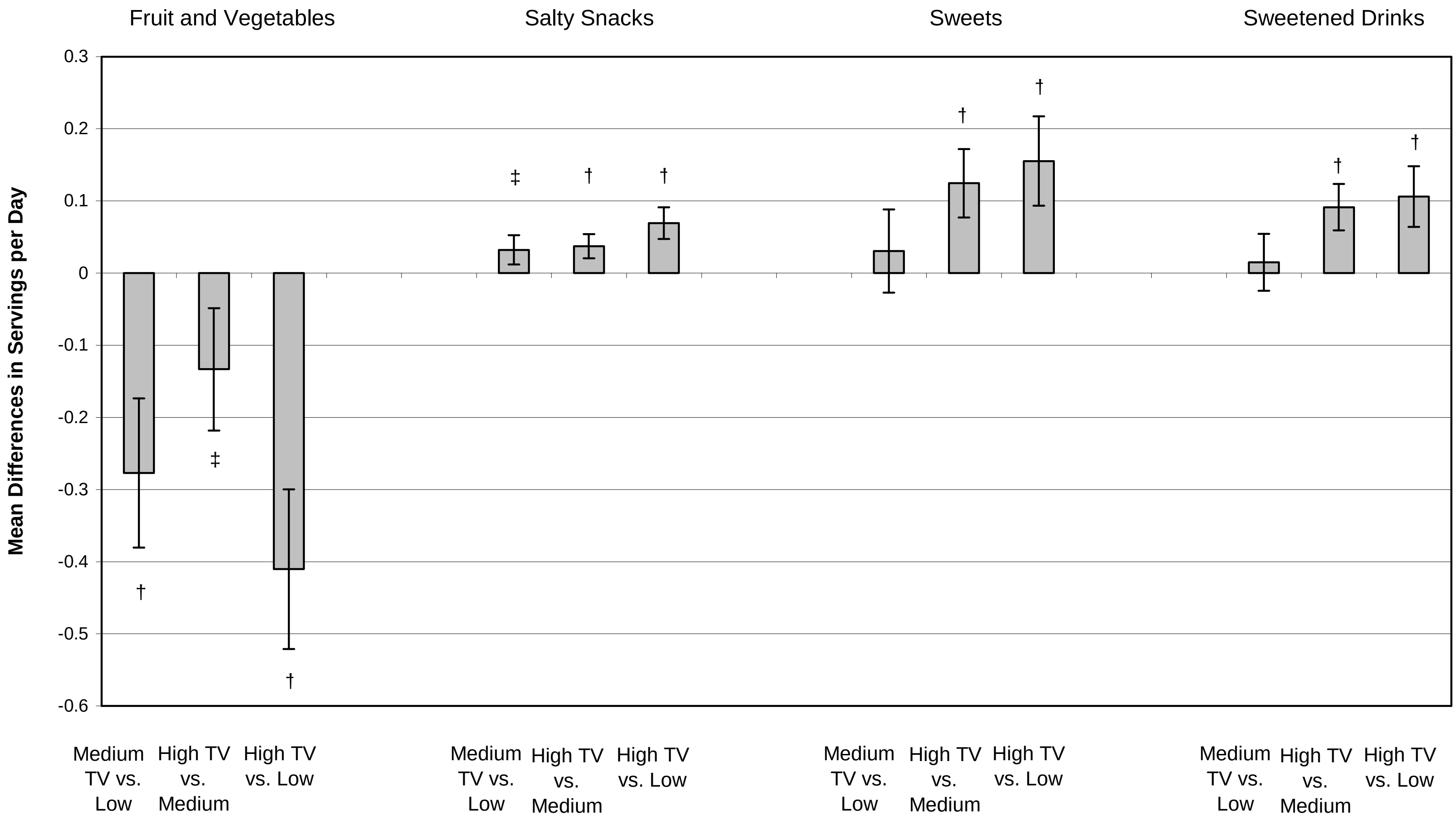


Models adjusted for age, BMI, gender, education, health status, smoking, and race – center
† $p \leq .0001$
‡ $p \leq 0.01$
§ $p \leq 0.05$

Prospective association with television watching

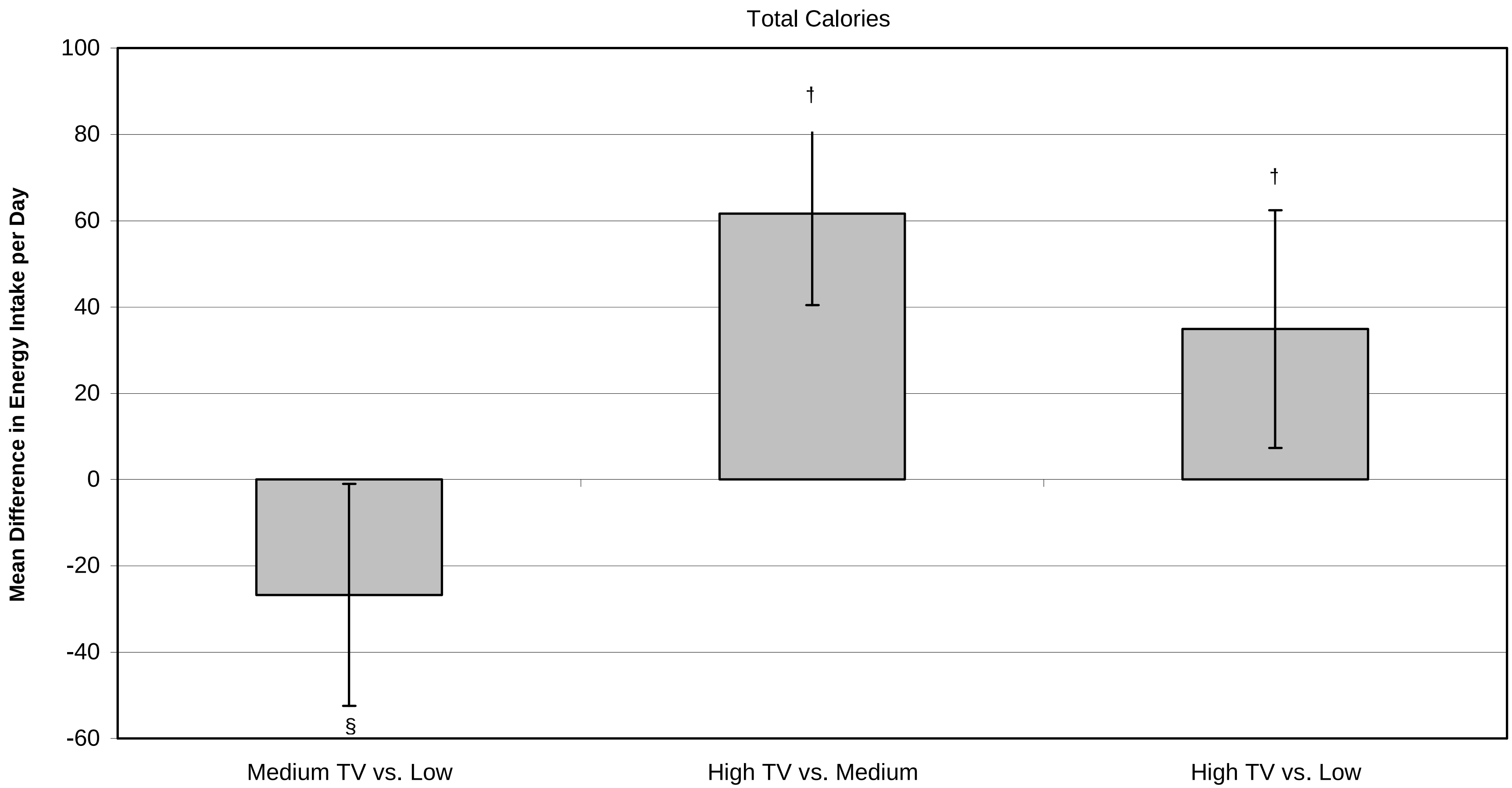
Compared with low exposure, high and medium exposure to television remained a predictor of physical activity and dietary outcomes over the six years of follow-up (**Tables 4.4-4.5**). Although the six-year associations were attenuated compared to the baseline associations, a graded relationship with greater television exposure was still observed with every outcome, except the work index. High television exposure was associated with greater odds of being inactive, below the median for the sports index and work index, as well as being less likely to walk or bike for transportation or during leisure. The odds of poor diet choices were also associated with higher television watching relative to low exposure. When compared with low television exposure, people with high exposure had an approximately 35% greater odds of being below the median of fruit and vegetable consumption. This group was also significantly more likely to be above the median for consumption of salty snacks, sweets, sweetened drinks, total calories, total fat, and percent of calories from fat or saturated fat.

Figure 4.2. Adjusted mean differences and 95% confidence intervals in fruit and vegetable, salty snack, sweets, and sweetened drink servings per day by television exposure at baseline (n=15,574)



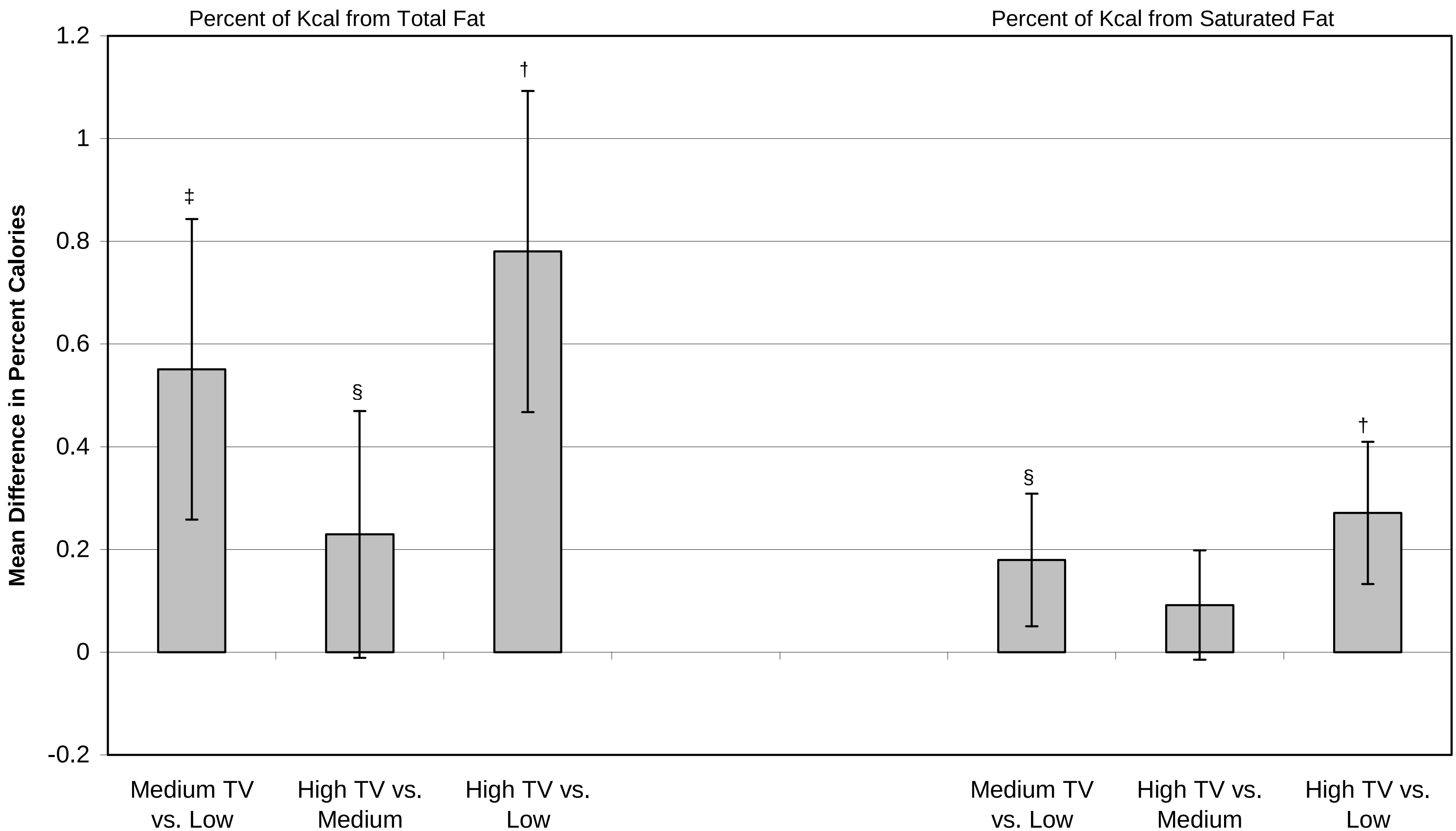
Models adjusted for age, BMI, gender, education, health status, smoking, and race – center
† p ≤ 0001
‡ p ≤ 0.01
§ p ≤ 0.05

Figure 4.3. Adjusted mean differences and 95% confidence intervals in total calories by television exposure at baseline (n=15,574)



Models adjusted for age, BMI, gender, education, health status, smoking, and race – center
† $p \leq 0001$
‡ $p \leq 0.01$
§ $p \leq 0.05$

Figure 4.4. Adjusted mean differences and 95% confidence intervals in percent of calories from fat and saturated fat by television exposure at baseline (n=15,574)



Models adjusted for age, BMI, gender, education, health status, smoking, and race – center

† $p \leq 0001$

‡ $p \leq 0.01$

§ $p \leq 0.05$

Table 4.4. Adjusted odds ratios and 95% confidence intervals for association of physical activity and diet with television exposure over six years n=12,678

	Medium television exposure		High television exposure	
	OR	**95% CI**	**OR**	**95% CI**
Inactive	1.10	1.00, 1.22	1.31	1.18, 1.46
Sport index ‡	1.16	1.05, 1.28	1.50	1.34, 1.66
Work index ‡	1.21	1.07, 1.37	1.20	1.05, 1.38
Leisure walking #	1.38	1.24, 1.54	1.44	1.28, 1.62
Leisure biking #	1.25	0.99, 1.57	1.47	1.12, 1.92
Leisure minutes of walking and biking for transportation #	1.13	1.00, 1.28	1.28	1.11, 1.46
Leisure sweating #	1.14	1.01, 1.29	1.24	1.09, 1.42
Fruit & vegetable servings‡	1.21	1.10, 1.33	1.34	1.21, 1.49
Salty snack servings §	1.11	1.00, 1.22	1.24	1.11, 1.38
Sweet servings §	1.06	0.96, 1.17	1.23	1.11, 1.36
Sweetened drink servings §	1.18	1.07, 1.30	1.31	1.18, 1.46
Total calories §	0.96	0.87, 1.05	1.08	0.97, 1.20
Total fat §	1.06	0.96, 1.17	1.20	1.08, 1.33
Percent kcal from fat §	1.08	0.98, 1.20	1.20	1.08, 1.34
Percent kcal from saturated fat §	1.16	1.05, 1.28	1.26	1.14, 1.40

Models adjusted for age, BMI, gender, education, health status, smoking, and race – center
‡ At or below median
§ At or above median
# Never, seldom, sometimes vs. often, very often

Table 4.5. Adjusted odds ratios and 95% confidence intervals for association of physical activity and diet with television exposure over six years n=12,678

	Medium television exposure		**High television exposure**	
Baseline-adjusted[†]	**OR**	**95% CI**	**OR**	**95% CI**
Inactive	1.06	0.95, 1.17	1.22	1.08, 1.36
Sport index [‡]	1.13	1.02, 1.25	1.35	1.21, 1.51
Work index [‡]	1.27	1.10, 1.46	1.23	1.05, 1.43
Leisure walking [#*]	1.19	1.06, 1.33	1.30	1.15, 1.47
Leisure biking [#]	1.17	0.92, 1.49	1.43	1.09, 1.88
Leisure minutes of walking and biking for transportation [#]	1.13	1.00, 1.28	1.23	1.08, 1.41
Leisure sweating [#]	1.04	0.91, 1.18	1.18	1.02, 1.36
Fruit & vegetable servingsv[‡]	1.15	1.04, 1.28	1.23	1.09, 1.37
Salty snack servings [§]	1.06	0.95, 1.17	1.13	1.01, 1.27
Sweet servings [§]	1.02	0.92, 1.13	1.12	1.00, 1.25
Sweetened drink servings[§]	1.12	1.01, 1.25	1.21	1.08, 1.36
Total calories [§]	0.99	0.89, 1.10	1.06	0.94, 1.19
Total fat [§]	1.08	0.97, 1.21	1.15	1.02, 1.29
Percent kcal from fat [§]	1.08	0.96, 1.21	1.15	1.02, 1.29
Percent kcal from saturated fat [§]	1.07	0.96, 1.19	1.17	1.04, 1.31

Baseline-adjusted models include the baseline value of outcome variable, age, BMI, gender, education, health status, smoking, and race – center

[‡] At or below median

[§] At or above median

[#] Never, seldom, sometimes vs. often, very often

We carried out post-hoc exploratory analyses to examine the effect of different cut-points and model choices. Regardless the cut-points or model choice, consistent associations were observed between television and our outcomes with different exposure and outcome categorizations (continuous, tertile, quartile, different dichotomization). Even when outliers were removed, our conclusions were the same (data not shown).

E. DISCUSSION

With the exception of work physical activity, a graded relationship was observed between television exposure, level of physical activity, and dietary behaviors. This relationship was still apparent in prospective analyses, although attenuated after controlling for the baseline association between television and each outcome. Adjusting for baseline in this manner helped us examine the temporal sequence between exposure and outcome over the six years. These adjusted models provide some of the best evidence to date that television is associated with negative behavioral choices over time.

Our results also provide some evidence in support of the ‘displacement hypothesis’, which holds that sedentary activities, such as television watching, are substituted for more active pursuits. Because many adults have only a few hours daily for discretionary activities (Bouchard 1999; Robinson & Godbey 2005a; Robinson & Godbey 2005b), watching television during free time may displace exercise or physically activity leisure pursuits. We observed an inverse association with television exposure with each type of physical activity (i.e., sport, work, leisure walking, or leisure biking). If high exposure to television encourages people to expend less energy in other aspects of their daily lives, then the chances of these individuals meeting the recommended guidelines for physical activity are reduced.

Although the magnitude of the associations we observed between television and diet appear small, the impact on the population could be significant. Results from the cross-sectional multivariable linear models indicated that adults with high television exposure consumed approximately one-half serving of fruits and vegetables less per day than those with low exposure and had higher energy intake and fat intake. If these differences occur daily, with no additional dietary changes, they would project to a yearly burden of thousands of additional calories and hundreds of grams of fat.

Previous literature has shown that television may impact risk of chronic disease, independent of physical activity (Fung et al. 2000; Hu et al. 2001; Hu et al. 2003). The Men's Health Professionals and Nurses Health cohort studies have identified significant associations between television watching and biomarkers for cardiovascular disease, such as low density lipoprotein, high density lipoprotein, leptin, as well as higher risk of becoming overweight and developing type 2 diabetes (Ching et al. 1996; Coakley et al. 1998; Fung et al. 2000; Hu et al. 2003). Sedentary behavior and inactivity (such as television watching) appear to have an effect on physiology and even gene expression (Levine 2004; Levine et al. 2005; Levine et al. 2006). The results from this study also suggest television watching may influence the chronic disease risk factors of diet and physical activity.

F. LIMITATIONS

This study is the first large cohort analysis to examine the associations of reported television exposure with both physical activity and dietary intake patterns. However, it is important to recognize that television exposure in our study was assessed as a single, semi-quantitative question that has not been validated. Although better measurement tools have been developed and improvements have been made in physical activity epidemiology (Ward et al. 2005), we are not aware of adequate tools for measuring sedentary behaviors such as television watching. Our television question is also a subjective measure of exposure and not an absolute measure of time. To minimize this limitation, we obtained ancillary data (M. Hulens, personal communication, 2004 (Hulens et al. 2003)), which compared the Baecke television question with a concurrent report of the continuous number of hours of television exposure in a Belgian population. Agreement between continuous hours of television and the single item Baecke was high (chi square 92.3, $p<0.0001$).

The reliability and validity of the Baecke physical activity questionnaire has not been examined within the ARIC cohort, but it has demonstrated acceptable validity and reliability in other populations (Jacobs et al. 1993; Philippaerts et al. 1999; Voorrips et al. 1991). Food frequency questionnaires like the ARIC-FFQ collect information on a limited number of food items and do not assess total energy intake; therefore, our dietary outcomes contain measurement error. Until better methods are developed, FFQs are a practical method for gathering information on dietary behaviors in large cohort studies (Subar et al. 2001b). Although validation of the ARIC FFQ is not available, the Willet FFQ, on which the ARIC questionnaire is based, has been validated and used in other well-recognized cohort studies (Feskanich et al. 1993; Rimm et al. 1992; Willett et al. 1985). Repeatability of this tool has been shown to be between 0.45 – 0.63 across visits (3 years) in our study population (Stevens et al. 1996).

Another limitation of our study design is the loss of participants between visits. These individuals (n=2,847) were less healthy, reported higher television exposure, and had more negative diet and physical activity patterns than those who remained in the study. Because these individuals are in both the high exposure and more unhealthy outcome categories at baseline, it is unlikely that the results would be different had these participants remained in the study.

This study is observational and relies on recall of both exposure and outcomes. The generalizability of this study to other populations may be limited. Lastly, although we attempted to establish temporality, true cause and effect cannot be ascertained from this study design.

G. CONCLUSIONS

The results from this analysis suggest that television exposure is associated with deleterious effects on physical activity and dietary behaviors in adult participants of the ARIC cohort. Television exposure was associated cross-sectionally and prospectively with both physical activity and dietary outcomes. A graded association was observed between higher television exposure and more unhealthy diet and physical activity behaviors (except the work index). Adjusting for the baseline relationships attenuated, but did not eliminate, the prospective associations. Our results support the hypothesis that television may be a substitute for time spent in more physically active pursuits and may contribute to both immediate and future dietary behaviors. It is important for adults to recognize the amount of time spent in front of the television being sedentary may contribute to unhealthy physical activity and dietary behaviors.

VI. Test-Retest Reliability of the Women's Health Initiative (WHI) Physical Activity Questionnaire

A. ABSTRACT

Purpose Few physical activity questionnaires were designed to measure the lifestyles and activities of women. We sought to examine the test-retest reliability of a physical activity questionnaire used in the WHI study. Differences in reliability were also explored by important covariates including race/ethnicity, age, time between test and retest, and amount of reported physical activity. **Methods** Participants (n=1092) were post-menopausal women aged 50-79 years, randomly selected from the baseline sample of participants in the WHI Observational Study (n=93,676). The WHI physical activity questionnaire collects usual frequency, duration, and pace of recreational walking, frequency and duration of other recreational activities or exercises (mild, moderate and strenuous), household, and yard activities. Summary variables were calculated by multiplying the frequency by duration and the metabolic equivalent (MET) level for that activity to obtain MET-hours per week. Approximately half of the women (n=569) repeated questions on recreational physical activity, the other half (n=523) repeated questions related to household and yard activities (mean 3 months apart). Test-retest reliability was assessed with weighted kappa and intraclass correlation coefficients (ICC). **Results** Overall, questions on recreational walking, moderate, and strenuous recreational physical activity had higher test-retest reliability (weighted kappa range 0.50-0.60) than questions on mild recreational physical activity (weighted kappa range 0.35-0.50). The ICC for moderate to strenuous recreational physical activity was 0.71 (95% CI 0.67, 0.75) and total recreational physical activity was 0.75 (95% CI 0.71, 0.78). Substantial reliability was observed for the summary measures of yard activities (ICC 0.71; 95% CI 0.66, 0.75) and household activities (ICC 0.60, 95% CI 0.55, 0.66). No meaningful differences were observed by race/ethnicity, age, time between test and retest, and amount of reported physical activity. **Conclusions** The WHI physical activity questionnaire demonstrated moderate to substantial test-retest reliability in a diverse sample of post-menopausal women. An important next step to understanding the psychometric properties of this physical activity questionnaire will be to assess validity.

B. INTRODUCTION

Understanding physical activity and its on impact on health is an important public health challenge (Surgeon General 1996b). Nearly half of the American population does not engage in enough physical activity to prevent disease or benefit health (MMWR 2004). Compared to men, women participate in less vigorous physical activity (e.g., exercise and sports participation) (MMWR 2001; MMWR 2004) and engage in more sedentary behaviors (Nielsen Media Research 2006; MMWR 2004; Television At A Glance, 2005). Furthermore, minority women report even less physical activity than white women (MMWR 2001; MMWR 2004; Ransdell et al. 1998; Surgeon General 1996b). Additional research on physical activity behaviors in women and minority populations would help guide public health policy and interventions.

Previous research demonstrates that women engage in different types and patterns of physical activity than men (Ainsworth 2000; Ainsworth et al. 1999; Tudor-Locke & Myers

2001). Women may have a different interpretation or understanding of what physical activity means to them (Ainsworth 2000; Henderson et al. 2001; Henderson & Ainsworth 2003; Masse et al. 1998; Sternfeld et al. 1999; Tudor-Locke & Myers 2001). Because many physical activity questionnaires used in epidemiologic research were designed for white male populations, they may not accurately measure physical activity in women (Ainsworth 2000; Masse et al. 1998; Tudor-Locke et al. 2003). This makes accurate and reliable measurement of physical activity in women and minority populations especially challenging. While the validity and reliability of physical activity questionnaires may be affected by both race/ethnicity and gender, it can also be impacted by other attributes such as age, length of time between test and retest, or level of physical activity. These attributes may affect the ability of individuals to remember, comprehend, and answer questions or their ability to follow directions.

One study that has attempted to address physical activity measurement in women is the Women's Health Initiative Observational Study. The WHI Observational Study is a large, multi-center cohort designed to examine health status, risk exposures, and disease events in racially and ethnically diverse postmenopausal women from across the United States (Langer et al. 2003). The objective of this paper is to examine the test-retest reliability of the WHI physical activity questionnaire in a random sample of the WHI cohort overall and by race/ethnicity, age, time between test and retest, and level of recreational physical activity.

C. METHODS

Between 1994 and 1998, over 93,676 women between 50 and 79 years of age were enrolled at one of 40 clinic centers across the United States into the WHI Observational

Study (Langer et al. 2003). Eligibility for enrollment included the intention to reside in the area for at least three years, free from any major medical condition which would impact survival within three years of study entry, and no reported mental illness, dementia, alcoholism, or drug dependency. Full details on the study cohort and design are available elsewhere (Langer et al. 2003).

Between October 1996 and June 1997, a sub-sample of the women enrolled in the WHI Observational Study was selected to participate in the Measurement and Precision Study. Participants (n=1,092) were randomly recruited within the 40 clinic centers and stratified by age and race/ethnicity (American Indian/Alaskan Native, Asian or Pacific Islander, Black or African American, Hispanic/Latino, White).

The purpose of the Measurement and Precision Study was to assess test-retest reliability of several self-administered questionnaires. Each clinic center was randomly assigned to repeat a set of baseline questionnaires (Langer et al. 2003). At approximately 12-week intervals (range: 8-15 weeks), half of the women (n=567) repeated questions on exercise/recreational activities (Form 34) and the other half (n=512) repeated questions related to household, yard, and sedentary activities (Form 42).

Physical Activity Questionnaire

The physical activity questionnaire was self-administered at enrollment. The questionnaire was designed to collect different types of activities by grouping them together by intensity. This was done to reduce the burden and time needed to complete the questionnaire. The questionnaire was divided into two forms to collect information on usual physical activity. On the first form, participants reported their usual exercise, or recreational activity (mild, moderate, strenuous, and walking activities). On the second form, participants were asked about heavy indoor household activities and yard activities. Both forms were completed at the same time, either at the clinics or mailed to the participant, and then returned to the clinic for review. The questionnaire and scoring protocol can be found in **Appendix D**.

Exercise or recreational activity was assessed by frequency (6 categories, from 0 to 5+ days per week) and duration (4 categories, from < 20 minutes to >= 60 minutes) of mild, moderate, and strenuous activities. Participants reported episodes (10 minutes or more) of walking outside of the home by frequency (6 levels, 0 to 7 days per week), duration (4 levels, <20 minutes to >=60 minutes), and usual speed (4 levels, 2 mph to 5 mph). The women were also asked to recall whether or not they engaged in strenuous activity (yes or no) at 18, 35, and 50 years of age. Questions on household activities were assessed as hours per week (5 categories, from <1 hour to >=10 hours). Yard activities included the number of months per year (5 categories, <1 month to >=10 months) and hours per week (5 categories, <1 hour to >=10 hours) the activities were performed. Participants were also asked to report number of hours spent sitting and lying down, including sleep, each day (8 categories, <4 hours to >=16 hours).

The WHI physical activity measures were designed to be summarized into continuous variables estimating weekly energy expenditure [Metabolic equivalent (MET)-hours per week] from each type of activity (mild, moderate, strenuous, walking, household, and yard). An estimated MET level for the types of activity was assigned from a compendium of activities (Ainsworth et al. 2000), where the MET level is kilocalories per kilogram of body weight expended each hour during a specific activity. The summary variables in "MET-hours" quantify the total kilocalories expended per kilogram per week. MET units are independent of body weight.

Socio-demographic Measures

Participants answered questions on a number of important health behaviors and demographic attributes. Race/ethnicity (American Indian/Alaskan Native, Asian or Pacific Islander, Black or African American, Hispanic/Latino, White), education (10 levels), main occupation (Professional/Managerial, Technical/Sales/Administrative, Service/Labor, Homemaker), retirement status, martial status, smoking status, and general health were all self-reported at the first clinic visit. Additionally height and weight for each individual were measured at this visit and used to calculate body mass index (BMI) (weight in kilograms divided by height in meters squared), and categorized as underweight (<18.5 kg/m^2), normal weight (18.5-<25 kg/m^2), overweight (25- <30 kg/m^2), and obese (≥30 kg/m^2) (WHO 1995).

Statistical Analysis

Two-level kappa and weighted kappa (3-8 levels) statistics were used to assess the test-retest reliability of each individual question or corresponding component (e.g., frequency, duration). Weighting for the kappa statistics was applied using the default in SAS, the Cicchetti-Allison form, which took into account the degree of non-agreement between the test and retest. Agreement between the test and retest were categorized into five categories: poor (0 to ≤ 0.2), fair (0.2 to ≤ 0.4), moderate (0.4 to ≤ 0.6), substantial (0.6 to ≤0.8), and almost perfect (0.8 to 1.0) (Landis et al. 1977). Test-retest reliability of the continuous variables was assessed with the intraclass correlations coefficient (ICC). ICC and 95% confidence intervals were based on a one-way analysis of variance model (ANOVA)

(Streiner et al. 1995; Streiner 1995) and assessed the proportion of the total variance (true variability and measurement error) that was due to participant variability or differences between tests.

Stratified analyses were performed overall and by race/ethnicity, time between test and retest (<=3 months vs. >3 months), age (50 - ≤65 years, > 65 - 79 years), and by level of recreational activity (one or more episodes vs. none). Lastly, because the participants were not randomized to the type of activity form (exercise/recreation form vs. household/yard form), differences between the two samples were also examined.

D. RESULTS

Study Sample

The majority of the sample (n=1092) reported good, very good, or excellent health (90%) and the average age was 64 years old (**Table 6.1**). The population was predominantly White (66%) followed by Hispanic (14%), African American (13%), and Asian/Pacific Islander (7%). Only 1% of the women identified themselves as American Indian/Alaskan Natives (n=13). These women were excluded from the racially stratified analysis only because of inadequate sample size. Most women had completed high school (93%) and reported an occupation (current or former) other than being a homemaker (90%), more than half of them (55%) were retired at the time of the first test. Approximately half of the sample (51%) reported never smoking and more than half (58%) were overweight or obese. The majority of the women were married, while one-third were either widowed or divorced.

Although participants were randomly chosen from within each center, each center was assigned to only one of the two physical activity forms (exercise/recreational activity vs. yard/household). Several differences in the population distributions were found between the two forms. Differences of 5% or more were observed between the two samples for the following variables: race/ethnicity, education, and BMI. A greater proportion of the participants who answered the questionnaire on exercise/recreation activities were normal weight (43% vs. 36%), White (69% vs. 63%), and college graduates (40% vs. 34%), compared to the sample that answered the questions on household/yard activities. Differences were not observed between general health, occupational status, marital status, and smoking status.

Table 6.1. Socio-demographic description of participants in theWHI Measurement and Precision Study at the first clinic visit (n=1092)

	N	%
Education		
Less than high school	75	6.9
High school	197	18.2
Some college or vocational/associates	406	37.6
College degree	402	37.2
Missing	12	
Race/Ethnicity		
American Indian or Alaskan Native	13	1.2
Asian or Pacific Islander	74	6.8
Black or African-American	138	12.6
Hispanic/Latino	148	13.6
White	719	65.8
General Health		
Excellent	178	16.4
Very good	421	38.8
Good	382	35.2
Fair	91	8.4
Poor	14	1.3
Missing	6	

Table 6.1 cont.

Occupation		
Managerial / Professional	415	39.3
Technical / Sales / Administrative	340	32.2
Service/Labor	190	18.0
Homemaker	110	10.4
Missing	37	
Retired		
No	487	45.0
Yes	596	55.0
Missing	9	
Marital		
Never married	52	4.8
Divorced, separated or widowed	345	31.7
Presently married or marriage-like relationship	680	63.5
Missing	5	
Body Mass Index		
Underweight	31	2.8
Normal	433	39.7
Overweight	360	32.0
Obese	268	24.5
Missing		
Smoking		
Never	553	51.3
Former	458	42.5
Current	67	6.2
Missing	14	
Total exercise and recreational activity		
No exercise or recreational activity	50	8.9
Some activity of limited duration or frequency	254	45.4
2 to <4 episodes per week	108	19.3
4 or more episodes per week	148	26.4
Missing	9	

At baseline, 73% of the women were not strenuously active, and more than half had not participated in regular strenuous activity in their earlier adulthood (ages 18, 35, 50 years) (data not shown). At least 80% of the women reported some walking. However, when all exercise was combined about half of the women reported fewer than 10 MET-hours per week (median 9.0 MET-hours/week, S.D. 14.3). Whites and Asian/Pacific Islanders had higher median levels of total recreational activity than Hispanic and African Americans (9.8, 8.7, 7.5, 7.5 MET-hours/week, respectively). A similar pattern was observed for strenuous recreational activity and moderate to strenuous recreational activity by race/ethnicity (data not shown). More women reported at least one episode of moderate recreational activity (e.g., easy swimming, biking, or dancing), than mild recreational activity (e.g., bowling, golf) (**Table 6.2**).

Table 6.2. Physical activity descriptive statistics at the first clinic visit, among participants in the WHI Measurement and Precision Study

Variable	N	Mean	Median	SD	Missing
Form 34: Exercise or recreational physical activity (n=569)					
Mild recreational physical activity (MET-hours/week)	551	1.2	0	2.6	18
Moderate recreational physical activity (MET-hours/week)	553	3.2	0	5.1	16
Vigorous recreational physical activity (MET-hours/week)	562	4.0	0	9.0	7
Walking recreational physical activity (MET-hours/week)	563	4.9	2.5	6.2	6
Moderate to vigorous recreational physical activity (MET-hours/week)	544	9.8	4.5	13.2	25
Total recreational physical activity (MET-hours/week)	526	13.3	9.0	14.3	43
Form 42 – Household and Yard physical activity (n=523)					
Household physical activity (MET-hours/week)	518	7.7	7.0	9.1	5
Yard physical activity (MET-hours/week)	515	3.8	0	6.8	8
Sitting and lying down (hours per week)	519	14.5	15.0	4.3	4

Test-retest Reliability

Within the entire sample, substantial test-retest reliability was demonstrated in most summary measures, with the exception of mild recreational activity, which showed moderate reliability (**Table 6.3**). Two estimates of total physical activity, one continuous and another categorical, both showed substantial test-retest reliability (ICC 0.73, weighted kappa 0.61, respectively) (**Tables 6.3 and 6.6**).

Reliability was similar when the sample was reduced to only those women who reported at least one episode of exercise or recreational activity (**Table 6.3**). Stratifying by race/ethnicity resulted in a loss in precision but the associations were similar (**Table 6.4**). The exception was mild recreational activity which consistently demonstrated the lowest reliability, especially in non-white participants. When stratified by age, women who were <=65 years of age demonstrated higher reliability than women >65 years (**Table 6.5**). However the magnitude of these differences was small, as the measures in both strata remained moderate to substantial. Additionally, the population of women who repeated the tests within three months also tended to have higher reliability compared to women for whom more than three months had passed at retest (**Table 6.5**).

In general, the reliability of the individual questions on the components of frequency and duration of exercise (strenuous, moderate, mild, and walking) was moderate (weighted kappas 0.36 – 0.62) (**Table 6.6**). Better reliability was observed for the strenuous and walking components than moderate or mild components.

Table 6.3. Intraclass correlation coefficients and 95% confidence interval of physical activity measures among participants in the WHI Measurement and Precision Study

	Total		**≥1 episode of recreational physical activity[#]**	
	ICC	**95% CI**	**ICC**	**95% CI**
Form 34: Exercise or recreational physical activity	n=569		n=310	
Mild recreational physical activity (MET-hours/week)	0.51	0.45, 0.57	0.55	0.47, 0.62
Moderate recreational physical activity (MET-hours/week)	0.57	0.52, 0.63	0.60	0.53, 0.67
Strenuous recreational physical activity (MET-hours/week)	0.76	0.73, 0.80	0.76	0.71, 0.80
Walking recreational physical activity (MET-hours/week)	0.74	0.70, 0.77	0.71	0.65, 0.76
Moderate to strenuous recreational physical activity (MET-hours/week)	0.71	0.67, 0.75	0.74	0.68, 0.78
Total recreational physical activity (MET-hours/week)	0.75	0.71, 0.78	0.73	0.67, 0.77
Form 42: Household and yard physical activity	n=523			
Household physical activity (MET-hours/week)	0.60	0.55, 0.66	N/A*	
Yard physical activity (MET-hours/week)	0.71	0.66, 0.75		
Sitting and lying down (hours per week)	0.60	0.54, 0.65		

* Only applicable for women who completed recreational physical activity form
# One episode of any recreational physical activity, regardless of intensity or duration

Table 6.4. Intraclass correlation coefficients and 95% confidence interval of physical activity measures by race/ethnicity, in the WHI Measurement and Precision Study

	White		African American	
	ICC	**95% CI**	**ICC**	**95% CI**
Form 34: Exercise or recreational physical activity	n=390		n=60	
Mild recreational physical activity (MET-hours/week)	0.53	0.46, 0.60	0.07	-0.19, 0.31
Moderate recreational physical activity (MET-hours/week)	0.77	0.72, 0.81	0.68	0.52, 0.79
Strenuous recreational physical activity (MET-hours/week)	0.74	0.69, 0.78	0.64	0.46, 0.77
Walking recreational physical activity (MET-hours/week)	0.75	0.70, 0.79	0.87	0.79, 0.92
Moderate to strenuous recreational physical activity (MET-hours/week)	0.77	0.72, 0.81	0.68	0.52, 0.79
Total recreational physical activity (MET-hours/week)	0.73	0.68, 0.77	0.72	0.58, 0.83
Form 42: Household and yard physical activity	n=329		N=78	
Household physical activity (MET-hours/week)	0.62	0.55, 0.68	0.65	0.50, 0.76
Yard physical activity (MET-hours/week)	0.78	0.73, 0.73	0.70	0.56, 0.80
Sitting and lying down (hours per week)	0.56	0.48, 0.63	0.66	0.52, 0.77

	Hispanic		Asian / Pacific Islander	
	ICC	**95% CI**	**ICC**	**95% CI**
Form 34: Exercise or recreational physical activity	n=82		n=35	
Mild recreational physical activity (MET-hours/week)	0.44	0.24, 0.59	0.66	0.60, 0.72
Moderate recreational physical activity (MET-hours/week)	0.82	0.74, 0.88	0.73	0.54, 0.86
Strenuous recreational physical activity (MET-hours/week)	0.92	0.88, 0.95	0.80	0.76, 0.84
Walking recreational physical activity (MET-hours/week)	0.69	0.56, 0.79	0.75	0.70, 0.79
Moderate to strenuous recreational physical activity (MET-hours/week)	0.82	0.74, 0.88	0.73	0.54, 0.86
Total recreational physical activity (MET-hours/week)	0.85	0.78, 0.90	0.78	0.74, 0.82
Form 42: Household and yard physical activity	n=66		n=39	
Household physical activity (MET-hours/week)	0.52	0.31, 0.67	0.77	0.60, 0.87
Yard physical activity (MET-hours/week)	0.31	0.07, 0.51	0.59	0.34, 0.76
Sitting and lying down (hours per week)	0.67	0.51, 0.78	0.54	0.28, 0.73

Table 6.5. Intraclass correlation coefficients and 95% confidence interval of physical activity measures by age and time between tests, in the WHI Measurement and Precision Study

	<=65 years		>65 years	
	ICC	**95% CI**	**ICC**	**95% CI**
Form 34: Exercise or recreational physical activity	n=313		n=256	
Mild physical activity MET-hours per week	0.66	0.59, 0.72	0.40	0.29, 0.50
Moderate physical activity MET-hours per week	0.59	0.51, 0.66	0.56	0.47, 0.64
Strenuous physical activity MET-hours per week	0.80	0.76, 0.84	0.71	0.64, 0.76
Walking MET-hours per week	0.75	0.70, 0.79	0.76	0.70, 0.80
Moderate to vigorous physical activity MET- hours per week	0.79	0.75, 0.83	0.73	0.67, 0.78
Total recreational physical activity MET- hours per week	0.78	0.74, 0.82	0.72	0.65, 0.77
Form 42: Household and yard physical activity	n=288		n=235	
Household physical activity (MET-hours/week)	0.65	0.58, 0.71	0.52	0.42, 0.61
Yard physical activity (MET-hours/week)	0.67	0.60, 0.73	0.77	0.72. 0.82
Sitting and lying down (hours per week)	0.68	0.62, 0.74	0.48	0.37, 0.57

	<= 3 months		>3 months	
	ICC	**95% CI**	**ICC**	**95% CI**
Form 34: Exercise or recreational physical activity	n=274		n=295	
Mild physical activity MET-hours per week	0.60	0.51, 0.67	0.44	0.34, 0.52
Moderate physical activity MET-hours per week	0.57	0.48, 0.64	0.58	0.50, 0.65
Strenuous physical activity MET-hours per week	0.71	0.65, 0.77	0.80	0.76, 0.84
Walking MET-hours per week	0.84	0.81, 0.87	0.62	0.54, 0.68
Moderate to vigorous physical activity MET- hours per week	0.75	0.70, 0.80	0.78	0.74, 0.82
Total recreational physical activity MET- hours per week	0.76	0.70, 0.80	0.75	0.69, 0.79
Form 42: Household and yard physical activity	n=274		n=249	
Household physical activity (MET-hours/week)	0.60	0.55, 0.66	0.54	0.45, 0.62
Yard physical activity (MET-hours/week)	0.71	0.66, 0.75	0.66	0.58, 0.72
Sitting and lying down (hours per week)	0.60	0.54, 0.65	0.59	0.51, 0.67

Table 6.6. Weighted kappa statistics and 95% confidence intervals of the physical activity components among participants in the WHI Measurement and Precision Study

	Entire sample			≥1 episode of recreational physical activity[#]		
	N	**Weighted Kappa**	**95% CI**	**N**	**Weighted Kappa**	**95% CI**
Form 34: Exercise or recreational physical activity						
Mild physical activity, days per week	548	0.36	0.27, 0.45	303	0.40	0.28, 0.51
Mild physical activity, minutes per session	528	0.52	0.43, 0.61	295	0.51	0.40, 0.62
Moderate physical activity, days per week	563	0.53	0.47, 0.59	314	0.54	0.47, 0.47
Moderate physical activity, minutes per session	544	0.48	0.41, 0.54	297	0.44	0.36, 0.53
Strenuous physical activity, days per week	555	0.62	0.55, 0.68	314	0.62	0.55, 0.69
Strenuous physical activity, minutes per session	546	0.61	0.54, 0.68	306	0.60	0.52, 0.68
Number of walks per week >= 10 minutes	567	0.60	0.55, 0.65	314	0.55	0.48, 0.61
Minutes per walk	555	0.59	0.54, 0.65	307	0.59	0.52, 0.66
Usual speed of walk	556	0.60	0.54, 0.65	306	0.58	0.50, 0.66
Total exercise and recreational activity exposure	569	0.61	0.56, 0.66	314	0.51	0.42, 0.59
Form 42: Household and yard physical activity						
Heavy indoor chores hours per week	517	0.52	0.45, 0.58	N/A*		
Yard work, months per year	511	0.67	0.62, 0.71			
Yard work, hours per week	509	0.64	0.59, 0.70			
Historical strenuous physical activity	**N**	**Simple Kappa**	**95% CI**	**N**	**Simple Kappa**	**95% CI**
Strenuous physical activity at age 18 years	527	0.55	0.48, 0.63	288	0.57	0.47, 0.66
Strenuous physical activity at age 35 years	526	0.55	0.48, 0.63	294	0.55	0.45, 0.65
Strenuous physical activity at age 50 years	535	0.53	0.46, 0.60	301	0.53	0.44, 0.63

* Only applicable for women who completed recreational physical activity form
# One episode of any recreational physical activity, regardless of intensity or duration

History of strenuous activity at the ages of 18, 35, and 50 years was also moderately reliable (0.53 – 0.55) and did not appear to follow a consistent pattern of higher or lower reliability over the three age periods. Similar to the summary measures, reliability was not greatly influenced by restricting the analysis to only women who reported at least one episode of exercise, or recreational activity. When we stratified by the other relevant covariates (age, race/ethnicity, and time between tests) the reliability of moderate, strenuous, and walking physical activity were all fair to moderate.

E. DISCUSSION

The WHI Physical Activity Questionnaire had moderate to substantial test-retest reliability in a racially diverse sample of post-menopausal women. The reliability estimates observed in this sample are similar to reliability measures from other self-reported questionnaires designed for women (Cauley et al. 1987) and for older adults (Washburn 2000). Additionally, the physical activity in this population generally parallels activity patterns observed in the US population of adults (MMWR 2001; MMWR 2004; Surgeon General 1996b).

The most consistent difference in the test-retest reliability estimates appeared to be lower reliability in the mild exercise or activity measures. Although it is possible that the lower reliability observed in the mild intensity questions may be an artifact of reduced precision, it is consistent with other research (Sallis et al. 1985; Washburn 2000). Activities of mild intensity are less memorable and less likely to be recalled, and are consequently less well captured by self-report questionnaires. Another potential explanation for the weaker performance of the mild activity measures may be a result of the questionnaire design. Mild walking, a popular recreational activity in this population, was assessed independently from other mild-intensity activities, and showed higher reliability than mild activity. Therefore, if walking had been included in the mild activity measure, instead of assessed independently, mild activity might have shown higher reliability.

Differences in test-retest reliability were not observed when reducing the sample to only women who reported at least one episode of any exercise or recreational activity. There were also no meaningful differences observed across race/ethnic groups. Previous studies have been mixed in their reporting of differences in reliability by race/ethnicity (Brownson et al. 1999; Evenson et al. 2005; Shea et al. 1991). However, it is also important to consider the wide confidence intervals in the race/ethnicity estimates, as stratifying the data resulted in a loss of precision.

Although we did not observe differences in reliability between the different race/ethnic groups, or by physical activity, patterns were observed by age and length of time between test and retest. Women who were 65 years or younger demonstrated better test-retest reliability than women who were older. Variability of physical activity in older women may be influenced by a number of factors, such as changing health status, (e.g., fatigue, injury, disease progression), retirement, or loss of a spouse (Brown et al. 2003; Evenson et al. 2002a; Eyler 2003; Eyler et al. 2003). Any of these changes within the study period could impact questionnaire reliability as women's activity patterns are affected. Additionally, aging is associated with cognitive decline that can impact memory and could in turn affect reliability (Rikli 2000).

Not surprisingly, a pattern of slightly higher reliability was also observed in the sample of women who repeated tests within a three-month time period compared to women who experienced more than three months between the tests. One explanation could be because tests repeated within a shorter time frame are more likely to be given in the same season or comparable time of year with regards to weather. Furthermore, a change in activity could have occurred after the administration of the first questionnaire, such that the reliability estimates would be lower.

Limitations

Despite the diverse and large sample, this study had several limitations. The WHI sample was not population-based and may not be representative of a specific source population. White women make up a larger sample than other racial/ethnic groups. Because of the small sample sizes representing Hispanic, African American, and Asian/Pacific Islander women, the bounds of the lower confidence interval were estimated below zero in several of the stratified analyses. Additionally the level of education in our sample was very high and we were unable to examine variation in test-retest reliability by education.

Another limitation to this study was that participants were not randomized to the two forms and some differences were observed between the two groups. While the WHI physical activity assessment included a measure of yard and household activity, it was not a comprehensive measure of women's potential activities. Several domains of activity such as non-motorized transportation (active travel), child or elder care activity, and work or occupational physical activity were not included in the WHI physical activity questionnaire.

F. CONCLUSIONS

Reliable and valid questionnaires are a cost-effective and useful method for collecting physical activity information in large cohort studies, such as the WHI observational study . However, measurement of physical activity is challenging as many questionnaires do not collect detailed information on types of activities and use terminology many women do not identify with (Ainsworth 2000; Masse et al. 1998; Tudor-Locke et al. 2003; Tudor-Locke & Myers 2001). The WHI Physical Activity Questionnaire measures several domains of physical activity behavior and this study demonstrated it can reliably estimate recreational, yard, and household physical activity in an ethnically diverse sample of post-menopausal women.

VII. Walking Intensity, Frequency, Duration, and the Risk of Coronary Heart Disease in the Women's Health Initiative Observational Study

A. ABSTRACT

Purpose Walking is the most popular leisure time physical activity for US adults. It is an activity that requires almost no additional expense, training, or specialized equipment. A brisk walk performed for 30 minutes on most days of the week meets the current physical activity recommendations for health. Walking has been associated with decreased risk of CHD in several epidemiologic cohorts of women. However very little research exists on the relative importance of intensity, duration, and frequency of walking on risk of CHD. Therefore, we estimated the risk of CHD associated with total walking energy expenditure as well as each walking component (intensity, duration, frequency) among participants from the Women's Health Initiative observational cohort (n=71,502). **Methods** Cox proportional hazards regression was used to estimate the hazard ratios (HR) of CHD associated with several walking exposures. Separate models were used to examine total recreational walking and the individual walking components while controlling for important covariates (age, race, income, education, marital status, diet, general health, region, smoking, and occupation). **Results** In the multivariate model, an increase of 10 MET – hours per week of recreational walking was associated with an 19% reduction in risk of CHD (HR 0.81, 95% CI 0.76, 0.87). Relative to never walking, walking very fast was associated with lower risk of CHD (HR 0.36, 95% CI 0.19, 0.68). Walking seven or more times per week and walks of one hour or

longer were also associated with lower risk of CHD (HR 0.76, 95% CI 0.64, 0.90 and HR 0.69, 95% CI 0.56, 0.83, respectively). When stratified by the level of recreational physical activity energy expenditure, the observed associations were stronger in participants with higher walking exposure. **Conclusion** Each walking component appeared to have a significant effect on risk of CHD. How physical activity is performed (intensity, duration, frequency) may influence individual CHD risk.

B. INTRODUCTION

More than 50 years have past since occupational physical activity was first examined as a risk factor for CHD (Morris et al. 1953). The first health recommendation regarding exercise and fitness followed 25 years later, published by the American College of Sports Medicine (ACSM 1978). This recommendation focused on the development and maintenance of physical fitness for health and encouraged vigorous exercise, at least three times per week performed as a continuous bout (≥20 minutes). In the years that followed, recommendations regarding exercise for cardiorespiratory fitness or health were revisited as specific health benefits and various exercises or activities were examined (ACSM 1994; ACSM Position Statement 1990 1990; ACSM 1998).

By 1992, the American Heart Association identified physical inactivity as a primary risk factor for cardiovascular disease (Fletcher et al. 1992). Three years later, the mounting evidence that moderate amounts of activity conferred protection from chronic disease led to changes in the physical activity recommendations and the adoption of a national standard for public health (Pate et al. 1995; U.S. Department of Health and Human Services 1996). Continued research has helped to elucidate the dose-response relationship between physical activity and health (Kesaniemi et al. 2001). However today, more than fifty years after physical activity was first studied as a risk factor for CHD, the debate continues regarding the optimal prescriptive dose of activity (i.e., intensity, frequency, duration) that will prevent disease (Barinaga 1997; IOM 2002; Kesaniemi et al. 2001; Lee & Skerrett 2001b; Martin et al. 2000).

An international group of experts gathered in the fall of 2000 to examine the evidence of the dose-response relationship related to physical activity and health. A recurring theme at the conference was the lack of epidemiologic evidence on the health effects of the various components of activity (i.e., intensity, frequency, duration) (Kesaniemi et al. 2001). Specifically, scientists were unable to assess the impact of these individual components apart from their contribution to physical activity energy expenditure. They concluded that there was insufficient evidence on the relative importance of intensity, frequency, and duration with regards to morbidity and mortality, and recommended that future studies examine these separate components in greater detail (Lee & Skerrett 2001b).

In order to rigorously examine the components of activity, physical activity data needs to be collected such that intensity, frequency, and duration are assessed independently, but also contribute to a summary variable of volume measuring total energy expenditure (i.e., energy expenditure as MET-time or kilocalories). The volume of physical activity energy expenditure should be matched or controlled for in the analysis in order to examine the individual contribution of each component. This is necessary because an individual who performs activities that are frequent, of long duration, or of vigorous intensity will expend more total energy than another who engages in infrequent activity, of shorter duration, or of moderate intensity. Therefore, until the total volume of energy expenditure is considered, it is difficult to understand if the resultant health effect observed in more active individuals is solely an artifact of greater energy expenditure or a result of additional frequency, longer duration, or higher intensity.

The WHI physical activity questionnaire assesses recreational walking activity in a way that allows examination of intensity, frequency, and duration. Thus, the purpose of this study was to explore the effect of recreational walking on risk of CHD and assess the relative contribution of each walking component.

C. METHODS

Study Population

Participants were selected from the observational cohort of the WHI (Langer et al. 2003). Between 1993 and 1998, approximately 161,000 women from 40 clinical centers across the United States were recruited to participate in several WHI studies as part of a broad initiative to examine women's health. An ethnically and racially diverse group of women, who were post-menopausal, age 50 to 79 years were targeted for enrollment. The WHI included an observational cohort of 93,676 women who provided information on various health behaviors and exposures and have been followed annually to explore major causes of morbidity and mortality.

Women enrolled in the observational cohort completed a baseline screening visit between 1993 and 1998, at their respective clinics. During this visit they completed self-administered questionnaires, which ascertained information on physical activity, diet, personal medical history, and other occupational, lifestyle, and behavioral risk factors. At the same visit, certified staff recorded physical and clinical measurements (e.g., anthropometrics, blood pressure, etc).

To be eligible for the observational cohort, the women had to have no reported mental illness, dementia, alcoholism, or drug dependency, be free from any major medical condition which would impact survival within three years, and have the intention to reside in the area for at least three years (Langer et al. 2003). Women were also ineligible if they had a history of cardiovascular disease, cancer, or stroke. For the aims of this study, women were excluded if they were missing information on physical activity (n=7,439) and important covariates (n=12,510) (i.e., age , body mass index, income, education, marital status, diet, occupation, general health status, or race/ethnicity). We also excluded women who reported poor health at baseline (n=631) or were unable to walk one block (n=1171). Lastly, 423 women were ineligible because of missing follow-up information. The final sample size consisted of 71,502 women. Informed consent was obtained through materials approved by the institutional review boards at each center.

Physical Activity Assessment

The physical activity questionnaire asked participants to report their usual recreational activity (i.e., mild, moderate, vigorous, and walking), indoor household, and yard activities. Because walking is such a prevalent and important recreational activity for this population, it was assessed separately with three questions. Participants were asked how often (frequency) they walked outside the home for more than 10 minutes without stopping, how long (duration) they usually walked, and their usual walking speed (intensity). Six possible categories assessed frequency (0, 1-3 times/month, 2-3 times/week, 4-6 times/week, and 7 or more times/week), four time categories gauged average walk duration (<20 minutes, 20-39 minutes, 40-59 minutes, ≥60 minutes), and five speed categories assessed intensity (causal/slow, normal/average, fairly fast, very fast, don't know). Women who responded "don't know" to the question on usual speed (4%) were assigned to the lowest category (causal/slow).

Recreational physical activity energy expenditure was estimated by summing the MET-hours per week of walking, mild, moderate, and vigorous recreational activities. One MET is approximately equivalent to 3.5 ml of oxygen used per minute, for each kilogram of body weight, in an adult. MET units are independent of body weight and the estimated MET level for the types of activity was assigned from a compendium of activities (Ainsworth et al. 1993; Ainsworth et al. 2000).

The test-retest reliability of the physical activity measures was estimated in a random sample of women participating in the observational cohort. Test and retest occurred approximately 12 weeks apart (range, 8-15 weeks). Intraclass correlation coefficients for the summary variables of walking total recreational activity were moderately to substantially reliable (chapter 6). The agreement for walking intensity, frequency, and duration measured through weighted kappa statistics was 0.60, 0.60, and 0.59 respectively. The agreement within the categories of each component is presented in **Appendix G**.

Coronary Heart Disease Assessment

End points for this analysis were incident CHD events. We defined an incident event, after baseline, but before September 2005, as including either a definite or probable myocardial infarction (MI) or coronary revascularization (percutanerous transluminal coronary angioplasty or coronary artery bypass graft). Participants were contacted annually for their medical or health information and completed a standardized questionnaire either self-completed, over the phone, or in-person during an interview. Medical records data (discharge and relevant diagnostic/lab tests) were collected for each event. Elements used to help define the events included all available electrocardiograms, cardiac enzyme and /or troponin levels, and medical history (Curb et al. 2003). Adjudication of events occurred at two levels. First, the local Clinical Center physician reviewed the documents and assigned a diagnosis. Second, events were centrally reviewed at the Clinical Coordinating Center(Curb et al. 2003). A high level of agreement was found between local and central adjudication for cardiovascular disease outcomes (90-94%) (Curb et al. 2003).

Covariate Description

Body mass index was collected during the baseline clinic visit and categorized into underweight (<18.5 kg/m^2), normal weight (18.5-<25 kg/m^2), overweight (25- <30 kg/m^2), and obese (≥30 kg/m^2) (WHO 1995). Smoking was self-reported as current, former, or never smoker, and caloric intake was estimated from a food frequency questionnaire. All socio-demographic variables were self-reported using standardized questionnaires and were self-reported by the participants at baseline. Participants could self-identify a single race or ethnicity from six possible categories: non-Hispanic American Indian, non-Hispanic Asian/Pacific Islander, non-Hispanic Black, non-Hispanic White, Hispanic, or Other. Family income was also reported and categorized into five levels from <$20,000 per year to ≥$75,000. Occupation was categorized into four broad types: managerial/professional, technical/sales/administration, service/labor, and homemaker. Marital status was categorized into currently married or in a marriage-like relationship, divorced or separated, widowed, and never married. Education was divided into four categories (less than high school, high school/GED, some college or associates degree, and college degree). The 40 clinic centers were categorized by region of the country and defined as Northeast, South, Midwest, and West. Lastly, a single question asked participants to report their perceived health status by asking "In general, would you say your health is excellent, very good, good, fair or poor?".

Statistical Analysis

Using a Cox proportional hazards model, we first examined walking as a continuous energy expenditure variable and its association with risk of CHD. Second, we examined the association of each walking component (intensity, frequency, duration) with CHD in separate Cox models. Person-time for each participant was calculated from the time of enrollment into the study until the date of a confirmed event or until September 12, 2005. Hazard ratios were computed for each category of the walking component and were adjusted for age, race/ethnicity, total caloric intake, smoking status, marital status, household income, education, occupation, and general health.

Following this, we explored three modeling strategies to adjust for recreational energy expenditure, all of which used Cox proportional hazard models. In the first analysis, we assessed each component of walking separately in a standard multivariable model. In the second, we adjusted for recreational energy expenditure by including as a covariate, a linear term the total recreational energy expenditure (MET-hours/week). Because of the high correlations between our exposure (or component) and the recreational energy expenditure variable, we employed a third approach which used the "nutrient" residual method common in nutritional epidemiology. This method is applied when a effect of a specific nutrient requires adjustment for total caloric intake (Willet 1998). To do this we regressed each activity component (intensity, frequency, duration) separately in a model with recreational physical activity energy expenditure as the independent variable and the component as the dependent variable (Willet 1998). This provides us with an "energy-adjusted" component estimate that is uncorrelated with physical activity energy expenditure. We then used this "residualized" (or energy adjusted) component as our main exposure in the Cox model while controlling for other covariates to estimate risk of CHD.

Lastly, although this analysis does not allow us to test the strength of the associations of one component relative to another, we dichotomized each component into roughly equal distributions to draw comparisons. This was done by collapsing the two highest response categories in each component and defining these as exposed relative to the remaining categories.

D. RESULTS

The vast majority of our sample was white (86%), with smaller proportions of African American (7%), Hispanic (3%), Asian (3%), and other races (1%) (**Table 7.1**). Although this cohort represented an older population (mean age 64 years), the majority of women reported very good or excellent health (42% and 19%, respectively) and were currently married (63%). Almost all of the women had a high school diploma (96%) and many of them had a college degree (42%). Most women also reported household incomes near or above the median U.S. household income at the beginning of the study period (1993, median income $31,241) (US Census Bureau: Income 1975 to 2005 2006).

Table 7.1. Participant characteristics and covariate description n=71,502

	Frequency	Percent
Age Group		
50-59	23200	32.5
60-69	31663	44.3
70-79	16639	23.3
Race/ethnicity		
non-Hispanic White	61251	85.7
non-Hispanic African American	4834	6.8
Hispanic	2269	3.2
non-Hispanic Asian/Pacific Islander	2144	3.0
Other	1004	1.4
Region		
Northeast	16280	22.8
South	17765	24.9
Midwest	16253	22.7
West	21204	29.7
General Health Status		
Excellent	13255	18.5
Very good	30044	42.0
Good	22706	31.8
Fair	5497	7.7
Marital Status		
Married or marriage-like relationship	45148	63.1
Never married	3393	4.8
Divorced or Separated	11096	15.5
Widowed	11865	16.6
Education		
Less than High School	2881	4.0
High School or GED	11362	15.9
Some College or Associate Degree	26078	36.5
College Degree	31181	41.6

Table 7.1 cont.

Occupation		
Managerial / Professional	31728	44.4
Technical / Sales / Admin	20780	29.1
Service / Labor	11746	16.4
Homemaker only	7248	10.1
Household Income		
<20,000	9780	13.7
20,000 – 34,999	16106	22.5
35,000 – 49,999	14327	20.0
50,000 – 74,999	14451	20.2
>= 75,000	16838	23.6
Recreational Physical Activity		
No activity	9123	12.8
Some activity of limited duration	22702	38.7
2 to <4 episodes per week	13184	18.4
4 or more episodes per week	21493	30.1

The majority of the women did not engage in regular recreational physical activity (**Table 7.1**). However, walking was the most common recreational physical activity and only 15% of the sample did not report any recreational walking activity (**Table 7.2**). Sixty percent of the women reported that they walked outside at least 2 or more times per week. The most commonly reported speed or intensity of walking was "average or normal pace" and most common duration was between 20 and 39 minutes per walk.

Total walking was first examined in a crude model which showed a 2% decrease in risk of CHD (HR 0.98, 95% CI 0.97, 0.99) with every one MET increase in walking. In a second model adjusting for covariates, an increase of 10 MET-hours per week in recreational walking was associated with an almost 20% reduction in risk for a CHD event (HR 0.81, 95% CI 0.76, 0.87).

Table 7.2. Distribution of walking intensity, frequency, and duration n=71,502

Walking Component	Frequency	Percent
Walking Intensity (speed)		
No walking	10687	15.0
Causal or slow walking	12814	18.0
Average or normal walking	30219	42.3
Fairly fast	16878	23.6
Very fast	904	1.3
Walking Frequency		
0 days per week	10687	15.0
1-3 times per month	9963	14.0
1 time per week	7330	10.3
2-3 times per week	20197	28.3
4-6 times per week	17032	23.8
7 or more times per week	6293	8.8
Walking Duration		
0 minutes	10687	15.0
0 – 19 minutes	15581	21.8
20 – 39 minutes	29160	40.8
40 – 59 minutes	11238	15.7
1 hour or more	4836	6.8

Examination of the Walking Components

In crude, multivariable adjusted, and recreational energy adjusted models, all walking intensities greater than slow or casual were associated with lower risk of CHD (**Table 7.3**). Walking at the fastest intensity was associated with a 64% reduction in risk (HR 0.36, 95% CI 0.19, 0.68). Further adjustment for recreational energy expenditure had no affect on the estimates.

A similar, albeit weaker, association was observed with increasing frequency, where statistically significant decreases in CHD risk were not observed until the women walked at least 4 to 6 times per week. In the multivariable adjusted model, walking every day was associated with a 24% lower risk (HR 0.76, 95% CI 0.64, 0.90), and walking for more than 60 minutes per walk was associated with 31% lower risk (HR 0.69, 95% CI 0.56,0.83) of CHD (**Table 7.3**). Including a term for recreational energy expenditure attenuated the associations but did not meaningfully change the results (**Table 7.3**).

The results from all three modeling strategies provided similar results for the association between duration of walking and risk of CHD. Women who reported walks of 40 to 60 or more minutes were at significantly lower risk of CHD. In the multivariable adjusted model, walks of one hour or more conferred more than 30% lower risk of CHD (HR 0.69, 95% CI 0.56, 0.65) (**Table 7.3**). Similar to the other components, including recreational energy expenditure in the model did not appreciably affect the estimates.

Table 7.3. Crude, multivariable-adjusted, and energy-adjusted hazard ratios and 95% confidence intervals associated with walking intensity, frequency, and duration and risk of coronary heart disease n=71,502

	Crude	Multivariable* adjusted	Recreational Energy** Adjusted
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Walking Intensity (speed)			
No walking	Ref	Ref	ref
Causal or slow walking	1.21 (1.08,1.35)	1.13 (1.00, 1.26)	1.13 (1.00, 1.26)
Average or normal walking	0.78 (0.71,0.87)	0.89 (0.80, 0.99)	0.89 (0.80, 0.99)
Fairly fast	0.48 (0.42,0.54)	0.66 (0.57, 0.75)	0.66 (0.57, 0.75)
Very fast	0.21 (0.11,0.40)	0.36 (0.19, 0.68)	0.36 (0.19, 0.68)
Walking Frequency	Ref		
0 days per week		Ref	ref
1-3 times per month	0.83 (0.73,0.95)	0.95 (0.84, 1.09)	0.96 (0.84, 1.09)
1 time per week	0.81 (0.70,0.94)	0.94 (0.81, 1.08)	0.94 (0.82, 1.09)
2-3 times per week	0.81 (0.72,0.90)	0.93 (0.83, 1.04)	0.95 (0.84, 1.06)
4-6 times per week	0.74 (0.66,0.83)	0.88 (0.78, 0.99)	0.91 (0.80, 1.03)
7 or more times per week	0.62 (0.52,0.73)	0.76 (0.64, 0.90)	0.80 (0.67, 0.96)
Walking Duration			
0 minutes	ref	Ref	ref
0 – 19 minutes	0.92 (0.82,1.03)	0.98 (0.88, 1.10)	0.98 (0.88, 1.11)
20 – 39 minutes	0.80 (0.72,0.89)	0.93 (0.83, 1.03)	0.94 (0.84, 1.05)
40 – 59 minutes	0.60 (0.53,0.69)	0.79 (0.69, 0.91)	0.81 (0.70, 0.94)
1 hour or more	0.54 (0.44,0.65)	0.69 (0.56, 0.83)	0.71 (0.58, 0.88)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Because of a potential bias due the correlation between components and recreational energy expenditure, we stratified by tertile of recreational energy expenditure. When the population was stratified in this way, differential effects were observed (**Table 7.4a – 7.4c**). In the stratified analysis, intensity of walking was the only beneficial component across all tertiles of recreational physical activity. Only in the highest tertile (>= 16.2 MET-hours/week of recreational physical activity) did women experience a lower risk from all three components. These effects were only slightly attenuated after adjusting for recreational physical activity energy expenditure.

Because the effects of walking appeared stronger in women who were more active, the data were dichotomized at the median and restricted to women who engaged in 10 or more MET-hours/wk of recreational physical activity) (**Table 7.5**). Results in this sample (n=36,426) mirrored the results observed in the entire cohort, although the magnitudes of the effects for each component were slightly greater. Women in the highest categories of each component experienced the greatest reductions in risk of CHD.

Table 7.4a. Crude, multivariable-adjusted, and energy-adjusted models hazard ratios and 95% confidence intervals associated with walking intensity and risk of coronary heart disease, by tertile of recreational physical activity n=71,502

	Crude Hazard Ratio (95% CI)	Multivariable* Adjusted Hazard Ratio (95% CI)	Recreational Energy Adjusted** Hazard Ratio (95% CI)
Tertile 1 n=22,854 0 to <5 MET-hours/week			
No walking	ref	ref	ref
Causal or slow walking	1.23 (1.07,1.42)	1.17 (1.01, 1.35)	1.17 (1.00, 1.37)
Average or normal walking	0.72 (0.61,0.84)	0.83 (0.70, 0.97)	0.83 (0.69, 1.00)
Fairly fast	0.46 (0.31,0.68)	0.65 (0.43, 0.74)	0.64 (0.43, 0.95)
Very fast	not estimated	not estimated	not estimated
Tertile 2 n=24,611 ≥5 to <16.2 MET-hours/week			
No walking	ref	ref	ref
Causal or slow walking	1.33 (1.04,1.69)	1.11 (0.94, 1.31)	1.11 (0.94, 1.30)
Average or normal walking	0.94 (0.75,1.17)	0.94 (0.81, 1.09)	0.94 (0.81, 1.09)
Fairly fast	0.47 (0.36,0.61)	0.65 (0.54, 0.78)	0.65 (0.54, 0.78)
Very fast	0.34 (0.08,1.37)	0.31 (0.10, 0.97)	0.31 (0.10, 0.98)
Tertile 3 n=24,037 ≥16.2 MET-hours/week			
No walking	ref	ref	ref
Causal or slow walking	0.99 (0.73,1.34)	0.86 (0.63, 1.16)	0.85 (0.63, 1.16)
Average or normal walking	0.69 (0.54,0.89)	0.71 (0.55, 0.92)	0.71 (0.55, 0.91)
Fairly fast	0.48 (0.37,0.62)	0.59 (0.46, 0.77)	0.60 (0.46, 0.78)
Very fast	0.19 (0.09,0.40)	0.31 (0.15, 0.65)	0.33 (0.16, 0.68)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Table 7.4b. Crude, multivariable-adjusted, and energy-adjusted models hazard ratios and 95% confidence intervals associated with frequency of walking and risk of coronary heart disease, by tertile of recreational physical activity n=71,502

	Crude Hazard Ratio (95% CI)	Multivariable* Adjusted Hazard Ratio (95% CI)	Recreational Energy Adjusted** Hazard Ratio (95% CI)
Tertile1 n=22,854 0 to <5 MET-hours/week			
0 days per week	ref	ref	ref
1-3 times per month	0.86 (0.73,1.01)	0.96 (0.81, 1.13)	0.98 (0.83, 1.15)
1 time per week	0.90 (0.74,1.08)	1.01 (0.83, 1.21)	1.05 (0.86, 1.28)
2-3 times per week	0.98 (0.83,1.15)	1.00 (0.84, 1.18)	1.08 (0.88, 1.32)
4-6 times per week	0.98 (0.69,1.38)	1.00 (0.71, 1.41)	1.09 (0.76, 1.58)
7 or more times per week	0.76 (0.34,1.70)	0.72 (0.32, 1.61)	0.79 (0.35, 1.81)
Tertile 2 n=24,611 ≥5 to <16.2 MET-hours/week			
0 days per week	ref	ref	ref
1-3 times per month	0.90 (0.68,1.20)	1.06 (0.80, 1.41)	1.06 (0.80, 1.41)
1 time per week	0.85 (0.63,1.13)	0.99 (0.74, 1.33)	1.00 (0.74, 1.34)
2-3 times per week	0.86 (0.68,1.08)	1.01 (0.80, 1.27)	1.01 (0.80, 1.27)
4-6 times per week	0.93 (0.73,1.17)	0.98 (0.77, 1.24)	0.98 (0.77, 1.24)
7 or more times per week	0.82 (0.60,1.13)	0.90 (0.66, 1.24)	0.90 (0.65, 1.23)
Tertile 3 n=24,037 ≥16.2 MET-hours/week			
0 days per week	ref	ref	ref
1-3 times per month	0.67 (0.47,0.95)	0.78 (0.55, 1.10)	0.77 (0.54, 1.10)
1 time per week	0.59 (0.41,0.86)	0.66 (0.45, 1.10)	0.66 (0.45, 0.96)
2-3 times per week	0.64 (0.49,0.84)	0.71 (0.54, 0.93)	0.71 (0.54, 0.96)
4-6 times per week	0.61 (0.47,0.79)	0.68 (0.52, 0.87)	0.68 (0.52, 0.87)
7 or more times per week	0.52 (0.39,0.70)	0.58 (0.43, 0.78)	0.60 (0.45, 0.81)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Table 7.4c. Crude, multivariable-adjusted, and energy-adjusted models hazard ratios and 95% confidence intervals associated with increasing level of walking duration and risk of coronary heart disease, by tertile of recreational physical activity n=71,502

	Crude Hazard Ratio (95% CI)	Multivariable* Adjusted Hazard Ratio (95% CI)	Recreational Energy Adjusted** Hazard Ratio (95% CI)
Tertile1 n=22,854 0 to <5 MET-hours/week			
0 minutes	ref	ref	ref
0 – 19 minutes	0.99 (0.86,1.14)	1.02 (0.88, 1.18)	1.04 (0.89, 1.21)
20 – 39 minutes	0.85 (0.73,1.00)	0.95 (0.81, 1.11)	0.98 (0.82, 1.17)
40 – 59 minutes	0.64 (0.43,0.97)	0.83 (0.55, 1.26)	0.86 (0.56, 1.32)
1 hour or more	0.73 (0.39,1.36)	0.92 (0.49, 1.72)	0.95 (0.50, 1.80)
Tertile 2 n=24,611 ≥5 to <16.2 MET-hours/week			
0 minutes	ref	ref	ref
0 – 19 minutes	0.96 (0.75,1.23)	1.07 (0.84, 1.37)	1.08 (0.84, 1.38)
20 – 39 minutes	0.90 (0.72,1.12)	1.00 (0.80, 1.25)	1.00 (0.80, 1.26)
40 – 59 minutes	0.74 (0.56,0.97)	0.88 (0.67, 1.16)	0.88 (0.67, 1.16)
1 hour or more	0.70 (0.45,1.07)	0.81 (0.53, 1.25)	0.81 (0.52, 1.24)
Tertile 3 n=24,037 ≥16.2 MET-hours/week			
0 minutes	ref	ref	ref
0 – 19 minutes	0.72 (0.53,0.97)	0.73 (0.54, 0.99)	0.73 (0.54, 0.99)
20 – 39 minutes	0.69 (0.53,0.88)	0.74 (0.57, 0.96)	0.74 (0.57, 0.95)
40 – 59 minutes	0.53 (0.40,0.69)	0.62 (0.48, 0.82)	0.63 (0.48, 0.82)
1 hour or more	0.47 (0.35,0.64)	0.53 (0.39, 0.72)	0.55 (0.40, 0.75)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Table 7.5. Crude, multivariable-adjusted, and energy-adjusted hazard ratios and 95% confidence intervals associated with walking intensity, frequency, and duration and risk of coronary heart disease in women with 10 or more MET-hours per week of recreational physical activity n=36,426

	Crude Hazard Ratio (95% CI)	Multivariable* Adjusted Hazard Ratio (95% CI)	Recreational Energy**Adjusted Hazard Ratio (95% CI)
Walking Intensity (speed)			
No walking	ref	ref	ref
Causal or slow walking	1.21 (1.08,1.35)	1.04 (0.83, 1.32)	1.04 (0.82, 1.32)
Average or normal walking	0.78 (0.71,0.87)	0.88 (0.72, 1.07)	0.88 (0.72, 1.07)
Fairly fast	0.48 (0.42,0.54)	0.66 (0.53, 0.81)	0.66 (0.54, 0.82)
Very fast	0.21 (0.11,0.40)	0.34 (0.17, 0.68)	0.36 (0.18, 0.71)
Walking Frequency			
0 days per week	ref	ref	ref
1-3 times per month	0.83 (0.73,0.95)	0.91 (0.8469 1.19)	0.91 (0.69, 1.19)
1 time per week	0.81 (0.70,0.94)	0.87 (0.66, 1.168)	0.87 (0.66, 1.16)
2-3 times per week	0.81 (0.72,0.90)	0.90 (0.73, 1.11)	0.90 (0.73, 1.11)
4-6 times per week	0.74 (0.66,0.83)	0.77 (0.63, 0.95)	0.78 (0.63, 0.96)
7 or more times per week	0.62 (0.52,0.73)	0.70 (0.55, 0.89)	0.72 (0.56, 0.92)
Walking Duration			
0 minutes	ref	ref	ref
0 – 19 minutes	0.92 (0.82,1.03)	0.96 (0.76, 1.21)	0.96 (0.76, 1.21)
20 – 39 minutes	0.80 (0.72,0.89)	0.85 (0.70, 1.04)	0.85 (0.69, 1.04)
40 – 59 minutes	0.60 (0.53,0.69)	0.76 (0.61, 0.95)	0.77 (0.62, 0.96)
1 hour or more	0.54 (0.44,0.65)	0.61 (0.47, 0.80)	0.63 (0.48, 0.83)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for Total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Component Comparisons

The methods applied in this study do not allow us to test which component was associated with the strongest risk reduction. Additionally, the categories within each component were not equivalent. In order to try and draw a comparison between the components, we examined the distributions of the categories within each component and roughly dichotomized each component at the highest 20th to 30th percentile of exposure. When comparing the effect estimates from these three models, intensity was the component associated with the greatest risk reduction. In the multivariable-adjusted model, being in the highest two categories of walking intensity (the top 24%) conferred a 34% reduction in risk of CHD (HR 0.66, 95% CI 0.60, 0.74). Relatively speaking, the highest two categories of frequency (33%) or duration (23%) conferred only a 12% or 22% reduction in risk of CHD (HR 0.88, 95% CI 0.81, 0.95 and HR 0.78, 95% CI 0.71, 0.87, respectively) (**Table 7.6**).

Table 7.6. Crude, multivariable-adjusted, and energy-adjusted hazard ratios and 95% confidence intervals associated with walking components and risk of coronary heart disease dichotomized at the highest two categories n=36,426

		Crude	Multivariable* Adjusted	Recreational Energy**Adjusted
Component	**Percent exposed**	**Hazard Ratio (95% CI)**	**Hazard Ratio (95% CI)**	**Hazard Ratio (95% CI)**
Walking Intensity	**24**	0.50 0.45, 0.56	0.66 0.60, 0.74	0.68 0.61,0.76
Walking Frequency	**33**	0.83 0.76, 0.90	0.88 0.81, 0.95	0.92 0.84, 1.00
Walking Duration	**23**	0.67 0.61, 0.74	0.78 0.71, 0.87	0.81 0.73, 0.90

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity
** Adjusted for Total recreational energy expenditure, age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

E. DISCUSSION

Of the three walking components in our study, intensity or pace of walking appeared to have the strongest, most consistent association with risk of CHD. A graded, inverse association with` risk of CHD was observed in all modeling strategies applied to the data (e.g., multivariable-adjusted, energy-adjusted, and residual). Previous analyses on the WHI, Nurses Health Study, and Health Professional's Followup Study have all shown a reduction in risk of cardiovascular diseases associated with walking pace (Manson et al. 2002; Manson et al. 1999; Tanasescu et al. 2002). However, not all cohort studies have observed the same risk attenuation with pace of walking (Lee et al. 2001a).

Intensity

Intensity has been the most frequently examined component of physical activity and although results have been mixed, many analyses have found greater health benefits from vigorous activity and/or higher intensity (Lee & Skerrett 2001b; Swain & Franklin 2006). Vigorously performed activity at 6 METs results in twice as much energy expenditure as moderate activity of 3 METs. Controlling for total activity energy expenditure attempts to adjust for this inequality. While it may seem counterintuitive to isolate the effect from energy expenditure, it is plausible that intensity has differential physiologic effects (Wilmore et al. 2004). At the same caloric expenditure, more intense exercise may result in changes to muscle structure, function, biochemistry, pulmonary adaptations, and hormone levels not associated with lower intensities. In this analysis intensity or pace of walking was consistently associated with a significant reduction in risk of CHD over the study period. Relative to never walking or walking at a slower pace, walking fairly or very fast conferred between 40-60% reduction in risk of CHD.

Frequency

Compared to intensity, the effect of increasing frequency on risk is not as straightforward. When we examined the entire sample, there was weak evidence for risk attenuation in the lowest frequency categories. Meaningful attenuation was seen only in women who walked four or more times per week. Energy adjustment did not have a large impact on these results. Few epidemiologic studies have examined frequency of activity as an independent variable, and these results have been mixed. Two separate studies of mortality and physical activity found a graded inverse association between activity frequency and mortality (Kushi et al. 1997; Sundquist et al. 2004). However, neither of these studies accounted for energy expenditure. In another observational study that did not adjust for energy expenditure, frequency was a better predictor of cardiovascular risk factors than intensity or duration (Mensink et al. 1997). More recently the Harvard Alumni Study was used to examine people who engage in high volumes of activity (>1000 kcal per week) but during infrequent bouts ("weekend warriors") (Lee et al. 2004). This analysis found that weekend warriors had a lower risk of mortality than their sedentary peers, but a slightly elevated risk compared to those who were more regularly active.

Duration

Duration of activity episodes or "bouts" has also been neglected in the epidemiologic literature. Each model in this analysis supported a graded association between higher duration and decreasing risk, including models adjusting for energy expenditure. However, statistically significant risk reduction was only apparent when women walked for 40 minutes or more. Only a handful of other epidemiologic studies have examined duration of activity and health outcomes (Hu et al. 2004; Hu et al. 2007; LaCroix et al. 1996; Lee et al. 2000b). All of these have reported decreases in risk with higher duration of activity. Two of these found a lower risk of cardiovascular risk factors or mortality with higher duration of transport-related physical activity (Hu et al. 2004; Hu et al. 2007). Nonetheless, in one of the few analyses to adjust for energy expenditure, Lee et al. (Lee et al. 2000b) found no additional benefit of higher duration, even after controlling for physical activity energy expenditure.

The components of physical activity, and the relative benefits of different activity prescriptions has been largely neglected physical activity epidemiology. Because the physical activity recommendations are specific in regard to the components (i.e., level of intensity, number of days per week, or minutes per bout) it is important to gauge the relative health effect of each. Each component should be studied with, and without its contribution toward physical activity energy expenditure. Without controlling for the volume of activity it is impossible to discern if a higher intensity, extra episode, or longer duration has an independent health benefit. Several analyses have attempted to address this by stratifying on total volume of physical activity energy expenditure to examine the components (Lee et al. 1995) (Lee et al. 2004) (Manson et al. 1999; Tanasescu et al. 2002). To our knowledge this is the first analysis of all three components that has attempted statistical adjustment for energy expenditure in a large epidemiologic cohort.

F. LIMITATIONS

Energy adjustment techniques are controversial. The activity components are not independent of energy expenditure or of one another. Additionally, the correlations between the variables can be substantial and possibly differential by level of energy expenditure (Bellach et al. 1998; Day et al. 2004).

It is also difficult to understand which estimate of energy expenditure to use for adjustment. In addition to the recreational activity energy expenditure, additional analyses were performed controlling for energy expenditure from all available activity measures (e.g., recreational, yard, and household physical activity) (**Appendix J**). Using this estimate of "total" energy expenditure had no effect on the magnitude or precision of the estimates compared to the model with only recreational activity energy expenditure.

Results from the third modeling approach with the "residualized" component were more difficult to interpret, but showed similar effects (**Appendix H-I**). In a residual model the components or "exposures" lose their units of measurement and interpretation of the beta parameters can be challenging (Mackerras 1996; Wacholder et al. 1994). Additionally, the analogy of energy adjustment in physical activity to energy adjustment in nutrition epidemiology is not perfect. First, total energy intake is an absolute measure where kilocalories are consumed through a finite number of items, whereas energy expenditure can occur from an almost infinite number of activities and physiologic functions. Secondly, in energy intake the components of diet (carbohydrate, fat, protein) are additive; in energy expenditure the physical activity components are multiplicative (intensity, frequency, duration).

In this application, using the residual was also not ideal because the components were collected as categorical variables. Applying the residuals to categorized data can cause bias and is not equivalent to a continuous model (Brown et al. 1994). The residual method may also underestimate error, as the variance estimate from the residual is not the same as the variance estimate of the true component. Exploring the residual method using continuous measures of physical activity (accelerometer data) might be more applicable.

Examining the effects of the components outside of a laboratory environment is challenging. Epidemiologic studies are more limited in measuring energy expenditure compared to a controlled, randomized trial environment with an easily quantified "activity prescription" (intensity, frequency, duration). There are also domains of activity and energy expenditure that are not captured in our data including occupational activity, transportation, and child or elder care activity. A measure of very high intensity, or vigorous activity is also not represented in our data. According to the compendium of activities a "very fast" or brisk pace of walking does not qualify as a "vigorous" activity (Ainsworth et al. 1993; Ainsworth et al. 2000). There can be no comparison made between vigorous and moderate intensity in these data. A number of studies have attempted to compare walking with vigorous activity, or compared moderate activities to vigorous activates, but none of these have controlled for level of energy expenditure (Hu et al. 1999a; Manson et al. 2002; Manson et al. 1999; Swain & Franklin 2006).

Although the WHI observational cohort includes a large number of minority women, the study population is not representative of all post-menopausal women. Furthermore, the majority of the women reported low levels of physical activity. Less than 20,000 women (28 %) reported any vigorous recreational activity. In a more active population with higher physical activity levels, controlling for energy expenditure might have a greater influence on the results than what was found in this study. Additionally, all of the physical activity data was self-report and therefore subject to several biases including recall and responder bias. The walking exposure information was also collected as categorical data, which may result in misclassification, and although the reliability of the walking components was moderate to substantial, there is presently no data on the validity of this questionnaire.

Despite the limitations of this study, the WHI observational cohort comprises a large, diverse sample of women with over 10 years of followup information. Medical history and event data have been rigorously verified. The physical activity questionnaire collected the three components of walking activity separately along with summary measures of physical activity energy expenditure. This study remains the first analyses to examine the independent effects of all three components of walking, while controlling for a measure of energy expenditure.

G. CONCLUSION

Research on the health benefits of physical activity has been ongoing for decades, yet the optimal prescription for disease prevention and health effects is still unclear. Additional studies, including better measures of physical activity and applying new methods of analysis are required in order to understand the health benefits from different types of physical activities or components of activity, such as frequency, intensity, and duration.

Laboratory studies with controlled doses and prescriptions of physical activity are one way to test the effects of the components. However, epidemiologic studies provide opportunities to examine patterns of the components, activity behaviors, and long-term health outcomes that are not available in smaller, shorter laboratory trials. Energy adjustment techniques to isolate the effects of the components have not been widely used in physical activity research. Further research into these methods and their application to different questionnaires and populations is needed.

VIII. CONCLUSIONS AND PUBLIC HEALTH IMPLICATIONS

Technological advances have significantly changed our lives over the last century. The impact of these changes on behavior and chronic disease is not well understood. Public health scientists have learned a great deal about chronic disease treatment. However, there is considerably less information about the behaviors that cause or prevent these diseases. For example, the terms physical inactivity, physical activity, and physical fitness are often used interchangeably, but they are three different risk factors with different determinants and influences on health. Additionally, a standardized definition or term for sedentary behavior or sedentarism has not yet found its way into the field. This dissertation attempted to examine these aspects of human behavior.

With the increasing prevalence of many chronic diseases (Mack & Ahluwalia 2003; Pleis et al. 2006), physical activity research has rapidly expanded. Thirty years have passed since the first recommendations were published regarding physical activity (ACSM 1978). Yet, the optimal prescriptive dose of activity (intensity, frequency, duration) for disease prevention is still unclear (Kesaniemi et al. 2001).

As work on this dissertation was concluding, a group of experts met as part of a National Physical Activity Guidelines Advisory Committee to "[p]rovide science-based recommendations on the latest knowledge about activity and health"(Physical Activity Guidelines Advisory Committee Meeting 2007). However, very little research has been conducted to guide this committee concerning the relative contributions of components of physical activity. Even less research exists on the risks of spending the majority of the day being sedentary, sitting, and lying down. The average American household watches over eight hours of television each day (Nielsen Media Research, 2006). An immobile society has evolved as a consequence of the vast television and video technologies combined with the revolutionary changes in computer use. There is a pressing need for public health scientists to examine the effect of these sedentary pursuits on our risk profiles and health (ACSM 2007; Spanier et al. 2006). At the most recent ACSM conference there was a discussion of the necessity for a sedentary behavior recommendation (ACSM 2007). But before a scientific statement is made, we need a better understanding of measurement, determinants, and risks of these behaviors.

In the absence of a tool for sedentarism, television watching has become a surrogate measure. Using data from the ARIC study, we sought to describe the associations between television watching, physical activity, and diet. At baseline and six years follow-up, we explored television watching and the risk of being inactive or having an unhealthy diet. Individuals who reported high exposure to television watching were significantly more likely to be inactive and have a more unhealthy diet profile. These results persisted longitudinally, even when adjusting for the baseline associations. A graded relationship between television watching, physical activity, and diet behaviors was observed in all analyses. We found that in this population of US adults, sedentary behaviors could have deleterious effects on other chronic disease risk factors. It is the first study in adults to provide evidence for the possible displacement of physical activity by more sedentary pursuits. This study also highlights the need for better measurement tools.

While development of a sedentary behavior tool is important, it is equally crucial that measurement of physical activity continue to improve. For this to occur, new or adapted questionnaires must be developed that precisely and accurately quantify multiple domains of activity. Additionally, the measurement properties of questionnaires can help us understand patterns of behavior and how to improve questionnaires. The second paper in this dissertation examined the precision of the WHI physical activity questionnaire.

The WHI physical activity questionnaire was tailored for its audience of post-menopausal women. It included information on recreational activity and walking, as well as yard and household physical activities. The measures of moderate to vigorous physical activity demonstrated moderate to substantial test-retest reliability. The component questions on intensity, duration, and frequency were also reliably recalled by the women. On the other hand, mild activities were reported with less precision. This concurs with previous research that has shown that activities of low intensity are less memorable and prone to bias. This finding has important implications for development of a sedentary behavior questionnaire. If activities of mild intensity are easily forgotten, then completely sedentary, prevalent behaviors may also be difficult to measure.

One very positive aspect of the WHI questionnaire was the assessment of physical activity with regard to the components of intensity, frequency, and duration. All three components of walking were collected separately, in a way that allows investigators to explore the independent relationship of each with health outcomes. Because the physical activity recommendations for health (Pate et al. 1995) are specific with regard to intensity, frequency, and duration, it is vital to understand the relative importance of each. Very little research has been published on this topic (Kesaniemi et al. 2001). One reason is possibly because it is difficult to untangle the effect of each component from its contribution to total or recreational energy expenditure.

The final paper of this dissertation explored several methodologic approaches to this problem. In separate standard multivariable models, we examined each component of walking and risk of CHD with and without adjusting for energy expenditure from other activities. Using a term for recreational activity energy expenditure in a standard multivariable model helped control for the extra energy expended from the higher intensity, additional episode, or longer duration of a specific activity. However, the component (exposure) and energy expenditure (control) variable in this model were not completely independent.

Higher intensity, or pace of walking, was consistently and significantly associated with decreased risk of CHD. This finding is consistent with other cohort studies that have attempted to examine intensity of walking or physical activity. However, the majority of these studies have ignored the additional energy expenditure afforded by higher intensity. The components of frequency and duration showed a less consistent relationship with risk of CHD. A weaker gradient was observed with these two components, such that limited evidence of a beneficial effect was observed with shorter duration and infrequent walking. Significant risk attenuation was only seen in the highest categories of both frequency and duration. Furthermore, neither of the energy adjustment techniques appeared to significantly affect the conclusions. This analysis is the first epidemiologic study to examine the independent effect of intensity, frequency, and duration of walking on a health outcome while controlling for energy expenditure.

It is unlikely that there is one “optimal” physical activity recommendation that applies to all populations. But it is vital that research continue on the independent relationships of the components on health outcomes. Techniques to control for energy expenditure need to be applied to other populations and physical activity questionnaires. The current physical activity recommendations have been controversial since they were published (Barinaga 1997; Pate et al. 1995). Future recommendations need to be based on better measures of these risk behaviors and improved analytic methods. As public health practitioners, we risk alienating the public with drastic changes in recommendations or messages without a scientific basis. Exploration of the risks of sedentary behaviors, better measurement tools, and detailed assessment of physical activity will all contribute to more robust health recommendations.

IX. APPENDICES

Appendix A. Reliability and validity of the Baecke physical activity (PA) questionnaire

Reference	Population	Mean Values (SD)	Reliability	Validity
Baecke, Burema, Frijters 1982 Am J Clinc Nutr 36: 936-942	White, Dutch Age 20-22, 25-27, 30-32		3 month test- retest* Work 0.88 Sport 0.81 Leisure 0.74	(Older Dutch questionnaire) Product-moment Correlation coefficient:
	Dutch males N=139	men Work 2.6 (0.1) Sport 2.8 (0.1) Leisure 2.8 (0.1)		men Work 0.11 Sport –0.20 Leisure –0.29
	Dutch females N=167	women Work 2.9 (0.0) Sport 2.4 (0.1) Leisure 3.1 (0.0)		women Work 0.09 Sport –0.24 Leisure –0.18
Cauley, LaPorte, Sandler, Schramm, Kriska 1987 Am J Clin Nutr 45: 14-22	White, US post-menopausal N=255	Followup	None reported	Large-scale integrated (LSI) activity monitor, worn on hip, 3 days, in counts per day – Correlation coefficient[1]
	Intervention women	Work 2.7 (0.5) Sport 2.2 (0.7) Leisure 3.1 (0.6)		Work -0.11 Sport 0.17 Leisure 0.20
	Control women	Work 2.6 (0.4) Sport 2.0 (0.7) Leisure 2.7 (0.6)		Work 0.09 Sport 0.07 Leisure 0.16

[1] Undefined type of test or correlation

Reference	Population	Mean Values (SD)	Reliability	Validity
Albanes, Conway, Taylor 1990 Epidemiology 1: 65-71	White US men N=21 age 28-55 Energy Intake Level (n) 3257 (n=21) 2400-2800 kcal/day (n=5) 3200 kcal/day (n=9) 3600-4000 (n=7)	Overall Baecke index (sum of work, sport and leisure scores) 3257 kcal = 7.5 (0.4) 2400-2800 kcal/day = 6.8 (0.7) 3200 kcal/day = 7.5 (0.7) 3600-4000 kcal/day = 8.1 (0.5)		Energy-based validation Spearman Correlation Coefficient between total physical activity index and: 0.38 Energy Iitake 0.21 Energy intake – Resting Energy expenditure
Gretbeck, Montoye, 1990 MSSE 22: Abstract #474, p. S79	Male, US N=30 Mean age 37	N/A	N/A	Spearman rank order Caltrac 0.40 Daily physical activity record 0.53
Mahoney, Freedson 1990 MSSE 22: Abstract #475, p.S80	Females, US N=28 Aged 18-38	N/A	N/A	Caltrac R= 0.53 Work r= 0.10 Sport r=0.46 Leisure r=56
Voorrips, Ravelli, Dongelmans, Deurenberg, Staveren 1991 MSSE 23: (8) 974-979	White, Dutch Elderly N=60 (29 for reliability, 31 for validity study) Aged 63-80 26 men 34 women	Mean total activity baseline Men 11.0 (4.6)	20 day retest Spearman's 0.89	24-hr activity recall (3 times) Spearman's = 0.78 Pedometer Spearman's = 0.72

Reference	Population	Mean Values (SD)	Reliability	Validity
Rauh, Hovell, Hofstetter, Sallis, Gleghorn 1992 Int J Epidemiol 21(5): 966-71	Latino men and women N=45 Aged 18-55 (mean 33)	Work 2.2 (0.5) Sport 6.0 (9.2) Leisure 3.5 (2.6)	Pearson's, 2 week retest Work 0.87 Sport 0.79 Leisure 0.25	Caltrac: on hip 1 weekday and 1 weekend day Work 0.42 Sport 0.39 Leisure 0.41 Activity of subject as reported by significant other: Work 0.63 Sport 0.76 Leisure -0.05
Ainsworth, Jacobs, Leon, Richardson, Montoye 1993 J Occup Med. 35(10):1017-27.	Mostly white, college-ED, US N=75 Aged 23 –59 (mean 37) 27 Men 48 Women	Men Work 1.7 (0.3) Women Work 1.8 (0.4)	Pearson 1 month test-retest, age-gender adjusted Work 0.74	
Jacobs, Ainsworth, Hartman, Leon 1993 MSSE 25(1):81-91	Mostly white, college-ED US N=78 28 men 50 women	Men Work 1.7 (0.4) Sport 3.1 (0.9) Leisure 2.8 (0.5) Total 7.6 (1.3) Women Work 1.8 (0.4) Sport 2.9 (0.9) Leisure 2.8 (0.5) Total 7.5 (1.3)	Test-retest 1 month apart, age-gender adjusted Work 0.78 Sport 0.90 Leisure 0.86 Total 0.93	Age- gender adjusted correlation coefficients Caltrac MET min-day Work 0.11 Sport 0.32 Leisure 0.01 Total 0.19 VO_2 Work 0.23 Sport 0.52 Leisure 0.26 Total 0.54 Four week history Work 0.05 Sport 0.40 Leisure 0.28 Total 0.37

Reference	**Population**	**Mean Values (SD)**	**Reliability**	**Validity**
Richardson, Ainsworth, Wu, Jacobs, Leon Int J Epid 1995 24(4):685-93.	Mostly white, college-ED, US N=78 Aged 23 –59 (mean 37)		Pearson - 1 month test-retest, age-adjusted	Age-gender specific Pearson partial correlation coefficients
	28 Men	Men Total leisure 2.95(0.61) Sport leisure3.09 (0.92) Non-sport leisure 2.81 (0.50)	Men Total leisure: 0.92 Sport leisure: 0.92 Non-sport L: 0.88	48-hour Caltrac Men Total leisure: 0.24 Sport leisure: 0.34 Non-sport leisure: - 0.05
	50 Women	Women Total leisure 2.84 (0.68) Sport leisure 2.85 (0.93) Non-sport leisure 2.84 (0.56)	Women Total leisure: 0.90 Sport leisure: 0.87 Non-sport leisure: 0.86	Women Total leisure: 0.19 Sport leisure: 0.24 Non-sport leisure: 0.06
				VO_2 Men Total leisure: 0.57 Sport leisure: 0.67 Non-sport leisure: 0.13 Women Total leisure: 0.46 Sport leisure: 0.45 Non-sport leisure: 0.38
				48-hour PA record (Total MET min/day) Men Total L: 0.59 Sport L: 0.58 Non-sport L: 0.37 Women Total L: 0.33 Sport L: 0.24 Non-sport L: 0.42

Reference	**Population**	**Mean Values (SD)**	**Reliability**	**Validity**
Miller, Freedson, Kline 1994 MSSE 26(3):376-82	Physical therapists N=33 Mean age 28 7 men 26 female	N/A	N/A	Spearman rank Caltrac= 0.32 Corrected caltrac=0.40 7day recall=0.07 3 day recall=0.13 Caltrac Adjusted r2 from regression Caltrac = 0.46 Corrected = 0.54 (adjusted for underestimation)
Canon, Levol, Duforez 1995 J Cardiovasc Pharmacol 25 Suppl 1:S28-34	French men (white?) N=264 Aged 27-60 195 control 69 intervention	Control Sport index 2.24 (1.16) Leisure index 2.89 (0.5) Intervention Sport index 2.29 (1.25) Leisure index 2.70 (0.54)		VO_2 max correlation Control Sport 0.31 Leisure 0.09 Intervention Sport 0.11 Leisure 0.089
Pols, Peeters, Bueno-De-Mesquita, Ocke, Wentink, Kemper, Collette 1995 Int J Epidemiol 24(2):381-8	Dutch men and women N=126 Aged 20-70 64 men 62 women	Baseline scores 11/1991 Men Work 2.6 (0.6) Sport 2.7 (0.8) Leisure 2.8 (0.5) Women Work 2.7 (0.5) Sport 2.1 (0.7) Leisure 2.6 (0.5)	Pearsons Correlation coefficient between 1st and 2nd (5 months) between 1st and 3rd (11 months) Range 0.65-0.89 Cohen's kappa 55.7% men 45.5% women	Three day activity diary (Bouchard) Pearsons correlation coefficient between total index and mean energy expenditure 0.56 for men 0.44 for women

Reference	Population	Mean Values (SD)	Reliability	Validity
Pols, Peeters, Kemper, Collette 1996 MSSE 28(8):1020-5	Dutch women N=33 Aged 51-71	Mean total baseline 7.31 (0.93)	Pearsons correlation coefficient 5 months – 0.82 11 months – 0.73	Pearsons correlation coefficients Caltrac r=0.22 Bouchard 3 day history r=0.51
Philippaerts, Lefevre 1998 Am J Epidemiol 15;147(10):982-90	Flemish males (Belgian) N=90 Aged 30-40		Test-retest Intraclass correlation coefficients Work 0.95 Sport 0.93 Leisure 0.87 Kappa Work 0.69 Sport 0.61 Leisure 0.59	
Philippaerts, Westerterp, Lefevre 1999 Int J Sports Med 20(5):284-9	Flemish/Belgian males N=19 Aged 40 yrs		Given baseline, day 7, day 14	Doubly labeled water Pearson's correlation coefficient ADMR (average daily metabolic rate) Work 0.37 Sport 0.46 Leisure 0.50 Total 0.68 PAL Work 0.52 Sport 0.55 Leisure 0.22 Total 0.69

Reference	Population	Mean Values (SD)	Reliability	Validity
Philippaerts, Westerterp, Lefevre 2001 Int J Sports Med 22(1): 34-9	Flemish/Belgian males N=166 Aged 40 yrs	Work 2.3 (0.6) Sport 2.7 (0.8) Leisure 2.7 (0.6) Total 7.7 (1.2)	None	Tracmor (triaxial accelerometer) Pearson correlation coefficient Work 0.26 Sport 0.37 Leisure 0.19 Total 0.47 VO2 max Work 0.11 Sport 0.47 Leisure 0.28 Total 0.49

List of abbreviations in table

Kcal – kilocalories
Kcal/day – kilocalories per day
VO_2 – volume of oxygen consumption (milliliters of oxygen per minute per kilogram)
MET - metabolic equivalents of task
ADMR (average daily metabolic rate)

Appendix B. Ancillary television data on Baecke question with continuous measure of television hours, data from Leuven, Belguim (Hulens 2003)

Baecke categorical	N	Mean Hours of Television (95% CI)	Minimum, Maximum	Median	25%ile, 75%ile
Never	7	0.53 (-.29, 1.35)	0, 3.0	0.0	0.0, 0.5
Seldom	29	1.07 (0.74, 1.40)	0, 4.0	1.0	0.5, 1.0
Sometimes	138	2.04 (1.90, 2.18)	0.3, 5.0	2.0	1.5, 3.0
Often	97	3.74 (3.47, 4.01)	1.0, 6.0	4.0	2.5, 5.0
Very Often	6	4.6 (2.62, 6.56)	1.5, 8.0	4.0	3.0, 7.0

Citation: M. Hulens, personal communication, May 2004

Appendix C. ARIC physical activity and dietary variable quantification

Variable	Previous ARIC specification	Coding used in analyses	Variable names - derivations
Exposure			
Television Definition 1	Likert: (1-never, 2-seldom, 3-sometimes, 4-often, 5- very often)	Categorical – dummy coding	Visit 1 Baecke = #C28 – "RPAA67"
Television Definition 2	Likert	Categorical – dummy coding Low (never, seldom) Medium (sometimes) High (often, very often)	RPAA67
Television Definition 3	Likert	Dichotomized – Often + very often Never + seldom + sometimes	RPAA67
Outcomes			
Sport physical activity Index	Semi-continuous	Categorical – dummy variables 1 (low) to 5 (high)	SPRT_I02 = #'s (I9 + I10 +I11 + I12)/4.
Work physical activity Index	Semi-continuous	Categorical – dummy variables 1 (low) to 5 (high)	WORK_102 = #'s [I1 + (6 - I2) + I3 + I4 + I5 + I6 + I7 + I8]/8.
Regular physical activity	*None*	Dichotomized Inactive Active	FinalPA - [1 hour per week, 10 months per year]
Fruit*	*None*	Continuous – diet quality Combined servings per day of apples, pears, oranges, orange/grapefruit juice, peaches/apricots/plums, bananas and other fruit Categorical – Tertile	Fruit – [DTIA09 + DTIA10 + DTIA11 + DTIA12 + DTIA13 + DTIA14]
Vegetables*	*None*	Continuous Combined servings per day of beans, broccoli, cabbage/cauliflower or sprouts, spinach, collards, greens, peas, squash, sweet potatoes, beans or lentils and tomatoes (excludes white potatoes) Categorical – Tertile	Veggie - [DTIA15 + DTIA16 + DTIA17 + DTIA18 + DTIA19 + DTIA20 + DTIA21 + DTIA22 + DTIA23 + DTIA24 + DTIA25]
Salty snacks*	*None*	Continuous Combined servings per day potato or corn chips, French fries, or nuts Categorical –	Sltsnck – [DTIA53 + DTIA54 + DTIA55]

Variable	Previous ARIC specification	Coding used in analyses	Variable names - derivations
		Tertile	
Sweets*	*None*	Continuous Combined servings per day chocolate bar/pieces, candy, pie, donuts, biscuits, pastry/Danish, cake/brownie and cookies Categorical – Tertile	Sweet- DTIA39 + DTIA40 + DTIA41 + DTIA42 + DTIA43 + DTIA44 + DTIA45 + DTIA46 + DTIA47
Sugared drinks*	*None*	Continuous Combined servings per day regular soda and sugared fruit drinks Categorical – Tertile	[DTIA64 + DTIA65]
Total kcal	Continuous	Continuous Energy intake in kilocalories Categorical – Tertile	TCAL – derived in data
Total fat	Continuous	Continuous Total fat in grams Categorical – Tertile	TFAT– derived in data
Covariates			
Gender	Categorical	Dichotomized Female Male	GENDER
Race	Dichotomized	Dichotomized White African American	RACEGRP1
Age	Continuous	Continuous	V1AGEZ1 – directly from data
Smoking	Categorical	Categorical – dummy variables Current smoker Former smoker Never smoker Unknown	CIGT01 – derived in data
Employment	Categorical	Categorical – dummy variables	HOM55 + HOM57 – derived in data
Work2	*None*	Categorical Currently employed Unemployed	Work2
General Health Condition	Categorical	Categorical – dummy variables Excellent Good Fair	HOM09 – directly from data

Variable	Previous ARIC specification	Coding used in analyses	Variable names - derivations
		4 – Poor	
Race*Center	Categorical	Categorical – dummy variables African-American Forsyth, NC African-American Jackson, Mississippi White Forsyth, NC White Washington Co, MD White Minneapolis, MN	Directly from data
Education	Categorical	Categorical – dummy variables	ELEVEL02 -– derived in data

* Single food items combined together make up the diet quality variables. Each food item has 9 potential responses from the questionnaire which must be weighted in order to transform them into servings per day.
The appropriate weighting is as follows:

Questionnaire	*Serving frequency*	*Transformation freq/week*	*Transformation freq/day*
A - (>6/day)	6/day	42/week	6/day
B - (4-6 day)	5/day	35/week	5/day
C - (2-3/day)	2.5/day	17.5/week	2.5/day
D - (1/day)	1/day	7/week	1/day
E - (5-6/week)	5.5/week	5.5/week	0.79/day
F - (2-4/week)	3/week	3/week	0.43/ day
G - (1/week)	1/week	1/week	0.14/ day
H - (1-3/month)	0.5/week	.5/week	0.066/ day
I - (almost never)	0/week	0/week	0

Appendix D. Description and scoring of WHI physical activity questionnaire

Question	Responses	Scoring

The following questions are about your usual physical activity and exercise. This includes walking and sports.

Question	Responses	Scoring
1. Think about the walking you do outside the home. How often do you walk outside the home <u>for more than 10 minutes without stopping?</u> (Mark only one.)	Rarely or never 1-3 times each month 1 time each week 2-3 times each week 4-6 times each week 7 or more times each week	0 -- skip to #2 0.5 times 1.0 times 2.5 times 5.0 times 7.0 times
1.1 When you walk outside the home for more than 10 minutes do you usually walk?	Less than 20 min. 20-39 min. 40-59 min. 1 hour or more	15 min 30 min 50 min 70 min
1.2 What is your usual speed?	Casual strolling or walking (less than 2 miles an hour) Average or normal (2-3 miles an hour) Fairly fast (3-4 miles an hour) Very fast (more than 4 miles an hour) Don't know	2.0 METs 3.0 METs 4.0 METs 5.0 METs 2.0 set to lowest MET intensity

Not including walking outside the home, <u>how often each week</u> (7 days) do you usually do the exercises below?

Question	Responses	Scoring
2. STRENUOUS OR VERY HARD EXERCISE (You work up a sweat and your heart beats fast.) For example, aerobic dancing, jogging, tennis, swimming laps.	None 1 day per week 2 days per week 3 days per week 4 days per week 5 or more days per week	0 – skip to #3 1 times 2 times 3 times 4 times 6 times

2.1 How long do you usually exercise like this at one time?	Less than 20 min. 20-39 min. 40-59 min. 1 hour or more	10 min 30 min 50 min 70 min
3. MODERATE EXERCISE (Not exhausting). For example, biking outdoors, using an exercise machine (like a stationary bike or treadmill), calisthenics, easy swimming, popular or folk dancing.	None 1 day per week 2 days per week 3 days per week 4 days per week 5 or more days per week	0 – skip to 4 1 times 2 times 3 times 4 times 6 times
3.1 How long do you usually exercise like this at one time?	Less than 20 min. 20-39 min. 40-59 min. 1 hour or more	10 min 30 min 50 min 70 min
4. MILD EXERCISE. For example, slow dancing, bowling, golf.	None 1 day per week 2 days per week 3 days per week 4 days per week 5 or more days per week	0 -- skip to 5.1 1 times 2 times 3 times 4 times 6 times
4.1 How long do you usually exercise like this at one time?	Less than 20 min. 20-39 min. 40-59 min. 1 hour or more	10 min 30 min 50 min 70 min

For each of the ages below, did you usually do strenuous or very hard exercises at least 3 times a week? This would include exercise that was long enough to work up a sweat and make your heart beat fast. (Be sure to mark “No” if you did not do very hard exercises at the ages listed below.)

5.1 18 years old	No Yes	0 1
5.2 35 years old	No Yes	0 1
5.3 50 years old	No Yes	0 1

The next set of questions ask about some of your usual activities

6. About how many hours each week do you usually spend doing heavy (strenuous) indoor household chores such as scrubbing floors, sweeping or vacuuming?	Less than 1 hour 1-3 hours 4-6 hours 7-9 hours 10 or more hours	0 2.0 hours 5.0 hours 8.0 hours 12.0 hours
7. About how many months during the year do you usually do things in the yard, such as mowing, raking, gardening, or shoveling snow?	Less than one month 1-3 months 4-6 months 7-9 months 10 or more months	0 3.0 months 5.0 months 8.0 months 11.0 months
7.1 When you do these things in the yard how many hours <u>each week</u> do you do them?	Less than 1 hour 1-3 hours 4-6 hours 7-9 hours 10 or more hours	0 2.0 hours 5.0 hours 8.0 hours 12.0 hours
8. During a usual <u>day and night</u> about how many hours do you spend sitting? Be sure to include the time you spend sitting at work, sitting at the table eating, driving or riding in a car or bus, and sitting up watching TELEVISION or talking.	Less than 4 hours 4-5 hours 6-7 hours 8-9 hours 10-11 hours 12-13 hours 14-15 hours 16 or more hours	2.0 hours 4.5 hours 6.5 hours 8.5 hours 10.5 hours 12.5 hours 14.5 hours 16.5 hours
9. During a usual <u>day and night</u> about how many hours do you spend sleeping or lying down with your feet up? Be sure to include the time you spend sleeping or trying to sleep at night, resting or	Less than 4 hours 4-5 hours 6-7 hours	2.0 hours 4.5 hours 6.5 hours

napping, and lying down watching TELEVISION	8-9 hours 10-11 hours 12-13 hours 14-15 hours 16 or more hours	8.5 hours 10.5 hours 12.5 hours 14.5 hours 16.5 hours

Appendix E. Pearson correlations between total recreational physical activity energy expenditure and walking components n=71,502

	Total Recreational Physical Activity	Walking Total	Walking Intensity	Walking Frequency	Walking Duration
Total Recreational Physical Activity	1				
Walking Total	0.61	1			
Walking Intensity	0.41	0.58	1		
Walking Frequency	0.44	0.72	0.64	1	
Walking Duration	0.44	0.70	0.66	0.62	1

Appendix F. Pearson correlations between walking components stratified by tertile of recreational physical activity energy expenditure n=71,502

	Walking Intensity	Walking Frequency	Walking Duration
Tertile 1: 0 to 5 MET-hours per week (n=22854)			
Walking Intensity	1		
Walking Frequency	0.61	1	
Walking Duration	0.72	0.56	1
Tertile 2: 5 to 16.2 MET-hours per week (n=24611)			
Walking Intensity	1		
Walking Frequency	0.46	1	
Walking Duration	0.48	0.43	1
Tertile 3: 16.2 MET-hours per week (n=24037)			
Walking Intensity	1		
Walking Frequency	0.51	1	
Walking Duration	0.51	0.50	1

Appendix G. Test-retest reliability of the categories for each walking component in the WHI Measurement and Precision Study (n=569)

Walking Component	Simple Kappa	95% CI
Walking Intensity (speed)		
No walking	0.58	0.50, 0.67
Causal or slow walking	0.48	0.39, 0.57
Average or normal walking	0.46	0.38, 0.53
Fairly fast	0.60	0.52, 0.70
Very fast	0.33	-0.02, 0.67
Walking Frequency		
0 days per week	0.58	0.50, 0.67
1-3 times per month	0.23	0.12, 0.33
1 time per week	0.18	0.07, 0.30
2-3 times per week	0.36	0.27, 0.44
4-6 times per week	0.47	0.38, 0.56
7 or more times per week	0.40	0.26, 0.56
Walking Duration		
0 minutes	0.58	0.50, 0.67
0 – 19 minutes	0.40	0.31, 0.50
20 – 39 minutes	0.46	0.39, 0.54
40 – 59 minutes	0.45	0.34, 0.56
1 hour or more	0.63	0.50, 0.77

Table H. Hazard ratios associated with a 10-point increase in the residualized value of each walking component and risk of coronary heart disease n=71,502

	Multivariable* Hazard Ratio (95% CI)
Walking Intensity residual (10 point increase)	0.43 (0.32, 0.59)
Walking frequency residual (10 point increase)	0.80 (0.66, 0.97)
Walking duration residual (10 point increase)	0.96 (0.93, 0.98)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Table I. Hazard ratios associated with the residualized value of each walking component dichotomized at the mean and risk of coronary heart disease n=71,502

	Multivariable* Hazard Ratio (95% CI)
Walking intensity dichotomized at mean	0.82 (0.76, 0.88)
Walking frequency dichotomized at mean	0.92 (0.85, 0.99)
Walking duration dichotomized at mean	0.90 (0.84, 0.97)

* Adjusted for age, region, general health status, smoking, caloric intake, martial status, income, education, occupation, and race/ethnicity

Appendix J. Hazard ratios and 95% confidence intervals associated with walking intensity, frequency, and duration and risk of coronary heart disease – crude, multivariable, and total activity energy expenditure adjustment (recreational physical activity, yard, and household activity) n=71,502

	Crude	Multivariable* adjusted Hazard Ratio (95% CI)	Energy** Adjusted Hazard Ratio (95% CI)
Walking Intensity (speed)			
No walking	ref	ref	ref
Causal or slow walking	1.21 (1.08,1.35)	1.13 (1.00, 1.26)	1.13 (1.00, 1.26)
Average or normal walking	0.78 (0.71,0.87)	0.89 (0.80, 0.99)	0.89 (0.80, 0.99)
Fairly fast	0.48 (0.42,0.54)	0.66 (0.57, 0.75)	0.65 (0.57, 0.75)
Very fast	0.21 (0.11,0.40)	0.36 (0.19, 0.68)	0.36 (0.19, 0.68)
Walking Frequency			
0 days per week	ref	ref	ref
1-3 times per month	0.83 (0.73,0.95)	0.95 (0.84, 1.09)	0.96 (0.84, 1.09)
1 time per week	0.81 (0.70,0.94)	0.94 (0.81, 1.08)	0.94 (0.82, 1.09)
2-3 times per week	0.81 (0.72,0.90)	0.93 (0.83, 1.04)	0.95 (0.84, 1.06)
4-6 times per week	0.74 (0.66,0.83)	0.88 (0.78, 0.99)	0.91 (0.80, 1.03)
7 or more times per week	0.62 (0.52,0.73)	0.76 (0.64, 0.90)	0.80 (0.67, 0.96)
Walking Duration			
0 minutes	ref	ref	ref
0 – 19 minutes	0.92 (0.82,1.03)	0.98 (0.88, 1.10)	0.98 (0.88, 1.11)
20 – 39 minutes	0.80 (0.72,0.89)	0.93 (0.83, 1.03)	0.94 (0.84, 1.05)
40 – 59 minutes	0.60 (0.53,0.69)	0.79 (0.69, 0.91)	0.81 (0.70, 0.94)
1 hour or more	0.54 (0.44,0.65)	0.69 (0.56, 0.83)	0.71 (0.58, 0.88)

* Adjusted for age, region, general health status, martial status, income, education, and race/ethnicity
** Adjusted for Total activity energy expenditure (recreational, yard, household), age, region, general health status, martial status, income, education, and race/ethnicity

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