# ASSOCIATION OF OVERALL DIET QUALITY WITH FALLS AND PHYSICAL FUNCTION AMONG COMMUNITY DWELLING OLDER ADULTS - RESULTS FROM MrOS STUDY

by

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Submitted to the Graduate Faculty of

the Graduate School of Public Health in partial fulfillment of

the requirements for the degree of

Master of Science

University of Pittsburgh

2014

UNIVERSITY OF PITTSBURGH

Graduate School of Public Health

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## ABSTRACT

Falls among people aged 65 and older are recognized as an issue of public health significance in the United States which faces an increasingly aging society. The current study tests the hypothesis that lower diet quality is prospectively associated with incident falls and whether physical function as assessed by gait speed is a mediator of this association. For our prospective analysis, we studied 5849 men enrolled in the Osteoporotic Fractures in men study (MrOS). All men in MrOS were $\geq$ age 65 at baseline. Overall diet quality as assessed by Healthy Eating Index (HEI-2010) scores were calculated from a reduced version Block 98 food-frequency questionnaire and categorized into quartiles. An indicator variable for incident falls was computed using falls categorized by a yes/no response and number of falls reported at follow-up of 12 months. Recurrent falls were classified as ($\geq$2) vs single (1) or no fall (0). Gait speed was measured in meters/second on a standard six meter walking course. Multiple logistic regression methods were used to test the association between HEI-2010 scores and incident falls after adjusting for age, race, clinic site, smoking status, physical activity, Body Mass Index, diabetes, stroke, parkinson's disease, glaucoma, selective serotonin reuptake inhibitor antidepressants, tricyclic antidepressants, antidepressants, benzodiazepines and gait speed.

At the end of the follow-up period of 1 year, 1473 (25.7%) experienced a fall (≥1), 685 (11.7%) experienced recurrent falls (≥2). Compared to older men with the highest HEI-2010 scores, those with the lower HEI-2010 scores had a similar risk of falls. There was no significant association with falls in the unadjusted or adjusted models. Additional adjustment for gait speed showed similar associations. For recurrent falls, compared to men with the highest HEI-2010 scores, older men with the lower HEI-2010 scores had a higher risk of recurrent falls in the unadjusted model which remained significant after adjustment for age, race, clinic site (p trend=0.02), lifestyle factors including smoking status and physical activity (p trend=0.03) and BMI (p trend=0.04). Further adjustments for comorbidities reduced the overall significance of the trend (p trend=0.07). Finally adjusting for gait speed, there was no significant association although the risk for falls marginally increased (p trend=0.12). We concluded that there was no significant association between diet quality and incident falls.

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# 1.0 INTRODUCTION

This document reviews the definition, epidemiology and prevalence of their falls; economic and psychosocial impacts on older adults living in the community and various contributing factors to the occurrence of falls. It also reflects the current understanding of complex risk factors such as impaired gait speed and poor nutrition that directly or indirectly contribute to the occurrence of falls. This study prospectively examines the relation between diet quality and incident falls in a large community-based population of older men. It also tests the hypothesis that gait speed may mediate the effect of diet quality on fall risk.

## 2.0 OBJECTIVES

- Test the hypothesis that lower diet quality at baseline is prospectively associated with incident falls.

- To examine whether physical function as assessed by gait speed mediates the association between diet quality and incident falls.

# 3.0 LITERATURE REVIEW

## 3.1 DEFINITION OF A FALL

There is no ‘gold standard’ definition for falls despite being intuitively understood and studied for well over two decades. One of the earliest known definitions of falls that was found in the literature is the one consistent with the *International Classification of Disease (ICD-9).* According to the *WHO ICD-9 (1977)*, ‘a fall is an unexpected event where a person falls to the ground from an upper level or the same level.’ Following this, a fall results when the vertical line which passes through the center of mass of the human body comes to lie beyond the support base and correction does not take place in time (*Isaac B, 1985*). This purely defines fall in terms of a mechanical process, and is not a practical definition which can be used in a research setting. Another definition that is used more often in research defines falls as ‘unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke and epileptic seizure (*Kellogg International Working Group, 1987*).

These definitions two decades ago started off by being relatively broad and general. The Kellogg’s definition was specifically developed for studies aimed at identifying factors that impair sensorimotor function and balance control. However, broader definitions to include other causes such as cardiovascular causes of falls (postural hypotension, transient ischaemic attacks) were needed. Hence, depending on the focus of the study, researcher started to use such broader definitions of falls to include those that occurred as a result of dizziness, syncope or other reasons.

*The Frailty and Injuries: Co-operative Studies of Intervention Techniques (FICSIT)* defined falls as 'unintentionally coming to rest on the ground, floor or other lower level.' This broad definition could also include some stumbles and therefore the FICSIT centers also used modified definitions for their other studies. For example, the Atlanta group used the FICSIT definition as well as a narrower modified version, which excludes stumbles (*Wolf et al., 1996*). In their particular study of a 15-week Tai-Chi intervention, there was a significant reduction in falls (unadjusted) using the FICSIT definition but no significant reduction using the modified definition. This highlights that a small alteration in fall definition can alter the main message resulting from research studies.

*The American Nurses Association-The National Database of Nursing Quality Indicators (ANA-NDNQI, 2005*) defines fall as 'an unplanned descent to the floor (or extension of the floor, e.g., trash can or other equipment) with or without injury.' This definition comprises of all kinds of falls including those resulting from physiological reasons (eg. fainting) or environmental reasons (eg. slippery surface).

Based on a review of these definitions, it makes it clear that the definition of falls is diverse and there is a need for a standardized definition in order to make studies comparable. Wordings such as 'involuntary', 'unintentional', 'unexpected', 'inadvertent', 'unplanned', or 'sudden' describes an external perspective not always experienced or verbalized by fallers. Commonly used wordings may include stumbling, slipping or tripping. There is a gap in the way medical and lay community perceives falls and this area clearly needs more work. In the present study, although there is no clear definition for falls, we define frequency of falls (*Karlsson et al., 2012*); recurrent fallers are individuals who had more than one fall, occasional fallers are individuals who had one fall, and non-fallers are individuals who had no falls during the 12-month period, a time frame suggested by *Lamb et al. (2005)*.

## 3.2 EPIDEMIOLOGY AND PUBLIC HEALTH IMPACT OF FALLS

According to the 2010 census (*US Census Bureau, 2010*), 40 million people aged 65 and over live in the United States, which accounted for 13 percent of the total population. It also projects that the population aged 85 and over could grow from 5.5 million in 2010 to 19 million by 2050. Literature suggests that as individuals age, their susceptibility to falls increases. In 2001, the rates of fall injuries for adults 85 and older were four to five times that of adults 65 to 74 years (*Stevens et al. 2005*). In an earlier study, it was reported that in hospitals, falls are the largest single category of reported incidents (*Joint Commission Resources, 2005*). More recently, *Levinson (2010)* estimated that the national incidence of falls was 28% among Medicare beneficiaries admitted to hospitals. In the community setting, up to one-third of people over age 65 had a fall each year (*Tinetti et al., 1994*). About a decade later, 35-45% of community-dwelling adults reported a fall every year (*American Geriatrics Society et al., 2001*), similar to earlier statistics.

Recently, *Tinetti et al. (2010)* concluded that more than one-third of persons 65 years of age or older fall each year, and in half of such cases, the falls are recurrent. The risk doubles or triples in the presence of cognitive impairment or history of previous falls. Falls are recognized as a leading cause of injury and death, particularly in the elderly (*Spellbring, 1992*). Of all fall- related deaths in the United States, three-fourths occur among the elderly (*Rubenstein et al, 2006*). Between 1993 and 2009, the death rates from falls among older men and women have risen sharply (*CDC, 2010*). The most common fall-related injury among older adults are fractures (*Bell et al.,* *2000*). Of these, the most serious injury is hip fracture, a leading cause of morbidity and excess mortality among older adults (*Cummings et al., 1985*, *Leibson et al., 2002*). Ninety five percent of hip fractures in older adults result from a fall (*Nyberg L., 1996*) and mortality rates following hip fractures remain elevated for up to 10 years (SMR=2.58, 95% CI 1.29-5.17) (*Bliuc D, 2009*).

The financial costs associated with fall-related injuries are overwhelming. The total direct cost for falls among older adults in 2000 was about $19 billion (*Stevens et al., 2006*). With regards to the economic cost of falls, recently *Davis et al. (2010)* published that the mean cost of falls ranged from US $3476 per faller to US $10,749 per injurious fall to US $26,483 per fall requiring hospitalization. Given the growing population of this age group, this cost is expected to reach $43.8 billion by 2020 (*Englander et al., 1996*). In addition, falls can impact the emotional and psychological well-being. Older adults who sustain a fall develop a fear of falling that decreases their quality of life and causes them to limit their activities (*Zijlstra et al., 2005*). In summary, given the physical, psychological and financial burden of falls, prevention is an urgent public health concern in the United States which faces an increasingly aging society.

## 3.3 RISK FACTORS FOR FALLS

The ability to maintain one's stability is dependent on the intricate functioning of sensory, central integrative and musculoskeletal effector components (*Thomas et al., 2003*). As a result, the risk for falls is multifactorial. Studies examining the risk factors for falls and recurrent falls in different study designs (*Conroy, 2009*) are presented in Table 1 and Table 2.

*Rubenstein et al.* (2002) established the major causes of falls in elderly adults as being accident or environment related (31%), gait or balance disorders (17%), dizziness (13%), drop attack (sudden falls without loss of consciousness or dizziness) (9%) and confusion (5%). Risk factors such as postural hypotension (3%), visual disorders (2%) and syncope (0.3%) accounted for a very low proportion of falls. *Kron et al.* (2003) identified several risk indicators for falls in a prospective observational study with 1- year follow-up in a sample of institutionalized frail elderly. Short-term memory loss, transfer assistance, urinary incontinence, positive fall history were indicated as predictors of falls. Depressive symptoms, urinary incontinence and positive fall history were associated with frequent falls. *Inouye et al. (2007)* reviewed 12 studies and identified that older age, prior history of falls, functional impairment, use of a walking aid or assistive device, cognitive impairment or dementia, impaired mobility or low activity level, and balance abnormalities were the main causes for falls in older adults. *Ganz et al. (2007)* reported that the most consistent predictors of future falls were clinically abnormal gait or balance disorders (likelihood ratio range, 1.7–2.4). Most recently, *Ambrose et al. (2013)* summarized the major risk factors of falls among older adults and identified them as impaired balance and gait, polypharmacy, and history of previous falls. Other risk factors include advancing age, female gender, visual impairments, cognitive decline especially attention and executive dysfunction and environmental factors.

**Table 1. Overview of studies examining the risk factors for falls**

| Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|
| Graafmans et al. (1996) | Prospective study | n=354<br>Age=> 70 years<br>Community dwelling<br>Duration=28 weeks | Medical history: Poor distance vision, history of stroke, dizziness upon standing, falls in previous year, lower extremity disabilities, medicines.<br>Physical activity<br>Mobility impairment tests:<br>Score (0 - 4)<br>Balance-Tandem stand test<br>Leg-extension strength<br>3 m walk<br>Assistive devices<br>Cognitive test: MMSE Score (0-30)<br>Geriatric Depression scale<br>Postural blood pressure change | Any falls ( >1)<br>Recurrent falls ( >2) | Association with falls:<br>Mobility impairment (OR=2.6)<br>Dizziness (OR = 2.1)<br>Association with recurrent falls:<br>Mobility impairment (OR=5.0)<br>History of stroke (OR=3.4)<br>Poor mental state (OR=2.4)<br>Postural hypotension (OR=2.0) |
| Sakamoto (2006) | Intervention | n=553<br>Age=37-102 years<br>Community dwelling<br>Duration=6 months | Age, frequency of falls, fracture site, number of falls 6 months prior to the start of study, medical conditions among subjects | Number of falls and hip fractures | Cumulative number of falls:<br>Exercise group=118<br>Control group=121<br>Cumulative hip fractures:<br>Both=1 |
| Clough-Gorr (2008) | Intervention | n=1644<br>Age=>80 years | Validated questions on falls, mobility disability status (high | Incidence of falls | Overall incidence= 24%<br>Incidence increased by: |

**Table 1 Continued**

| Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|
| | | Community dwelling Duration=12 months | function, preclinical disability, task difficulty), and demographic and health-related characteristics | Predictors of falls | Worsening mobility disability status, High function (17%) Preclinical disability (32%) Task difficulty (40%) ($p < .003$) Predictors of falls: Moderate predictors - Depressive mood, limitation in ≥1 instrumental ADL, and use of ≥4 medications (not all statistically significant). Strongest predictors: Mobility disability status (OR = 1.7, 95% confidence interval [CI], 1.1-2.5) History of falls (OR = 1.7, 95% CI, 1.0-3.0) |
| Tinetti et al. (2008) | Intervention | N=204846 persons and 16,9995 households Age=>70 years Hospital based Duration=4 years | Age, Time between (evaluation vs intervention), sex, the proportion of residents over the age of 65 years who were nonwhite, resided in a nursing home, or lived in the community but reported having a disability; and the proportion of | Serious fall related injuries and use of medical practices | Adjusted rate ratio, 0.91; 95% credibility interval, 0.88 to 0.94 |

**Table 1 Continued**

| Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|
| | | | households headed by persons over the age of 65 years with an income of less than $15,000 or more than $75,000 | | |
| American Geriatric Society (2002) | Systematic reviews, RCTs, meta-analysis, cohort studies, non-randomized clinical trial, case control studies, cohort studies | n=16 studies Community dwelling (8), nursing home (8) | Risk factors | Data related to fall risk or fall prevention | Mean RR-OR<br>Muscle weakness (4.4)<br>History of falls (3.0)<br>Gait and Balance deficits (2.9)<br>Use of assistive device (2.6)<br>Visual deficits (2.5)<br>Arthritis (2.4),<br>IADL (2.3)<br>Depression (2.2)<br>Cognitive impairment (1.8)<br>Age over 80 (1.7) |
| Moreland et al. (2004) | Meta-analysis of prospective studies | n=13 studies<br>Age=>55 years<br>Community dwelling and nursing homes<br>Duration= 3 months to 3 years | Manual muscle testing or grip strength | Any fall during follow-up, recurrent falls or injurious falls | Lower extremity weakness:<br>Falls (OR=1.76)<br>Recurrent falls (OR=3.06)<br>Injurious falls (OR=1.52)<br>Upper extremity weakness:<br>Falls (OR=1.53)<br>Recurrent falls (OR=1.41)<br>Injurious falls (OR=1.5) |
| Gill et al. (2005) | Population-based survey<br>Retrospective | n=2619 interviews<br>Age=>65 years | Demographics<br>Falls ascertainment<br>General health | Falls<br>Number of falls | Female (OR=1.27)<br>Age 80 and over (OR=1.97) |

**Table 1 Continued**

| Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|
| | | Community dwelling Duration=12 months | | | Poor general health (OR=1.69) Living alone (OR=1.45) Not married (OR=1.42) |
| Sayer et al. (2006) | Cohort study | n=2148 participants Age=59-73 years Community dwelling Duration=1998-2004 | Medical and social history, including self-reported walking speed (six categories: unable to walk, very slow, stroll at an easy pace, normal speed, fairly brisk, and fast), alcohol intake (units per week), smoking habit (three categories: never, former, and current smoker), and social class, any falls in the past year, Anthropometric measures, skinfold thickness, grip strength, conditional infant growth. | Fall prevalence History of falls | Fall prevalence among men=14.3 % Lower conditional infant growth is significantly associated with a history of falls in older men. |
| Ganz et al. (2007) | Prospective cohort | n=18 studies Age=>65 years | Orthostatic Hypotension, visual impairment, gait or balance impairment, medication use, cognitive impairment, limitations in basic or instrumental activities of daily living | Falls | Baseline history of falls > 1 fall in 1 year (LR=2.8) > 1 fall in 11 months(LR=3.8) Orthostatic hypotension (LR=1.4) Gait or balance abnormalities (LR=1.9) 4 or more medications(LR=1.9) |

**Table 1 Continued**

| Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|
| | | | | | ADL/IADL(LR=4.3)<br>Cognitive impairment (LR=4.2) |
| Ambrose et al. (2013) | Literature Review | - | Performance oriented Mobility assessment<br>Four square step test<br>SPPB<br>Berg Balance scale<br>Mini-balance evaluation systems test<br>Dynamic gait index test<br>Timed up and go test | Risk Factors for Fall | Multiple missteps (RR=3.89)<br>Unsteady gait (RR=1.52)<br>Neuropathic gait (RR=1.94)<br>Slower gait speed (RR/10 cm/s < 1.069)<br>Lower extremity strength (OR=1.76)<br>Cognition (OR=2.13)<br>Uncontrolled hypertension (Hazard ratio=2.5)<br>Medications:<br>Benzodiazepines (OR=1.41)<br>Diabetes Medication |

**Table 2. Published summary of studies examining the risk factors for falls**

(*Conroy S, 2009*)

| **Risk factor** | **Source**<br>**(SR=Systematic review, R=Review, C=Cohort, MA=Meta-Analysis)** | **Approximate measure of effect** |
|---|---|---|
| **Age** | Iinattiniemi S, 2009, C , Segev-Jacubovski O, 2011, R, Dunlop D, 2002, C | Odds ratio ~ 2 |
| **History of falls** | Capon 2007, C, Morris 2007, C, Pluijm 2006, C, Papaioannou 2004, C, Stalenhoef 2002, C | Odds ratio ~ 2.6 |
| **Balanced Deficit** | Piirtola 2006, R, Pluijm 2006, C, Delbaere 2006, C, Stalenhoef 2002, C, Clark 2005, C | Odds ratio ~ 4 |
| **Reduced mortality** | Morris 2007, C, Tiedemann 2008, C | Odds ratio 3.7 |
| **Home hazards** | Lord 2006, R, Fletcher 2002, C, Pluijm 2006, C, Van Bemmel, 2005, C | Relative risk 3.6 |
| **Muscle weakness** | Otaka 2008, SR, Moreland 2004, SR, Pluijm 2006, C, Stalenhoef 2002, C | Odds ratio~3 |
| **Fear of falling** | Scheffer 2008, C, Delbaere 2004, C, Pluijm 2006, C, Delbaere 2006, C, Delbaere 2004, C, Murphy 2003, C | Odds ratio 3 |
| **Use of an assistive device** | Nandy 2004, R | Relative risk 2.6 |
| **Frailty** | Ensrud 2008 C | Odds ratio 2.4 (recurrent falls, frail vs. non-frail) |
| **Cognitive impairement** | Assantachai 2003, C, Shaw 2002, R, Fletcher 2002, C, Papaioannou 2004, C, Van Doorn 2003, C, Van Schoor 2002, SR | Odds ratio ~2-4 |
| **Arthritis** | Reyes-Ortiz 2004, C, Assantachai 2003, C | Relative risk 2 |
| **Diabetes** | Reyes-Ortiz 2004, C, Schwartz 2002, C | Odds ratio 1.7 |
| **Parkinson's Disease** | Fink 2006, C, Fletcher 2002, C | Odds ratio 3 |

**Table 2 Continued**

| | | |
|---|---|---|
| **Impaired ADL** | Capon 2007, C, Reyes-Ortiz 2004, C, Assantachai 2003, C, Perracini 2002, C, Pluijm 2006, C, Shumway-Cook 2005, C | Odds ratio 2 |
| **Neuropathy** | Schwartz 2008, C | Odds ratio 1.5 (diabetics) |
| **Medication** | Allain 2005, R, Hartikainen 2007, SR, Landi 2005, C | Odds ratio 1.5 (mainly benzodiazepines antidepressants, antipsychotics) |
| **Testerone deficit** | Orwoll 2006, C, Szulc 2003, C | Relative risk 1.8 |
| **Visual Deficit** | Schwartz 2008, C, Coleman 2007, C, Lord 2006, R, Assantachai, 2003, C, Perracini 2002, C, Lord 2002, C, Szabo 2008, C, McCarty 2002, C | Odds ratio 1.4 (diabetics)<br>1.5-3.0 other populations |

## 3.4 GAIT MEASUREMENTS AND FALLS

Slow gait speed (<1 m/s) has been consistently identified in many reviews as the strongest risk factor for falls (*Tinetti et al., 1998; Rubenstein et al., 1994; Verghese et al., 2009; Deandrea et al., 2010*).

In the Baltimore Longitudinal Study of Aging, maximal and comfortable walking speeds and gait characteristics were compared among middle-aged (32–57 years; N=27), old-age (58–78 years; N=125), and oldest-age (79–93 years; N=38). Older age was associated with slower self-selected walking speed, shorter stride length, and greater propensity of landing flat-footed (older participants showed shorter period of ankle planter flexion (PA1) resulting in a longer dorsiflexion duration in stance, which can be interpreted as a tendency for flat-footed landing) (*Ko et al., 2009*). *Barak et al. (2006)* assessed elderly patients who had fallen in the previous six months and compared them to a matched group that had no falls. Fifty seven percent of the fallers were unable to walk at the fastest speed, had shorter stride lengths, smaller lateral sway as well as smaller ankle plantar flexion and hip extension during push-off. In a study of 763 community dwelling by *Quach et al. (2011)*, participants with faster (>1.3 m/s, incident rate ratio (IRR) = 2.12, 95% CI 1.48-3.04) and slower (<0.6 m/s, IRR=1.60, 95% CI 1.06-2.42) gait speeds were at higher risk than those with normal gait speeds (1.0-<1.3 m/s). In adjusted analyses, slower gait speeds were associated with greater risk of indoor falls (<0.6 m/s, IRR=2.17, 95% CI=1.33-3.55; 0.6-<1.0 m/s, IRR=1.45, 95% CI=1.08-1.94), and faster gait speed was associated with greater risk of outdoor falls (IRR=2.11, 95% CI=1.40-3.16). A gait speed decline of more than 0.15 m/s per year predicted greater risk of all falls (IRR=1.86, 95% CI=1.15-3.01). They concluded that there was a nonlinear relationship between gait speed and falls, with a greater risk of outdoor falls in fast walkers and a greater risk of indoor falls in slow walkers.

Lack of physical activity, smoking, obesity and diet are modifiable risk factors that have been associated with poor walking speed (*Alipanah et al., 2009; Forrest et al., 2006; Simonsick et al., 2005; Stenholm et al., 2007*).

## 3.5 NUTRITIONAL STATUS

Malnutrition has been defined as a condition of an imbalance of energy, protein, and other nutrients that cause measurable negative effects on body composition, physical function, and clinical outcomes (*Malnutrition Advisory Group, 2000*). It is commonly reported in older hospitalized populations and in community dwelling or institutionalized people (*King et al., 1995, Rubenstein et al., 2001*). An estimated 5-10 % of elderly people living in the community setting are malnourished. About 60% of hospitalized older adults (age> 65 years) and 35-85% in long-term care facilities experience malnutrition (*Furman, 2006*). In a study conducted on 250 community dwelling recipients of domiciliary care services at home, subjects who were not well-nourished (43.2%) compared to well-nourished as determined by Mini Nutritional Assessment (MNA>24) were more likely to have been admitted in hospitals RR=1(.51, 95% CI 1.15-2.14), have two or more emergency hospital admissions (RR=2.96, CI 1.15-7.59), spend more than four weeks in hospital (RR=3.22, 95% CI 81.07)29- and fall (RR=1.65, 95% CI -21.41)13 (*Visvanathan et al., 2003*).

Malnourishment is associated with increased incidence of falls and fallers tend to have a lower nutritional status than non-fallers (*Vellas B et al., 1992; Coleman et al., 2000*). In a study conducted on 250 community dwelling recipients of domiciliary care services at home, subjects who were not well nourished (43.2%) compared to subjects who were well nourished as determined by Mini Nutritional Assessment (MNA>24) were more likely to be admitted in hospitals (RR=1.51, 95% CI 1.15 - 2.14), have two or more emergency hospital admissions (RR=2.96, 95% CI 1.15-7.59), spend more than 4 weeks at hospital (RR=3.22 95% CI 1.29-8.07) and fall (RR=1.65, 95% CI 1.13-2.41). *Vivanti et al. (2009)* conducted a prospective, cross-sectional study with a convenience sample of older (age > 60 years) fallers and non- fallers to assess the association between malnutrition and the risk of falls. Malnutrition Screening Tool (MST) and Subjective Global Assessment (SGA) tool were administered to 126 non-consecutive participants categorized as non-fallers, frail mechanical fallers (occur in a setting of muscle deterioration, poor foot placement, and visual or proprioceptive inadequacies and requires a more complete medical review to determine any underlying issue that caused the fall) or active mechanical fallers (occur during vigorous activity, in those with syncope or vertigo and only require assessment and treatment for fall injuries). Self-reported falls in past six months and hospital admission were documented. The authors concluded that participants who experienced an active mechanical fall or no fall were more likely to be well-nourished compared with those experiencing a frail mechanical fall. They suggested although falls etiology is multifactorial in nature, further adequately powered research is required to investigate the impact of nutritional intervention in frail patients with mechanical falls and the contribution that dietitians can make in a multidisciplinary ED setting.

*Woo et al. (1994)* conducted a prospective, randomized, single -blind trial in elderly patients discharged from hospitals after achest infection to examine the effect of nutritional supplementation of 500 ml of Ensure liquid daily versus no supplementation (500 ml of Ensure provides 500 kcal as 14% protein, 22% fat, and 64% carbohydrate, as well as minerals and vitamins) on the frequency of subsequent episodes of infection, well-being and functional status (as measured by modified Barthel Index). The supplement group showed improvement in anthropometric measurements, in thiamine and pyridoxine status, while the non- supplement group showed a lower level of functional ability after 3 months. This study showed a significant improvement in functional limitations after oral nutritional supplements. Thus, improving nutrition may reduce falls since functional limitations are a major risk factor for falls.

Vitamin D status is increasingly recognized as an important factor in fall status among elderly patients. One proposed mechanism is higher vitamin D levels may be associated with improved muscle function. In older adults, low serum vitamin D (serum 25OHD < 25nmol/L) and calcium levels have been associated with muscle weakness, poor physical performance, balance problems, and falls (*Houston et al., 2007*), although findings from different studies are somewhat inconsistent (*Verreault et al., 2002, Visser et al., 2003*). The recommendations of the *Institute of Medicine (IOM)*, largely based on bone health due to available evidence, calls for 600 IU of Vitamin D daily for all ages up to age 70 and 800 IU after age 71. The panel raised the safe upper limit of 2,000 IU daily to 4,000 IU for adults, and declared a safe upper limit of 1,000 to 3,000 IU per day in children depending on their age. Currently, the Institute of Medicine Prevention of falls and complications of falls in community-dwelling older adults concluded that there is insufficient evidence demonstrating a protective effect of vitamin D supplementation on falls and other non-skeletal outcomes (*Ross et al., 2011*).

In a meta-analysis by *Bischoff-Ferrari et al. (2009)*, 8 randomised controlled trials of fall prevention with a defined oral dose of supplemental vitamin D (vitamin $D_3$ (cholecalciferol) or vitamin $D_2$ (ergocalciferol) or oral active Vitamin D (1α-hydroxyvitamin $D_3$ (1α-hydroxycalciferol) or 1,25 dihydroxyvitamin D3 (1,25-dihydroxycholecalciferol)) and 2 randomized controlled trials of active forms of Vitamin D in individuals aged 65 years or older with a minimum follow-up of three months were identified. Out of 2426 individuals, high dose supplemental vitamin D (> 400 IU/day) reduced fall risk by 19% (pooled relative risk (RR) 0.81, 95% CI 0.71 to 0.92; n=1921 from seven trials), whereas achieved serum 25(OH)D concentrations of 60 nmol/l or more resulted in a 23% fall reduction (pooled RR 0.77, 95% CI 0.65 to 0.90). Falls were not notably reduced by low dose supplemental vitamin D (< 400 IU/day) (pooled RR 1.10, 95% CI 0.89 to 1.35; n=505 from two trials) or achieved by serum 25-hydroxyvitamin D concentrations of less than 60 nmol/l (pooled RR 1.35, 95% CI 0.98 to 1.84). Active forms of vitamin D reduced fall risk in 624 individuals by 22% (pooled RR 0.78, 95% CI 0.64 to 0.94). They concluded that supplemental vitamin D in a dose of 700-1000 IU a day reduced the risk of falling among older individuals by 19%. Doses of supplemental vitamin D of less than 700 IU or serum 25-hydroxyvitamin D concentrations of less than 60 nmol/l may not reduce the risk of falling among older individuals.

Two longitudinal studies examined the association between food groups and functional status and reported that lower fruits and vegetable consumption was associated with poor lower extremity physical performance, ADL, IADL and greater self-reported functional limitations in older adults (*Houston et al., 2005; Tomey et al., 2008*).

Several studies have confirmed that homocysteine is a risk factor for decline in physical function although its association with fall frequency is unknown. Older persons with elevated homocysteine (a chemical in the blood produced when an amino acid, a building block of protein, called methionine is broken down in the body)levels are also at increased risk of physical functional decline (*Kado et al., 2002*). The group conducted a prospective cohort study of 499 highly functioning men and women aged 70-79 years who were subsamples of the MacArthur Studies of Successful Aging. Their hypothesis was based on the evidence that elevated plasma homocysteine levels may cause toxicity by a variety of mechanisms, including oxidative damage which has been linked to increased rate of aging (*Hensley et al., 2002*). They investigated whether healthy, highly functioning older persons with elevated plasma homocysteine levels at baseline were at increased risk of subsequent decline in physical function. Total homocysteine levels and performance-based physical function were measured at baseline; physical function measures were repeated at an average of 28 months later. A summary measure of physical performance was calculated by adding tests of balance (tandem stand), gait (10 feet walking distance as quickly as possible), lower body strength and coordination (10 foot taps in 0- 30 seconds and five chair stands in 0-20 seconds), and manual dexterity (pick up a pencil and sign their names in 30- seconds) scores and adjusted for time. Socio-demographic characteristics, self-reported medical history and plasma folate/Vitamin B12/Vitamin B6 assays were also recorded. Their results showed with each SD increase in homocysteine, there was an increased risk of being in the worst quartile of decline in physical function (OR=1.5; 95% confidence interval:1.2, 1.9) in analyses that adjusted for age, sex, baseline physical performance, smoking status, vitamin B12 levels, and incident stroke. Similar results were seen when change in physical performance was treated as a continuous variable. They went on to conclude that older persons with elevated plasma homocysteine levels are at an increased risk of decline in physical function. Increased plasma total homocysteine (tHcy) has been shown to be a sensitive marker of Vitamin B12 deficiency (*Klee et al., 2000*)

It has been shown that low serum folate status is also associated with falling. *Shahar et al. (2009)* investigated the impact of essential nutritional elements on falls among a selected subsample of 54 elderly adults aged 65-91 years. Clinical function, balance, gait and disability tests and health and nutritional status assessments were performed and occurrence of falls in the past year was recorded. Blood tests for serum vitamin D, folate and B12 were carried out among the selected subsample. They found that serum folate was significantly lower in fallers than non-fallers (9.5 ± 7.1 vs. 16.2 ± 6.7 ng/ml, p = 0.02). Correlation analysis indicated that serum folate was highly and negatively associated with the number of falls and with prescribed medications and was the only protective factor against falls in a multivariate analysis. They concluded that serum folate was protective against falls and for every 1 ng/ml increase in serum folate the occurrence of falls decreased by 19%. This study suggests that nutritional folate supplies could drastically reduce falls.

*Rosenberg and Miller (1992)* have proposed that the most practical outcome of research on the relationship of diet and nutrition to aging would be to understand better how nutrition-related behaviors can help maintain an optimal functional status. Much of the current research examining the relationship between diet and functional status or diet and falls are limited in population distribution, women only participants (*Tomey et al., 2008; Riebe et al., 2009*), small sample sizes and self-reported measures of functional status. Many studies examining the relationship between diet and functional status have focused on single nutrients or food groups (*Houston et al., 2007; Sharkey et al, 2003; Tomey et al., 2008*). People consuming combination foods make it difficult to assess the effects of a single nutrient or food on health outcome (*Hu, 2002*). Increasingly whole foods (rather than nutrients), their combination in complex eating patterns and their potential synergistic effects are being recognized as important in the prevention of chronic disease.

The development of diet quality indexes several decades ago was with the goal to capture composite diets rather than specific nutrients. Currently, a number of diet quality indexes exist to reflect the nutritional needs of different populations. The Healthy Eating Index, one such diet quality measure follows compliance with the Dietary Guidelines for Americans which are the basis for all federal nutrition guidance. The accompanying U.S Department of Agriculture (USDA) food patterns translate the Dietary Guidelines into specific, quantified recommendations for types and amounts of foods to consume at 12 calorie levels with limits on calories from solid fats and added sugars (*USDA, 2010*). The USDA food patterns forms the basis for the scoring standards for HEI. The recent release of the 2010 Dietary Guidelines and revised USDA patterns necessitated an update to HEI -2005 to some key changes. The USDA Center for Nutrition Policy and Promotion (CNPP) convened a group of federal users of the HEI and the Dietary Guidelines to discuss the process and content for the update. This meeting and subsequent discussions of a working group of staff from CNPP and the National Cancer Institute led to the development of guiding principles for the update. Drawing upon these principles, the working group subsequently reviewed the HEI - 2005 in relation to the 2010 Dietary Guidelines and the USDA Food Patterns, discussed potential strategies to address key changes in the guidance and the Healthy Eating Index-2010 (HEI-2010) was released. The HEI-2010 differs from the 2005 version in several aspects: It consists of 12 components—total fruit, whole fruit, total vegetables, beans and greens, total grains, dairy, whole grains, total protein foods, oils, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories. These individual components represent all of the major food groups recommended. Greens and Beans replaced Dark Green and Orange Vegetables and Legumes to emphasize that dark green vegetables and beans and peas (also known as legumes) are the two vegetable subgroups for which intakes are furthest from recommended levels. Seafood and Plant Proteins has been introduced to capture specific choices from the protein foods group. Fatty Acids, a ratio of poly- and mono-unsaturated to saturated fatty acids, replaces Oils and Saturated Fat. This component recognizes the recommendation toreplace saturated fatwith poly- and mono-unsaturated fatty acids. A moderation component, Refined Grains, replaces the adequacy component from earlier, Total Grains, to assess over-consumption. This component is included in the moderation components because the 2010 Dietary Guidelines emphasized that consumption of these foods is too high. A key feature is that intakes of foods and nutrients are represented on a density basis, as amounts per 1,000 calories.

Studies using the earlier index (HEI-2005) have reported that lower HEI-2005 scores, indicating a less health promoting diet, are associated with a greater risk of obesity, arthritis, depression, cancer, and death (*Kuczmarski et al., 2009; Drewnowski et al., 2009*). In a paper published by *Xu et al. (2012)*, using data from 1999-2002 National Health and Nutrition Examination Survey Older adults, it was found that HEI-2005 scores were positively associated with gait speed and higher HEI -2005 scores had a faster gait speed compared with those with HEI-2005 scores in the lowest quartile. The associations between the scores and physical performance remained after further adjustment for comorbidities, medication use, cognitive function, and body mass index. However, the associations were no longer statistically significant after further adjustment for physical activity. Table 3 examined the studies which were conducted to study the association between specific nutrients and falls. Currently, there is lack in literature looking into the association between incident falls and diet quality scores given by HEI among elderly.

**Table 3. Summary of studies examining specific nutrient/nutritional status and falls and physical function**

| Nutrient(s) | Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|---|
| Vitamin D and Calcium | Houston et al. (2007) | Cross sectional | n=976 Age=≥65 Community based | Sociodemographic variables, behavioral characteristics, body mass index, season, cognition, health conditions, creatinine, hemoglobin, and albumin. | Vitamin D levels and Physical performance (hand grip strength and SPPB). | Vitamin D levels were significantly associated with SPPB score in men (β coefficient [standard error (*SE*)]: 0.38 [0.18], $p = .04$) and handgrip strength in men (2.44 [0.84], $p = .004$) and women (1.33 [0.53], $p = .01$). Men with serum 25OHD < 25.0 nmol/L had significantly lower SPPB scores whereas those with serum 25OHD < 50 nmol/L had significantly lower handgrip strength than those with serum 25OHD ≥25 and ≥50 nmol/L, respectively ($p < .05$). |
| | Bischoff-Ferrari et al. (2009) | Meta-analysis | n=2426, 624 Age=≥65 years Duration=1960-2004 | NA | Fall≥1 | High dose supplemental vitamin D reduced fall risk by 19% (pooled relative risk (RR) 0.81, 95% CI 0.71 to 0.92; n=1921 from seven trials), whereas achieved serum 25(OH)D concentrations of 60 nmol/l or more resulted in a 23% fall reduction (pooled RR 0.77, 95% CI 0.65 to 0.90). Falls were not notably reduced by low dose supplemental vitamin D (pooled RR 1.10, 95% CI 0.89 to 1.35; n=505 from two trials) or by achieved serum 25-hydroxyvitamin D concentrations of less than 60 nmol/l (pooled RR 1.35, 95% CI 0.98 to 1.84). Active forms of vitamin D reduced fall risk by 22% (pooled RR 0.78, 95% CI 0.64 to 0.94). |

**Table 3 Continued**

| Nutrient(s) | Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|---|
| Protein | Zoltick et al. (2011) | Cohort study | n=807<br>Age=67-93 years<br>Community based<br>Duration=12 months | Protein intake (total, animal and plant) was assessed as a continuous variable and by tertiles of intake. Falls were reported by participants using a validated questionnaire at baseline and 12 months. Weight was ascertained at each examination to examine the effect of weight loss over follow-up.<br>Covariates including age, sex, height, weight, total energy intake, baseline history of falls, dietary calcium intake, calcium supplement use, dietary vitamin D intake, vitamin D supplement use, alcohol intake, smoking status, and physical activity. | Falls (yes/no) and number of falls at 12 months | Higher dietary protein intakes were associated with a reduced odds of falling, although of borderline statistical significance (OR=0.80, 95% CI: 0.60–1.07) and were not associated with the rate of falls over follow-up (RR=0.93, 95%CI: 0.73–1.19). Tertile analyses tended towards a protective association, but most did not achieve statistical significance (P range: 0.12–0.50). For the rate of falls, total protein intake was found to be protective falls, but was only of borderline statistical significance for tertile 2 relative to tertile 1 (the reference group) (RR T3: 0.79, 95% CI: 0.55–1.13, RR T2: 0.69, 95% CI: 0.48–0.99). A similar pattern was observed for animal protein intake (RR T3: 0.88, 95% CI: 0.60–1.27, RR T2: 0.80, 95% CI 0.55–1.16). No significant associations were observed for plant protein intake. |
| Folate | Shahar et al. (2009) | Cross sectional study | n=54<br>Age= 65-91 years<br>Duration=1 month | Blood tests for serum folate among a randomly selected subsample.<br>Clinical function, balance, gait and | Any falls<br><br>( $\geq$1) | Overall function score (indicating better function): marginally higher in non-fallers. Serum folate was significantly lower in fallers (9.5 ± 7.1 vs. 16.2 ± 6.7 ng/ml, p = 0.02). |

**Table 3 Continued**

| Nutrient(s) | Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|---|
| | | | | disability tests and health and nutritional status assessments were performed and occurrence of falls in the last year was recorded. Subsequent comparisons between fallers and non-fallers were adjusted for overall function and depression scores. | | 1 ng/ml ↑ in serum folate, occurrence of falls ↓ by 19%. |
| Iron | Dharmarajan TS (2007) | Prospective | n=362 Age=59-104 years Hospitalized and community dwelling Duration=3.5 years | Laboratory values (hemoglobin [Hb], hematocrit [Hct]), routine laboratory tests, pertinent medical history, history of prior falls and demographics. | Fall occurrence | Patients who fell had a significant lower Hb (p<0.0005) and were more likely to be anaemic (56% vs 38%, p=0.001) than controls. There was a 22% decreased risk of falls for 1.0 g/dl increase in Hb (p<0.0005) and an overall 1.9 fold increased risk of falls in anaemic patients (p<0.001). |
| Homocysteine | Kado et al. (2002) | Prospective cohort | n=499 Age=70-79 years Community dwelling Duration=28 months | Age, sex, socioeconomic status measured by level of education attained, self-reported history of smoking, medical conditions, baseline serum creatinine and albumin levels, plasma folate, vitamin B6, B12, Non fasting plasma homocysteine | Physical function change score | With each SD increase in homocysteine, there was an increased risk of being in the worst quartile of decline in physical function (OR 1.5, 95% CI 1.2-1.9) adjusted for covariates. Similar results when physical performance was treated as a continuous variable. |

**Table 3 Continued**

| Nutrient(s) | Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|---|
| | | | | levels, physical function | | |
| Malnutrition | Visvanathan et al. (2003) | Prospective study | n=250 Age=67-99 Community based population Duration=12 months | Age and living status | Changes in their living situation, hospital admissions and their duration, the occurrence of nutritional intervention, subjective weight loss, and falls during the 12-month period after initial contact. | Not well-nourished subjects were more likely than well-nourished (MNA>24) subjects to have been admitted to the hospital (risk ratio (RR) = 1.51, 95% confidence interval (CI) = 1.07-2.14), have two or more emergency hospital admissions (RR = 2.96, 95% CI = 1.15-7.59), spend more than 4 weeks in the hospital (RR = 3.22, 95% CI = 1.29-8.07), fall (RR = 1.65, 95% CI = 1.13-2.41), and report weight loss (RR = 2.63, 95% CI = 1.67-4.15). |
| | Vivanti et al. (2009) | Prospective, cross sectional | n=126 non-consecutive participants Age= $\geq$ 60 years Convenience sample Duration=1 month | Gender, fall group, number of self-reported fallers in the 125 previous 6 months and subsequent admission or discharge was assessed against nutritional 126 status | Specific fall: Frail mechanical, active mechanical, non- faller | Increased risk of being assessed as malnourished when a frail mechanical faller relative to: a non-faller (RR: 1.5, 95% CI 1.0 -2.3, p=0.001); an active mechanical faller (RR: 3.1, 95% CI 1.0-10.9, Fisher's Exact test p=0.02); or a non-faller and active mechanical faller combined (RR: 1.5, 95% CI 1.0-2.1, p=0.001). Malnourished participants had an increased risk of self-reported falls over six months (RR: 1.5, 95% CI 1.0- |

**Table 3 Continued**

| Nutrient(s) | Author/Date | Study Design | Population | Exposure variable | Outcome variable | Magnitude of association |
|---|---|---|---|---|---|---|
| | | | | | | 2.5, p=0.03). There was over five times the risk of hospital admission if malnourished than if well-nourished (RR: 5.3, 95% CI 1.4-20.0, F Fisher's Exact test p=0.001). |

## 3.6 PHYSIOLOGICAL LINK BETWEEN DIET AND FALLS

The aging process is characterized by an involuntary loss of muscle (sarcopenia) and bone mass (osteoporosis). These chronic processes are associated with increased risk of falls (*Genaro S et al., 2010*). To understand the physiological link between diet and falls in order to assess the nutritional risk factors for falls, this section highlights the current knowledge of some studied, important dietary components that could help prevent the above mentioned conditions.

**Proteins:**

In a recent review by *Breen et al. (2011)*, they discuss the paradigm of muscle protein synthesis to anabolic stimuli such as diet and how aging contributes negatively to this association. Skeletal muscle proteins are frequently and simultaneously synthesized and degraded which aid in muscle mass upkeep. Net protein balance is defined as the difference between skeletal muscle protein synthesis (MPS) and breakdown (MPB). Thus, a significant rise in MPS (anabolism) and/or a reduction in MPB (catabolism), such that net protein balance remains positive can result in the accretion of skeletal muscle proteins. Conversely, a negative net protein balance, arising from a reduction in MPS and/or increase in MPB, will result in a loss of skeletal muscle protein. Net protein balance is maintained by ingestion of protein-containing meals which results in systemic hyperaminoacidemia that is stimulatory for the synthesis of new proteins. However, a progressive deterioration in skeletal muscle mass becomes apparent at the time of aging. This age-related loss of muscle protein must be attributed to an imbalance between muscle protein synthesis and breakdown rates, resulting in a negative muscle protein balance and, over time, a decline in skeletal muscle mass. In reality, even though the dietary protein digestion and absorption kinetics do not seem to be impaired in the elderly compared to younger individuals, the feeding-induced stimulation of MPS is blunted when small amounts of protein or the equivalent essential amino acid (EAA) content are ingested. That is, ingestions corresponding to 20 g of protein or more have been shown to be necessary to stimulate MPS in elderly. This phenomenon is termed ―anabolic resistance of elderly individuals. Additionally, the amount of protein ingestion that induces a maximal MPS response is higher in elderly than in young individuals. More specific, mixed MPS was higher after ingestion of 35 g compared to 20 g whey protein in elderly subjects (*Pennings et al. 2012*), unlike in young individuals. The underlying reason for the anabolic resistance to protein is not known. Specifically, an impaired endothelial function could limit blood flow and EAA delivery to the elderly muscles. Collectively, these findings justify that a poor quality protein might explain why the MPS response to lower doses of protein or EAA intakes is reduced in elderly and that higher intakes are needed to obtain the same response as in young individuals.

The other proposed theory which links protein intake to falls is associated with calcium excretion. High protein intakes have been shown to affect calcium homeostasis, resulting in increased calcium excretion, but findings regarding the effect of protein on calcium balance and bone health have been mixed. The increase in urinary calcium observed with purified proteins or amino acid infusions is not readily observed with food sources of protein leading to the conclusion that overall, there is general agreement that diets moderate in protein (≈1.0 to 1.5 g/kg/d) are associated with normal calcium metabolism and do not alter bone metabolism. However, at low protein intakes (<0.8 g/kg/d) intestinal calcium absorption is reduced and levels of parathyroid hormone increase, causing the release of calcium from bone (*Kersetter et al., 2003*).

Yet another factor influenced by protein is insulin-like growth factor (IGF-1), which plays a key role in bone metabolism. Higher levels of IGF-1 are osteotrophic. As individuals age, there is a decline in serum concentrations of IGF-1 (*Chahal et al., 2007*). Both the level and type of protein in the diet may have an effect on IGF-1 levels (*Larson et al., 2005*). Without adequate levels of these hormones, it may be impossible to maintain lean body mass, regardless of how they eat or exercise.

**Vitamin D and Calcium:**

Vitamin D can exert its effects by genomic and non-geomic pathways. Both can be involved in muscle function. Vitamin D is a steroid hormone because of its mechanism of action which is exerted either directly on membrane receptors affecting extracellular and intracellular concentrations of Ca++ via calcium channels and which define the non-genomic action, or by binding to nuclear receptors, which determines the genomic action. In this second case, the vitaminD/receptor complex formed induces the synthesis of messenger ribonucleic acid (mRNA) which codes for a protein, Calcium Binding Protein (CaBP), responsible for the biological effect. This type of action takes longer to be effective than the non-genomic action (*Freedman et al., 1999*).

The genomic pathway of action of vitamin D also influences the polymorphism of vitamin D receptor (VDR) responsible for multiple phenomena such as differentiation of myoblasts, calcium influx into the cell, membrane phosphate transport, phospholipids metabolism, and muscle fibre proliferation and differentiation. The non-genomic pathway has a complementary action to that of the genomic pathway either by activating a second messenger in the cell-cyclic AMP and/or diacylglycerol and/or inositol triphosphate and/or arachidonic acid - or by activating protein kinase C and the release of calcium into the cytosol. This effect is responsible for the active transportation of calcium into sarcoplasmatic reticulum by Ca -ATPase increasing the calcium pool which is necessary for the successive attachments and detachments of myofilaments leading to sarcomeric shortening responsible for muscular contraction. Vitamin D therefore participates in the good functional equilibrium of fast-twitch type II muscle fibres, thereby preserving high muscle contraction speed and muscle power (*Annweiler et al., 2010*). Thus, besides the muscle cell (type II fibers), Vitamin D can also influence neuromuscular action.

**Vitamin B12 and Folic Acid:**

Intakes of vitamin B 12 and folic acid are able to correct high levels of homocysteine (a non - protein amino acid). Vitamin B12 and/or folic acid might improve postural stability and/or muscle function and strength in turn helping to reduce falls (*Sato et al., 2005*).

**Acid-producing diets:**

Large numbers of the elderly chronically consume acid-producing diets. Although a dietary acid load does not change the intracellular pH of the muscle cells, it has been suggested that chronic intake of excess acid-producing nutrients such as meat and cereal grains in combination with a low intake of the alkalizing fruits and vegetables may lead to a chronic acid challenge and to negative effects on bone and muscle, causing an increased risk for falls. An acidic environment is an established stimulus for muscle catabolism. The efflux of amino acids from muscle increases with early starvation, trauma, sepsis and burns, chronic renal failure and in obese subjects who were acidotic while on weight loss diets. Muscle wasting appears to be an adaptive response to acidosis.

The released amino acids are converted to glutamine in the liver, and glutamine is used by the kidney to increase synthesis of ammonia. Ammonia accepts protons and is excreted as ammonium ions, thereby mitigating the acidosis. The underlying mechanisms by which alkali supplementation benefits muscle mass and performance are unknown. It is believed that the effect of acidosis on muscle may also be mediated through the suppression of IGF-I. However, the relevance of these observations to the mild metabolic acidosis associated with aging has not been established (*Aalkjaecr et al., 1997*).

Recently, diets high in alkali-producing fruits and vegetables have been associated with the preservation of lean tissue mass in older adults (*Hughes, B. et al., 2008*). There is some evidence that acid–base balance and vitamin D may be interdependent in their effects on muscle. For instance, acidosis may influence the action of vitamin D on muscle indirectly. The hydroxylation of vitamin D into active and inactive metabolites is pH dependent. The enzymes involved require an optimal pH of around 7.4. A higher or lower pH tends to result in a lower activity of the enzymes regulating 25(OH) D metabolism. On the other hand, chronic metabolic acidosis increases serum concentration of 1, 25-dihydroxyvitamin D in humans, hence, it is thought that there is a difference between the effects of acute versus chronic pH changes. In addition, pH variations could modify vitamin D binding proteins as well as vitamin D receptor interactions within target tissues. Alternatively, acidosis may be one mechanism by which vitamin D insufficiency adversely affects muscle. Clinical evidence for interaction of acid–base with vitamin D in their effects on muscle is lacking from what I reviewed.

**Conclusion:**

Given the present state of knowledge in this area, adequate dietary protein, vitamin D, calcium, Vitamin B12, folic acid and acid –base balance may play a role as a nutritional risk factors for falls. Despite a widely held belief that high-protein diets (especially diets high in animal protein) result in bone resorption and increased urinary calcium, higher protein diets are actually associated with greater bone mass and fewer fractures when calcium intake is adequate. Perhaps more concern should be focused on increasing the intake of alkalinizing fruits and vegetables rather than reducing protein sources. Also there is a gap in data regarding the mechanism of some of these risk factors including exploration of antioxidants and anti-inflammatory agents and how they physiologically impact falls among older adults.

# 4.0 SUMMARY

Although nutritional status is one of the major determinants of healthy aging, there is very little empirical data regarding the relationship between overall diet quality and incident falls and physical function among older adults. To my knowledge, no studies have been published testing the association of overall diet quality with incident falls. It is hypothesized that the adherence to the Dietary Guidelines would be associated with lower fall rates and better gait speed.

# 5.0 ANALYSIS PLAN

## 5.1 STUDY DESIGN AND PARTICIPANTS

The MrOS study is a prospective cohort study which enrolled 5994 older (age $\geq$ 65 years) community dwelling, US men between March 2000 and April 2002 at six U.S. clinical sites (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Monongahela Valley near Pittsburgh, PA; Portland, OR; and San Diego, CA). The study has been described in detail elsewhere (18, 19). Briefly, the goal of the study was to identify risk factors for osteoporosis and fractures among older men. The eligibility criteria included (1) ability to walk without assistance of another person or aide, (2) no history of bilateral hip replacement, (3) anticipated residence near a study site for the duration of follow-up, (4) absence of a medical condition that would result in imminent death, and (5) ability to provide self-reported data. All subjects provided written informed consent, and the institutional review boards of all clinical centers and the coordinating center approved the study.

For our prospective analysis, out of the total cohort of 5994, we excluded 67 (1.1%) subjects from this analysis based on the FFQ. This included 19 (0.3%) who refused to complete the FFQ, 21 (0.4%) whose report was lost and who had >10% missing data on the FFQ respectively, and 27 (0.5%) with caloric intake reported to be fewer than 400 calories/day (no maximum energy intake was set). Further exclusions included 11 participants whose gait speed data was missing, 10 participants whose follow-up was not expected (either died or terminated before the first year of follow-up) at the end of year 1 of post card follow-up and 57 participants whose postcard follow-up was missing leaving a final data set of 5849 participants aged 65–100 years for this analysis.

## 5.2 DIET QUALITY

Information about the participants' typical diet was obtained using a self-administered, reduced- length version of the Block 98 food-frequency questionnaire (FFQ). The reduced length version of the Block 98 semi- quantitative questionnaire used for this study was developed through an in-depth analysis of the NHANES III data to identify foods most commonly consumed by men of a similar age, geographic and racial distribution as those in the MrOS cohort. This specific reduced length version of the Block 98 FFQ did not undergo validation, though it is similar to other previously validated reduced length questionnaires produced by the Block group. Specific attention was paid to capturing intake of nutrients of interest to the MrOS study questions, including calcium, vitamin D and other selected nutrients that may influence risk of osteoporosis or prostate cancer in US men. The questionnaire included 69 individual food item questions and 14 items assessing nutritional supplement use. An additional 13 questions about food preparation and low-fat foods were asked and used to refine nutrient calculations. Individual nutrient intake was determined by the Block group using a database based on the USDA Database for Standard Reference for Version 12 and the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII) database. Food nutrient values were calculated separately from supplement nutrient values. Servings of food groups were calculated by creating groupings of all foods that contribute to approximately one serving (in gram weight) of a food group, using the 1992 Food Pyramid recommended serving sizes (e.g. cheeses − 42 g). The total grams of food consumed as part of each group was determined and then divided by the gram weight of a single serving size for that group.

To assess overall diet quality, a Healthy Eating Index (HEI-2010) score was calculated based on work by *Guenther et al. (2013)*. The Healthy Eating Index (HEI) is a measure of overall diet quality in terms of conformance with federal dietary guidance. Like its predecessor, the HEI-2010 was made up of 12 components, nine adequacy components and three moderation components. The 12 HEI-2010 components were summed for a total possible score of 100 points. Higher scores indicated greater dietary intake, except for SFA, sodium, and solid fats, alcohol, and added sugars (SoFAAS), in which higher scores indicated lower intake. Each participant's component score was calculated by dividing the total component intake by the total energy intake and multiplying by 1000.  Scores were energy-adjusted on a density basis (per 1000 kcal), which allowed for characterization of diet quality while controlling for diet quantity. For the purpose of this analysis, HEI-2010 scores were categorized into quartiles to help express the diet quality; the first quartile representing the lowest quality and the fourth quartile representing the highest quality. The highest quartile of HEI-2010 scores was chosen to be the reference group. Each of the HEI-2010 component scores was analyzed as dummy variables (those who met their recommendation vs all others). This is justified in an earlier paper by the same research group concerning the previous version of healthy eating index where the authors stated that it was acceptable to use the total HEI-2005 score for distinguishing very high scoring diets from very low scoring diets, as in epidemiologic dietary pattern analyses that model disease risk among those in the highest quartile compared with those in the lowest quartile of diet quality (*Guenther et al., 2012*).

## 5.3 INCIDENT FALLS

Information on falls was collected from tri-annual follow-up questionnaires that were mailed to study participants on March 1, July 1 and November 1. Each questionnaire asked if the participant had fallen in the past 4 months. The current study included follow-up of fall reports one year after the baseline period. The falls outcome was categorized as a yes/no response at the follow-up exam, and also evaluated as the rate of falls over follow-up (number of falls reported at follow-up of 12 months). We calculated the number of falls by adding the number of times fallen at follow-up one, two and three and recoded 5 or more number of falls as 5 falls. For one year following baseline, incident falls were categorized as a single fall (≥1) versus none, and recurrent falls (≥2) versus zero or one.

## 5.4 GAIT SPEED

Gait speed is a validated measure of function and disability in community-dwelling older adults (*Brach et al., 2007*). Gait speed was measured in meters/second on a standard six meter walking course using the time to complete the walk. Participants were instructed to walk at their normal pace for this examination. It was measured for two trials and the fastest speed (meters/second) was analyzed. A small number of participants refused to complete the gait speed measure (n=11, 0.2 %) and were excluded from the analysis.

## 5.5 CONFOUNDING VARIABLES

Covariates were selected based on their potential to impact the relationship between diet quality and falls, either as confounders or as significant risk factors for either falls or gait speed. Participants also completed a detailed self-administered questionnaire and were interviewed by trained and certified clinical staff regarding demographic characteristics, lifestyle factors, medical history, medication use, activities of daily living and a host of other items pertaining to fracture risk assessment during enrollment. Relevant to this analysis were age, race and ethnicity, clinic site, smoking status, physical activity score, Body Mass Index (BMI), comorbidities including transient ischemic attack or stroke, diabetes mellitus, Parkinson's disease and Glaucoma, prescription medicines including serum selective reuptake inhibitor (SSRI) antidepressants, tricyclic antidepressants, antidepressants and benzodiazepines. Weight and height were measured at the baseline clinic visit using a standardized protocol and BMI was calculated using the formula weight/(height)2 (kg/m2). Current smoking status and physical activity were chosen as markers of a healthy lifestyle. Physical activity was quantified using the Physical Activity Scale for the Elderly as provided by Washburn et al. (2002); a higher score represents greater activity.

## 5.6 STATISTICAL ANALYSIS

Mean and frequencies of demographics, anthropometrics, comorbidities and prescription medicines at baseline were conducted. Associations between confounding factors and quartiles of

HEI-2010 scores were tested with Chi-square tests for categorical variables and linear regression analysis for continuous variables. Logistic regression models were used to test the association between HEI-2010 and incident falls. For this analysis, HEI-2010 scores were categorized into quartiles to express diet quality, the first quartile representing the lowest quality and the fourth quartile (reference group) representing the highest quality. The outcome assessed was incident fall with gait speed as a mediator. Multiple logistic regression models were used to estimate the associations between quartiles of HEI-2010 scores and incident fall adjusting for the confounders. Covariates were entered individually and only those which were significant ($p<0.1$) were carried into further models. Age, race/ethnicity, clinic site, smoking status, physical activity score, BMI, comorbidities, prescription medicines and gait speed for the one year were controlled for $p<0.1$. Statistical significance was assigned at $p < 0.05$ (two sided).

# 6.0 RESULTS

## 6.1 DESCRIPTIVE CHARACTERISTICS OF THE SAMPLE

Descriptive characteristics of the analytic sample across quartiles of HEI-2010 scores are presented in Table 4. The average age was similar across the quartiles with a mean age of 73.6 years. The majority of the participants were white (89.8%). Among all men in the lowest quartile of HEI-2010 scores, 88.9% were white, 27.1% were from Pittsburgh clinic site and 93.1% were past or non-smokers. Men in the lowest quartile reported more comorbidities, however, overall trends were not significant. Regarding prescription drugs, men in the highest quartile self-reported fewer medications with an overall significance for tricyclic antidepressant drugs (p trend=0.04), antidepressantdrugs (p trend=0.01) and benzodiazepine (p trend=0.01) while SSRI antidepressant use was not significant (p trend=0.25).

Men with the highest healthy eating index scores had lower BMI, lower history of falls, and were more likely to report greater physical activity score (p trend=0.0003) in comparison to men with a lower healthy eating index (p trend=<0.001). Gait speed significantly increased (p trend=< 0.001) across increasing quartiles of the HEI-2010 with men in the lowest quartile reporting the lowest gait speed (1.16 m/s) compared to the highest reported in the highest scoring quartile (1.23 m/s). The mean number of incident falls decreased with increasing healthy eating index scores. Out of the total population, 1503 (25.6%) experienced an incident fall (fall >1 vs 0) and 685 (11.1%) experienced a recurrent fall (fall >2 vs 0, 1). The percentage of incident and recurrent falls among men across the quartiles of HEI-2010 scores are reported in Figure 1.

The descriptive table for the individual components scores of the HEI-2010 scores across the quartiles is presented in Table 5. Examining the data, we observed that men in the lowest scoring quartile had lower mean and median total HEI-2010 scores (mean=56.6, median=58.1, SD=6.6) compared to men in the highest scoring quartile (mean=88.5, median=88.0, SD=4.1).

Compared to men in the highest quartile, men in the lowest quartile had lower intakes of total vegetables (Mean=3.6 versus 4.6, Median=3.8 versus 5.0, SD=1.3 versus 0.7), greens and beans (Mean=3.5 versus 4.8, Median=4.1 versus 5.0, SD=1.6 versus 0.6), total fruit (Mean=3.4 versus 4.8, Median=3.6 versus 5.0, SD=1.5 versus 0.5), whole fruit (Mean=3.5 versus 4.9, Median=4.1 versus 5.0, SD=1.6 versus 0.5),whole grain (Mean=3.0 versus 8.1, Median=2.2 versus 9.4, SD=2.5 versus 2.5), dairy (Mean=5.9 versus 8.2, Median=5.6 versus 9.3, SD=2.8 versus 2.2), total protein (Mean= 4.1 Versus 4.7, Median= 4.6 versus 5.0, SD=1.1 versus 0.6), sea food and plant protein (Mean=3.0 versus 4.7, Median= 2.9 versus 5.0, SD=1.6 versus 0.9). However, it was seenthat men in thelowest quartile also had a lower consumption of foods recommended in moderationas well. Theseincluded fattyacid (Mean=6.4 versus 9.3, Median=6.5 versus 10.0, SD=2.5 versus 1.0), sodium (Mean=6.3 versus 7.1, Median=6.7 versus 7.3, SD=2.7 versus 2.0), refined grains (Mean=4.6 versus 8.9, Median=4.6 versus 9.8, SD=2.9 versus 1.5) and empty calories (Mean=9.3 versus 18.4, Median=9.4 versus 19.3, SD=4.0 versus 2.0).

**Table 4. Descriptive characteristics of analytic sample among participants by quartiles of HEI-2010 scores (n = 5849)**

| Covariates | Q1 (N=1462) | Q2 (N=1461) | Q3 (N=1466) | Q4 (N=1460) | Total (N=5849) | p trend |
|---|---|---|---|---|---|---|
| **Age, years (Mean + SD)** | 73.2 + 5.8 | 73.4 + 5.7 | 73.9 + 5.8 | 73.9 + 5.9 | 73.6 + 5.8 | **0.0002*** |
| **Race/Ethnicity N (%)** | | | | | | 0.11 |
| White | 1300 (88.9%) | 1306 (89.4%) | 1298 (88.5%) | 1346 (92.2%) | 5250 (89.8%) | |
| African American | 77(5.3%) | 54(3.7%) | 67(4.6%) | 34(2.3%) | 232 (3.9%) | |
| Asian | 34(2.3%) | 53(3.6%) | 44(3.0%) | 44(3.0%) | 175 (3.0%) | |
| Native Hawiian or other pacific Islander | 33(2.3%) | 32(2.2%) | 35(2.4%) | 23(1.6%) | 123 (2.1%) | |
| Others/Unknown | 18(1.2%) | 16(1.1%) | 22(1.5%) | 13(0.9%) | 69(1.2%) | |
| **Clinical Site N(%)** | | | | | | **0.11** |
| Birmingham | 268(18.3%) | 265(18.1%) | 215(14.7%) | 199(13.6%) | 947(16.2%) | |
| Minneapolis | 228(15.6%) | 260(17.8%) | 244(16.6%) | 256(17.5%) | 988(16.9%) | |
| Palo Alto | 172(11.7%) | 204(14.0%) | 275(18.8%) | 308(21.2%) | 959(16.4%) | |
| Pittsburgh | 396 (27.09%) | 246(16.8%) | 214(14.6%) | 141 (9.7%) | 997(17.1%) | |
| Portland | 206(14.1%) | 245(16.8%) | 254(17.3%) | 265(18.2%) | 970(16.6%) | |
| San Diego | 192(13.1%) | 241(16.5%) | 264(18.0%) | 291(19.9%) | 988(16.9%) | |
| **Cigarette Smoking status N (%)** | | | | | | **<0.0001*** |
| Never | 468(32.0%) | 495(33.9%) | 540(36.9%) | 683(46.8%) | 2186 (37.4%) | |

**Table 4 Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| Past | 893(61.1%) | 908(62.1%) | 901(61.5%) | 761(52.1%) | 3463(59.2%) | |
| Current | 101 (6.9%) | 58(4.0%) | 24(1.6%) | 16(1.1%) | 199(3.4%) | |
| **Comorbidities N (%)** | | | | | | |
| Diabetes | 149(10.2%) | 181(12.4%) | 182(12.4%) | 120 (8.2%) | 632 (10.8%) | 0.11 |
| Stroke | 95(6.5%) | 76(5.2%) | 99(6.8%) | 66(4.5%) | 336(5.7%) | 0.10 |
| Parkinson's | 9 (0.6%) | 15(1.0%) | 17(1.2%) | 10(0.7%) | 51 (0.9%) | 0.75 |
| Glaucoma | 123 (8.4%) | 129 (8.8%) | 137 (9.4%) | 146(10.0%) | 535(9.2%) | 0.13 |
| **Prescription Medicines N (%)** | | | | | | |
| SSRI Antidepressant use | 50(3.6%) | 39(2.8%) | 29(2.1%) | 43(3.1%) | 161(2.9%) | 0.25 |
| Tricyclic Antidepressant use | 36(2.6%) | 25(1.8%) | 20(1.4%) | 23(1.6%) | 104(1.9%) | **0.04*** |
| Antidepressant use | 111 (8.0%) | 88(6.4%) | 62(4.5%) | 84(6.1%) | 345(6.3%) | **0.01*** |
| Benzodiazepine | 54(3.8%) | 65(4.7%) | 44(3.1%) | 33(2.4%) | 196(3.5%) | **0.01*** |
| **Body Mass Index (BMI) (Mean ± SD)** | 28.0 ± 4.0 | 27.8 ± 3.9 | 27.4 ± 3.7 | 26.4 ± 3.4 | 27.4 ± 3.8 | **<0.0001*** |
| **Physical Activity Score for elderly (PASE score) (Mean ± SD)** | 142.0 + 70.5 | 145.7 + 66.2 | 147.9 + 68.2 | 151.0 + 67. 4 | 146.6 + 68.1 | **0.0003*** |
| **Gait speed (m/s) (Mean ± SD)** | 1.16 + 0.2 | 1.19 + 0.2 | 1.21 + 0.2 | 1.23 + 0.2 | 1.20 + 0.2 | **<0.0001*** |
| **Incident Fall (No.) (Mean ± SD)** | 2.2 + 1.4 | 2.1 + 1.4 | 1.9 + 1.3 | 1.8 + 1.2 | 2.0 + 1.3 | **<0.0001*** |

Table 5. Descriptive means and medians of the individual components of the HEI-2010 score across quartiles of HEI-2010 scores

| | Q1 (N=1462) | | | Q2 (N=1461) | | | Q3 (N=1466) | | | Q4 (N=1460) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HEI-2010 individual Component | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD |
| Total Vegetables | 3.6 | 3.8 | 1.3 | 4.2 | 4.9 | 1.1 | 4.4 | 5.0 | 0.9 | 4.6 | 5.0 | 0.7 |
| Greens and Beans | 3.5 | 4.1 | 1.6 | 4.3 | 5.0 | 1.2 | 4.6 | 5.0 | 0.9 | 4.8 | 5.0 | 0.6 |
| Total fruit | 3.4 | 3.6 | 1.5 | 4.3 | 5.0 | 1.2 | 4.6 | 5.0 | 0.9 | 4.8 | 5.0 | 0.5 |
| Whole fruit | 3.5 | 4.1 | 1.6 | 4.4 | 5.0 | 1.2 | 4.7 | 5.0 | 0.9 | 4.9 | 5.0 | 0.5 |
| Whole grain | 3.0 | 2.2 | 2.5 | 4.4 | 4.0 | 2.8 | 6.1 | 6.0 | 2.9 | 8.1 | 9.4 | 2.5 |
| Dairy | 5.9 | 5.6 | 2.8 | 6.8 | 6.8 | 2.7 | 7.3 | 7.7 | 2.5 | 8.2 | 9.3 | 2.2 |
| Total protein | 4.1 | 4.6 | 1.1 | 4.4 | 5.0 | 0.9 | 4.6 | 5.0 | 0.8 | 4.7 | 5.0 | 0.6 |

**Table 5 Continued**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sea food and plant protein** | 3.0 | 2.9 | 1.6 | 3.8 | 4.8 | 1.5 | 4.2 | 5.0 | 1.3 | 4.7 | 5.0 | 0.9 |
| **Fatty acid** | 6.4 | 6.5 | 2.5 | 7.6 | 8.1 | 2.3 | 8.4 | 9.3 | 1.9 | 9.3 | 10.0 | 1.4 |
| **Sodium** | 6.3 | 6.7 | 2.7 | 6.4 | 6.7 | 2.5 | 6.5 | 6.8 | 2.4 | 7.1 | 7.3 | 2.0 |
| **Refined grains** | 4.6 | 4.6 | 2.9 | 6.0 | 6.1 | 2.6 | 7.3 | 7.6 | 2.2 | 8.9 | 9.8 | 1.5 |
| **Empty calories** | 9.3 | 9.4 | 4.0 | 13.0 | 12.8 | 3.4 | 15.3 | 15.3 | 3.0 | 18.4 | 19.3 | 2.0 |
| **Total HEI-2010 scores** | 56.6 | 58.1 | 6.6 | 69.5 | 69.6 | 2.6 | 78.2 | 78.1 | 2.5 | 88.5 | 88.0 | 4.1 |

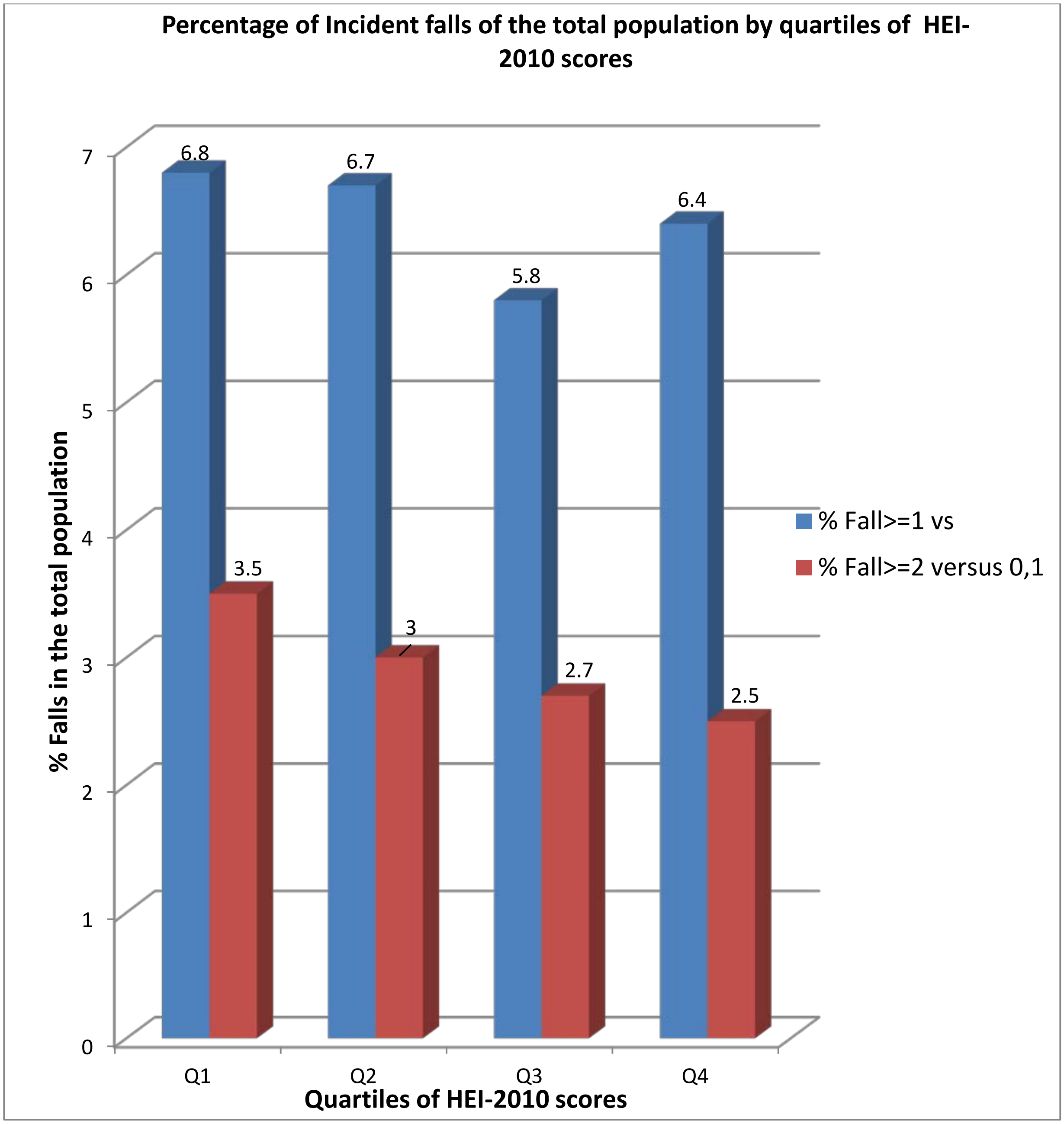


**Figure 1. Percentage of incident falls of the total population by Quartiles of HEI-2010 scores**

The association between the total HEI-2010 scores and incident falls by quartiles of HEI-2010 scores are summarized in Table 6 and 7.

Among the older men who experienced >1 incident fall, in the multiple logistic regression model, no significant association existed in men with the lowest HEI-2010 scores and incident falls in the unadjusted model (p trend=0.47) or after adjusting for age, race and clinic site (model 1, base model) (OR=1.11, 95% CI, 0.93-1.31) (p trend=0.43) versus men with the highest HEI-2010 scores. Model 2 was carried out in a number of steps. In step 1, additional adjustments for lifestyle factors including smoking status and physical activity were carried out. The results were slightly attenuated although no significant association was found between the HEI-2010 scores of men in the lowest quartile and incident falls (OR=1.04, 95% CI, 0.86-1.26) (p trend=0.91) compared to the HEI-2010 scores of men in the highest quartile. Neither covariates were significant and were eliminated from further models. In step 2, on further adjustment for BMI, there was still no significant association and the risks were attenuated (OR=0.98, 95% CI, 0.81-1.20) (p trend=0.68). BMI was significant (p value=0.0006) and was carried to the next model. After further adjusting for comorbidities including diabetes, stroke, parkinson's disease and glaucoma and also prescription medicines including SSRI antidepressants, tricyclic antidepressants, antidepressants and benzodiazepines in step 3, there was no significant association among men in the lowest quartiles (OR=0.92, 95% CI, 0.75-1.13) (p trend=0.30) with incident falls compared to men in the highest quartile. Only significant variables including stroke (p value=0.0063), parkinson's disease (p value=0.01), antidepressants (p value=0.0071) and benzodiazepine (p value=0.02) were carried over to the next model. Finally, when additionally adjusted for gait speed (Model 3), the association was further attenuated although still not significant (OR=0.92, 95% CI, 0.75-1.13) (p trend=0.30). The β coefficient of diet did not change

> 10% after introducing gait speed and hence gait speed does not mediate the relationship. The results are displayed in Table 6.

In contrast, among the older men who experienced recurrent falls (≥2 falls) versus one fall or less, we found a significant association (p trend=0.0008) between HEI-2010 scores and recurrent falls in the unadjusted model. After adjusting for age, race and clinic site (model 1 is base model), there was a significant, inverse risk for recurrent falls (p trend=0.02) with a 22% reduced risk for men with lower scores (OR=0.78, 95% CI, 0.61-1.01) versus men with higher HEI-2010 scores. Carrying over the variables from the base model to the next model, model 2 was carried out in a number of steps. In Step 1, after additionally adjusting for lifestyle factors including smoking status and physical activity, there was still a significant, 23% reduced risk for men in the lowest quartile (OR=0.79, 95% CI, 0.61-1.02) (p trend=0.03) compared to men in the highest quartile and values remained similar to the previous model across all quartiles. Smoking status (p value=0.98) and physical activity (p value=0.26) were not significant and were dropped from further models. In step 2, BMI was additionally adjusted. There was a significant, reduced risk of 20% for recurrent falls across increasing quartiles (OR=0.80, 95% CI, 0.62-1.03) (p trend=0.04). BMI was not significant (p value=0.16) and dropped from further models. Further adjustment for comorbidities and prescription medicines was not significant. Parkinson's disease (p value=0.25), SSRI antidepressants (p value=0.31), tricyclic antidepressants (p value=0.66) were eliminated from further models. Finally on adjusting for gait speed, the inverse risks for recurrent falls remained among those in the lowest quartile (OR=0.84, 95% CI 0.75-1.13) compared to those in the highest quartile although there was no significant association (p trend=0.12). Gait speed did not alter the β coefficient of diet quality by > 10% and was not considered a mediator. Gait speed was significant (p value<0.001). The final model is shown in Table 7.

**Table 6. Odds ratio (Fall> 1 vs 0) (95% CI) of incident falls across quartiles of HEI-2010 scores**

| **Model** | **Q1 (27.85-64.63) (N=1480)** | **Q2 (64.63-73.90) (N=1477)** | **Q3 (73.90-82.68) (N=1481)** | **Q4 (82.68-100.00) (N=1478)** | **p-trend** |
|---|---|---|---|---|---|
| **Model 1** | 1.11 (0.93-1.31) | 0.99 (0.83-1.17) | 1.08 (0.91-1.27) | (Ref) | 0.43 |
| **Model 2** | | | | | |
| **Step 1** | 1.04 (0.86-1.26) | 0.94 (0.77-1.13) | 1.02 (0.84-1.23) | (Ref) | 0.91 |
| **Step 2** | 0.99 (0.82-1.20) | 0.91 (0.75-1.12) | 1.00 (0.83-1.21) | (Ref) | 0.68 |
| **Step 3** | 0.94 (0.77-1.15) | 0.91 (0.75-1.12) | 1.00 (0.82-1.22) | (Ref) | 0.40 |
| **Model 3** | 0.92 (0.75-1.13) | 0.91 (0.74-1.11) | 1.00 (0.82-1.22) | (Ref) | 0.31 |

**Model 1:** Adjusted for age, race and clinic site

**Model 2:** Step 1: Adjusted for age, race, clinic site, lifestyle factors (smoking status, physical activity)

Step 2: Adjusted for age, race, clinic site, body mass index (BMI)

Step 3: Adjusted for age, race, clinic site, body mass index (BMI), comorbidities (diabetes, stroke, glaucoma, parkinson's disease), prescription medicines (SSRI antidepressants, tricyclic antidepressants, antidepressants, benzodiazepines)

**Model 3:** Adjusted for age, race, clinic site, body mass index (BMI), comorbidities (stroke, parkinson's disease), prescription medicines (antidepressants, benzodiazepines), gait speed

**Table 7. Odds ratio (Fall> 2 vs 0, 1) (95% CI) of incident falls across quartiles of HEI-2010 scores**

| Model | Q1 (27.85-64.63) (N=1480) | Q2 (64.63-73.90) (N=1477) | Q3 (73.90-82.68) (N=1481) | Q4 (82.68-100.00) (N=1478) | p-trend |
|---|---|---|---|---|---|
| **Model 1** | 0.78 (0.61-1.01) | 0.82 (0.64-1.06) | 0.97 (0.75-1.26) | (Ref) | 0.02* |
| **Model 2** | | | | | |
| **Step 1** | 0.79 (0.61-1.02) | 0.83 (0.64-1.06) | 0.98 (0.75-1.27) | (Ref) | 0.03* |
| **Step 2** | 0.80 (0.62-1.03) | 0.84 (0.65-1.09) | 1.00 (0.77-1.30) | (Ref) | 0.04* |
| **Step 3** | 0.82 (0.63-1.07) | 0.81 (0.62-1.06) | 0.96 (0.73-1.26) | (Ref) | 0.07 |
| **Model 3** | 0.84 (0.75-1.13) | 0.82 (0.74-1.11) | 0.96 (0.82-1.22) | (Ref) | 0.12 |

**Model 1:** Adjusted for age, race and clinic site

**Model 2:** Step 1: Adjusted for age, race, clinic site, lifestyle factors (smoking status, physical activity)

Step 2: Adjusted for age, race, clinic site, body mass index (BMI)

Step 3: Adjusted for age, race, clinic site, comorbidities (diabetes, stroke, glaucoma, parkinson's disease), prescription medicines (SSRI antidepressants, tricyclic antidepressants, antidepressants, benzodiazepines)

**Model 3:** Adjusted for age, race, clinic site, comorbidities (diabetes, stroke, glaucoma), prescription medicines (antidepressants, benzodiazepines), gait speed

# 7.0 DISCUSSION AND CONCLUSION

Our prospective study addressed the association between incident falls and HEI-2010 scores. The most consistent finding was that there was no significant association between men with the poorest diet quality and the risk for incident falls (>1 vs 0). These trends persisted even after adjusting for several confounding factors, including age, race, clinic site, smoking status, physical activity score, BMI, comorbidities and prescription medicines and these covariates attenuated the odds for incident falls across all the quartiles. For testing the association of recurrent falls (>2 vs 1,0), there was a significant association between men with the poorest diet quality and incident falls in the unadjusted model. After adjustment for multiple possible confounders like age, race, clinic site, smoking status, physical activity score and BMI, the trends continued to be significant although men in the lowest quartile were at lower risk of recurrent falls compared to those in the highest quartile. Further adjustments for prescription medicines, comorbidities and gait speed were not significant although the odds continued to increase. No significant associations were seen suggesting that there may be other factors contributing to our observation. Our results were in agreement with prior literature which supports that several risk factors for falls have been more strongly associated with recurrent fallers compared to single fallers or non-fallers (*Allen et al., 2013*).

To our knowledge, this is the first study to examine the association between overall diet quality, as measured by the latest released HEI-2010 index and a risk for incident fall. Among those older men with the lower HEI-2010 scores, their individual component scores offer an opportunity to articulate the important components of dietary intake and their relationship with incident falls and compare with prior knowledge on their association with physical performance. We found that men with a lower HEI-2010 scores were also found to have lowest dairy component score (Mean=5.9, Median=5.6, SD=2.8). *Sharkey and colleagues (2003)* reported that low intake of calcium, vitamin D, magnesium and phosphorous were found to be associated with increasingly worse levels of lower extremity physical performance including balance, gait speed and chair stands in homebound elderly men and women. Besides calcium and vitamin D, researchers also reported from the SAGE longitudinal study that insufficient consumption of fruits and vegetables were associated with increased risk for fall-related injuries (*Hestekin et al., 2013*). We found that the men in the lowest quartile reported lowest scores for total fruits (Mean=3.4, Median=3.6, SD=1.5), whole fruits (Mean=3.5, Median=4.1, SD=1.6), total vegetables (Mean=3.6, Median=3.8, SD=1.3) and greens and beans (Mean=3.5, Median=4.1, SD=1.6). In another study, *Sato et al. (2005)* conducted a randomized controlled trial among Japanese patients following stroke and reported that combined treatment with folate and vitamin B12 as opposed to a placebo greatly helped in reducing the risk for hip fracture, a fall-related injury. Folic acid is typically found in greens and vitamin B12 is found in meat products, dairy, eggs and fortified cereals. In our study, men in the lowest quartile reported to be having the lowest scores for these food components as well. We did not find a difference in the intake of moderate component foods as hypothesized, lower men still had a lower consumption of sodium, empty calories, refined grains and fatty acids which could be due to reporting bias.

In the HealthABC study, in those who lost weight, increased protein intake was associated with lean muscle mass unlike in those with a stable weight confirming the likely pathway between protein intake, muscle mass and falls (*Houston et al., 2008*). Researchers in a study investigating the association between skeletal muscle mass in a person’s legs with the relative risk of falling in 121 elderly men (Mean age=76.4 years) and women (Mean age=75.7 years) concluded that sarcopenia, the loss of muscle mass due to aging, is a risk factor for injurious falls in the elderly (Sato et al., 2005). Protein caloric intake was found to play a major role in the prevention of sarcopenia (*Jones and Rasmussen, 2009*). Total protein (Mean= 4.1 Versus 4.7, Median= 4.6 versus 5.0, SD=1.1 versus 0.6), Sea food and plant protein (Mean=3.0 versus 4.7, Median= 2.9 versus 5.0, SD=1.6 versus 0.9In our study, men in the lowest quartile had a lower total protein score (Mean= 4.1, Median= 4.6, SD=1.1) and sea food and plant protein (Mean=3.0, Median= 2.9, SD=1.6) and hence were at an increased risk for incident falls.

Our results are consistent with an earlier study by Xu et al. who reported that older adults with higher HEI-2005 scores had better physical performance, which has been found to be strongly associated with falls (*Xu et al., 2011*). However, they had controlled for fewer variables compared to our study which included age, gender, race/ethnicity, education and smoking status. In another recent publication from the HealthABC study, walking speed over eight years and overall diet quality measured using Mediterranean Diet (MedDiet) score, an alternate index, showed faster walking speed over eight years in those with higher MedDiet adherence at baseline and concluded that there was a long-term effect of diet on mobility performance with aging (*Shahar et al., 2012*). They adjusted for age, gender, race, study site, education, marital status, smoking status,self-reported health status,BMI, weekly physical activity, cognitive function, depression score, number of medications, comorbidities, body fat percent, levels of Interleukin-6 and C-reactive protein. Our study adds to the evidence that those who had a better overall diet quality score had faster walking speed and were less likely to fall more than once. These results suggest that improvements or maintenance of a healthy diet may be related to a higher physical function. These effects on physical performance may underlie the association between diet quality and falls. Not consistent with our hypothesis, adjusting for gait speed did not mediate the association significantly. We speculate that the association between overall diet quality and fall would be strongest when measured around the same time when diet was assessed (at baseline visit). Over time, other overriding factors more closely associated with the occurrence of a fall may possibly obscure the association giving us a negative study. If these results are corroborated in future studies, it would provide evidence for the importance of multi-faceted interventions study designs focusing on improving overall diet quality, rather than those focused on individual dietary components.

Our study has a number of strengths and limitations. One of the main limitations was that the MrOS study has been designed to be an observational study which could lead to residual confounding by factors not measured. It can be difficult to predict whether factors associated with incident falls and healthy eating index scores might confound the findings. For example, comorbidities related to falling in elderly could also relate to poor nutrient absorption which could lead to a weaker association between HEI scores and incident falls. Furthermore, these results are limited to community-dwelling men which may preclude its generalizability to other age groups, women or institutionalized persons who probably have a higher prevalence of disability than community-dwelling adults. Food frequency questionnaires have several disadvantages. They are less sensitive to measures of absolute intake for specific nutrients and also require regular eating habits in order to complete it efficiently. Retrospective methods of data collection and the arbitrary groupings of foods relies on the participants understanding and recollection which could lead to reporting bias especially among elderly. There could also be possible response distortion for health foods due to reporting bias by participants or social desirability bias by the interviewer. The modified FFQ used in this study was not validated, even though it was similar to another validated questionnaire. We do not know the reproducibility of this instrument and also cannot determine the absolute nutrient intake. In addition, the inclusion of a study specific modified FFQ focused of measuring nutrients such as calcium, vitamin D and other selected nutrients influencing risk of osteoporosis or prostate cancer in US men and could cause some bias in the estimation of diet quality. We relied on self-report of falls and it is possible that there may have been under ascertainment of falls among men with lower HEI-2010 scores, however, there is no evidence suggesting difference in ascertainment across the HEI-2010 quartiles.

Despite the limitations, there are several strengths to this study. The new HEI-2010 contains 12 components which not only take into account total fruits, vegetables and grains but also look into whole fruits and grains and specific vegetables consumed. It reflects the current 2010 Dietary guidelines of Americans and the MyPyramid food guidance system which provides recommended food intake patterns which have been modified to meet the needs of the older adults (*Alice et al., 2010*). Falls were ascertained every four months to avoid reporting bias. Future work should be directed towards prospective examination of diet quality and falls in longitudinal studies to provide greater understanding into this relationship over longer duration. Particularly, it is important to understand the causal relationship, how poor diet quality can be part of the falls pathway and vice versa, how increased falls can lead to poor dietary intake.

In conclusion, this large study involving older men showed that those with a lower diet quality score at baseline were not significantly associated with higher risk for falls and gait speed did not mediate this association. This work highlights the importance of the quality of diet as a potential modifiable risk factor for fall prevention in older men. More work is needed to focus on prospectively studying their association for a longer duration. Further research to confirm and elucidate these findings could enhance our understanding and address an issue of public health significance.

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