Falls in the elderly: Can self-reported indicators of postural control problems predict injury?

by

Mary B. Lavelle, R.N., B.S.

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APPROVED:

[redacted]

Mark Hornbrook, Ph.D., Project Advisor

[redacted]

Joyce Semradek, R.N., M.S.N., Reader

[redacted]

Barbara Gaines, R.N., Ed.D., Department Chair,
Community Health Care Systems

Abstract

Title: Falls in the elderly: Can self-reported indicators of postural control problems predict injury?

Author: Mary Lavelle

Approved: [redacted]______________________
Mark Hornbrook, PhD

Responses to a large-scale survey of health and functional status were analyzed to determine if indicators of postural control difficulties could be used to identify those at risk of falls and fall-injuries. Logistic regression was used to identify those factors associated with falls; multiple regression was used to identify factors associated with multiple falls and fall-injuries.

Foot problems, eye medications, psychotropic drugs, Parkinson's Disease, use of adaptive equipment or severe mobility impairment, a history of recent falls, and female gender were self-reported items found to independently predict multiple falls and fall-injuries. It is suggested that health care practioners may be able to use simple screening questions to identify many of those at risk of falls and fall-injuries.

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FALLS IN THE ELDERLY: CAN SELF-REPORTED INDICATORS OF POSTURAL CONTROL PROBLEMS PREDICT INJURY?

Introduction

Falls are the most common cause of injuries and of hospital admissions for trauma for all age groups (Baker et al., 1992). Falls experienced by older people are much more likely to have serious consequences (Baker et al., 1992; DeVito et al., 1988; Fife, 1987; Fife et al., 1984), and for some a fall is considered to be the beginning of the end (Hogue, 1992).

Growing awareness of the tremendous economic and social costs of falls has prompted a number of investigations of risk for falls and fall injuries in older persons. Evidence so far suggests that risk of injury is closely related to fall frequency (Nevitt, Cummings & Hudes, 1991), and that most identified risk factors are indirect indicators of underlying postural control problems (Dayhoff, 1992; Lord et al., 1992). The links between fall risk and postural control mechanisms is rarely made explicit. Current research on postural control has provided us with a growing understanding about the reasons for falls, and provides a framework for review and design of falls studies. The study reported here was conducted to determine if general indicators of postural dyscontrol identified through self-report could be used in preliminary identification of those at risk of falls and fall-related injuries.

Postural Control

Falls occur when the center of gravity is moved too far from its base of support. Coordinated sensorimotor responses, or postural control mechanisms, normally maintain the body's center of gravity over its base by correcting center of gravity position or preventing its movement (Horak, Shupert & Mirka, 1989). These responses are thought to be preprogrammed postural strategies that are activated on the basis of available sensory information, the environmental context, biomechanical constraints, and prior experience. The movement synergies, an ankle, hip, and stepping strategy, restore equilibrium in varying circumstances (Horak, Shupert & Mirka, 1989). Use of a particular strategy normally depends on the size of the disturbance and configuration of the support surface. Sensory information about body position is used to determine what postural adjustment will be used; use of an inappropriate strategy can result in a fall (Horak, Shupert & Mirka, 1989; Shumway-Cook & Horak, 1990; Woollacott & Shumway-Cook, 1990).

Because sensory cues related to postural control are often reduced or conflicting in the elderly, older adults have a higher risk of falling (Woollacott, 1990). Further, the ability to execute the postural movement patterns used to maintain balance can be compromised by any disease or disability affecting the bones, muscles and joints, conditions often associated with increased age.

Neuroscientists studying disequilibrium (Horak, Shupert & Mirka, 1989) have broken down the postural response into functional components that might be used to identify sources of postural instability in elders who fall. Although posture is a sensorimotor task, the components are placed into either motor or sensory categories in the model. Motor components include coordination of postural movement patterns, latency to postural response, scaling the postural response to the stimulus, motor learning, and biomechanics. Sensory components include detection of peripheral sensory stimuli, central selection and weighing of sensory information, sense of stability limits, and sensorimotor integration (Horak, Shupert & Mirka, 1989, p.729).

Evidence so far indicates that risk of falling increases with the number of identified risk factors, and that most of these risk factors are either markers of musculoskeletal or neurological impairments that affect strength and balance or medications that affect postural control (Reinsch et al., 1992).

Fall Risk

Reviewing published studies, an Institute of Medicine (IOM) committee (Berg & Cassells, 1990) found strong evidence that certain health conditions, performance indicators, medication use and individual characteristics (age and sex), were independent indicators of fall risk. Among factors consistently linked to increased risk of falling, the following are also indicators of postural control problems: mobility and functional impairment, Parkinson's Disease, dementia, depression, a history of falls, reduced knee, hip, ankle or grip strength, impaired visual acuity, gait abnormalities, reduced walking speed, impaired dynamic balance, difficulty rising from a chair, and reduced mental status score. Incontinence was the only identified health condition not directly related to postural control that predicted falls. Inconsistent evidence for other fall risk indicators linked to postural difficulties included postural hypotension, foot problems, and impaired lower extremity sensory function.

The committee also found strong evidence that sedatives, hypnotics, anxiolytics, and number of medications, all but the last with clear sensorimotor effects, independently predict falls. The linkage of another predictor, a combination of gender (male) and age (above age 80), to postural control is unclear, as there is inconsistent evidence that being female over age 80 predicts falls (Berg & Cassells, 1990).

The relationship between independent fall risk factors and postural dyscontrol is complex: some factors are indicators of sensorimotor impairment, others may interact with such impairment to increase fall risk. For example, the combination of drug side-effects and preexisting sensorimotor problems is thought to increase the risk of falls (Sorock & Shimkin, 1988) and fall-related injuries (Grisso et al., 1991; Shorr et al., 1992), but the mechanisms of interaction have not been well-explored, and specific data about the onset and duration of drug therapy are not included in published analyses (Ray & Griffin, 1990). Cardiovascular problems (Jonsson & Lipsitz, 1990a, 1990b; Rubenstein et al., 1988) have also been identified as causes of falls but since these conditions are so prevalent among the elderly, studies have produced mixed findings (Hertzeanu & Aron, 1985). Vascular-related syncopal falls are associated with increased risk of major injury as protective responses are lost (Nevitt, Cummings & Hudes, 1991; Sattin et al., 1990), but they are currently considered to be difficult to predict or prevent. Environmental hazards were identified as fall risk factors since the earliest published studies, but recent prospective studies have been unable to demonstrate a relationship between falling and identified hazards (Campbell et al., 1990; Nevitt et al., 1989; Tinetti et al., 1988). It may be that "hazards" are situation-specific, that is, those unable to employ the appropriate postural strategy in a given situation will fall.

Risk Factors for Two or More Falls

Prior falls, a fall-related injury, arthritis, Parkinson's Disease, poor tandem gait, and difficulty changing from a sitting to standing position predicted two or more falls in a recent prospective study (Nevitt et al., 1989); in addition, decreased depth perception, a history of seizures, and absent knee reflexes predicted three or more falls. Similar findings linking fall risk with indicators of postural difficulties were reported by Lord et al. (1991). Decreased lower limb proprioception, ankle strength and visual contrast sensitivity, slower reaction time, and increased sway with eyes closed significantly differentiated multiple fallers from single or nonfallers in that study.

Risk Factors for Injury Falls

Few studies have investigated the relationship between fall risk factors and injuries, and most studies of injury falls include only those falls resulting in serious injury, such as a fracture. Nevitt et al. (1991), who studied risk factors for both major and minor injuries, found that neuromuscular and cognitive impairments, as well as fall circumstances, affected the risk of injury.

Fall risk factors that have been associated with hip fractures include poor vision in one or both eyes (Felson et al., 1989; Grisso et al., 1991), Parkinson's Disease (Johnell et al., 1992), lower limb dysfunction, neurological conditions and barbituate use (Grisso et al., 1991). Kelsey et al. (1992) found that in addition to low bone density, poor visual acuity and multiple falls were associated with falls resulting in fracture of the distal forearm, while recent declining health status, insulin dependent diabetes, and indicators of neuromuscular weakness, were associated with falls resulting in fracture of the humerus. The finding that frequent walkers who fell were more likely to sustain a forearm fracture, while infrequent walkers were more likely to sustain a fracture of the humerus, suggests that fitter individuals are better able to employ protective responses (Kelsey et al., 1992).

A number of risk factors for falls have been identified in both retrospective and prospective studies; many are indicators of problems with postural control. It is not clear, however, that the same factors predict injury-falls. Only recently have investigators begun to identify factors associated with fall-related injuries, evidence to date suggests that most risks of injury are also indicators of postural dyscontrol. Assessment of postural control components currently requires sophisticated balance platform technology. Although simpler performance tests of mobility and balance (Mathias, Nayak & Isaacs, 1986; Tinetti, 1986) offer promise in linking fall risk to postural dyscontrol, their predictive value may not be reliable for some subgroups (Speechley & Tinetti, 1991), and costs of in-person assessment make them impractical for mass screening. It remains unclear whether more general indicators of postural dyscontrol, detected in self-report surveys, are useful in preliminary identification of those at risk of falls and fall-related injuries.

Self-report

National surveys of health and disability have used self-report measures with some confidence to describe the epidemiology of disability (Cornoni-Huntley, Huntley & Feldman, 1990), although others have noted disparities attributed to advanced age and cognitive impairment between self-report and observed functional limitations (Kelly-Hayes et al., 1992).

Nevertheless, few age-associated differences in the quality of self-reported data on chronic illness were found in a recent RAND report (Sherbourne & Meredith, 1992), and patient self-ratings of function were also more accurate than family or physician ratings in a recent comparison with performance-based measures in a geriatric rehabilitation setting (Elam et al., 1991). Thus, self-report may be as reliable as clincal assessment for some purposes.

It is clear that documented or reported health impairments alone are not predictive of fall risk (Campbell et al., 1989, 1990; Nevitt et al., 1989; Tinetti, Speechley & Ginter, 1988); it remains to be seen if self-reported performance indicators, in combination with reported health conditions, can identify those at risk. The study reported here, therefore, was conducted to determine if self-report data could identify those at risk of falls and fall-related injuries who would benefit from further injury risk assessment and intervention.

While targeted intervention studies are underway, work on development of practical screening tools to identify those who might benefit from further fall risk assessment and preventive efforts must be ongoing. Since frequency of falls and factors associated with postural dyscontrol have been linked to fall injuries in other studies, it seems useful to determine if the more general indicators of postural dyscontrol identified through self-report can be used in preliminary identification of those at risk.

Methods

Responses to a large-scale survey of health and functional status were analyzed to determine if indicators of postural control difficulties could be used to identify those at risk of falls and fall-injuries. Logistic regression was used to identify those factors associated with falls; multiple regression was used to identify factors associated with multiple falls and fall-injuries.

Data

In order to determine the clinical relevance of screening questions for fall prediction, baseline health status and fall data from the study of accidental falls in the elderly (SAFE) was used to identify what factors, if any, predicted single and multiple (two or more) falls or fall injuries. In the original study, conducted by the Northwest Kaiser Permanente Center for Health Research, an approach to fall prevention was designed and tested (Hornbrook, et al., 1991). Detailed descriptions of the recruitment procedures, sample characteristics, and aims of the original study have been published elsewhere (Hornbrook et al., 1991; Stevens et al., 1991).

The recruitment cohort consisted of persons age 65 and above who were members of the Northwest Region of Kaiser Permanente, a prepaid group practice health maintenance organization (HMO). Nonambulatory, housebound, institutionalized, terminally ill, blind, deaf and parttime residents were excluded from the study. Three thousand one hundred eighty two (3182) eligible members agreed to participate; comparative age distributions of the recruitment cohort, participants, and the U.S. population were similar except that a smaller percentage of participants were in the age category 80 and above (Stevens et al., 1991).

Participants were followed for approximately 2 years; they were asked to fill out a baseline questionnaire, the Falls History Questionnaire (FHQ), and to report each fall to the research center. Followup interviews were conducted to explore the antecedents, circumstances and consequences of reported falls; those who did not report falls were contacted every 3-4 months (Hornbrook et al., 1991).

Sample

Inclusion criteria. Data from the FHQ and fall reports were used for the present study. Participants who did not return the baseline FHQ (15.5%) and those with inaccurate fall data (0.2%) (Darlene Wingfield, personal communication, June, 1992) were excluded. Few differences between respondents and nonrespondents were detected. Those in age categories 65-69 and 80 and above were somewhat less likely to return the questionnaire $\chi^2(4, n=3175) = 17.6$, $p<.001$; nonrespondents were also somewhat less likely to fall $\chi^2(1, n=3175)= 60.22$, $p<.000$.

Age and gender. Responses of 2683 participants (84.5%) were used for this analysis. The age of participants ranged from 64 to 102 with a mean of 73.24; women (62.47%) outnumbered men (37.53%), with a similar distribution in each age category $\chi^2(4, n=2683) = 4.95$, $p=.292$. These demographic statistics are similar to those found in other studies of noninstitutionalized older people (Kelly-Hayes et al., 1992).

Functional status. Only 93 people, or 3.6% of the sample, reported needing help with one or more activities of daily living (ADLS). However, 599, or 23% of the sample required help with one or more instrumental activities (IADLS). The most frequently reported (and difficult to interpret) IADL need was for help in going places (17%), followed by shopping (10.3%), household chores (8.6%), laundry (6%), meal preparation (4.8%), money management (3.8%), phone use (2.5%) and medications (2.2%). Approximately 21% of the sample (522 people) reported having one or more pieces of adaptive equipment in their home. Grab bars (12.1%) were the most frequently reported mobility aid, followed by a cane (10.5%), bath bench (4.4%), walker (2.4%), wheelchair (0.9%) and crutches (0.9%). These statistics are hard to compare to other studies as different measures are used to describe the concept of disability.

Chronic health conditions. Chronic health conditions reported by respondents included arthritis

(46%), high blood pressure (37%), back problems (29%), heart disease (23.3%), knee problems (22.5%), foot problems (20.5%), circulatory problems (18.3%), hip problems (13.9%), deafness (13.6%), breathing problems (11%), memory loss (10.1%), osteoporosis (7.4%), diabetes (6.9%), and chronic cough (6.3%). An approximately equal number of respondents reported experiencing trouble with eyesight (34.5%) or hearing (34.3%) during the past week. A history of stroke was reported by 3.2% of the sample while 1.2% reported having Parkinson's Disease.

Use of medications. Antihypertensives (38.9%) were the most frequently reported category of medications used, followed by pain and antiinflammatory drugs (35.9%), cardiac medications (31.8%), thyroid medications (9.6%), psychotropics (7.3%), oral hypoglycemics (3.2%), insulin (1.4%), and eye medications (1.6%). These numbers are similar to those reported by participants in other epidemiologic studies (Chrischilles et al., 1992).

Outcome Variables

Self-reported falls, multiple (two or more) falls, and injury falls were the outcomes of interest.

Falls were defined for respondents as "losing your balance such that your hands, arms, knees, bottom, or body touch or hit the ground or floor" (FHQ). Although most studies of injury falls focus on fractures (Grisso et al., 1991; Kelsey et al., 1992; Johnell et al., 1992; Nevitt et al., 1991), for this study injury falls were defined as falls that result in a range of minor (some pain) to major (fracture) injuries. Minor injury falls were included because they may have serious consequences for older fallers, including loss of confidence, mobility and independence (Kiel et al., 1991; Maki et al., 1991; Nevitt et al., 1989).

Predictors

Predictor variables derived from responses to the FHQ included self reports of chronic health conditions and symptoms of sensory (hearing, vision) problems thought to affect motor or sensory function. Medications indicative of underlying conditions affecting balance or with direct effects on postural control were also included in preliminary analyses. Performance indicators, including use of adaptive or prosthetic equipment, problems with activities (ADL) or instrumental activities (IADL) of daily living, and degree of mobility impairment, were a third category of variables used in preliminary analyses.

Chronic health conditions. Based on clinical experience and review of the literature, health condition variables were characterized for this study as (1) conditions primarily affecting motor components of postural control, (2) sensory components, or (3) both.

Self-reported motor conditions included arthritis; hip, knee, foot and back problems; and osteoporosis. All of these musculoskeletal impairments or symptoms can affect the scaling and biomechanical components of posture; hip, knee, and foot problems may also affect coordination of movement patterns, since they can indicate muscle and nerve involvement, depending on the cause of the problem. Back problems and osteoporosis can affect every aspect of motor function if the problem affects spinal cord function.

Self-reported sensory conditions included difficulty with vision and hearing; heart, circulatory, blood pressure and lung problems; memory loss and diabetes. All of these conditions can adversely affect detection of peripheral stimuli, information selection and weighting, sense of stability limits, and sensorimotor integration, the major sensory components of postural control (Horak, Shupert & Mirka, 1989).

Self-reported neurological conditions such as stroke and Parkinson's Disease that can profoundly affect both sensory and motor components of postural control were also included. While a small percentage of syndromes may affect only motor performance, most neurological diseases affect both the motor and sensory systems.

<u>Medications</u>. Therapeutic classes of self-reported medications were used singly and in combination as predictors in this study. These medications may directly affect postural control mechanisms, distort sensory input, or indicate the presence of underlying conditions that affect balance.

Cardiovascular related drugs, digitalis, heart muscle depressants, coronary dilators and diuretics were included in the cardiac medication category. Diuretics were also included in the antihypertensive category, along with antihypertensives, as they are often prescribed for either heart failure, blood pressure management, or both. Other class combinations included pain medications (narcotics, non-narcotic analgesics and anti-inflammatory drugs) and psychotropic medications (cns depressants, hypnotics and sedatives, minor or major tranquilizers and antidepressants). Insulin, oral hypoglycemics, eye medications and thyroid medications were additional single drug categories used in preliminary analysis.

ADLS, IADLS and equipment. Activities identified as ADLS included eating, dressing, bathing, and transfers in and out of bed and onto and off the toilet. These can be narrowly described as measures of physical functioning, differentiating function at the very disabled end of the spectrum; in contrast, IADLS used as predictors -- doing laundry, preparing meals, taking medications, managing money, using the phone, shopping, doing household chores and going places, assess more complex activities that describe the ability of the person to meet his or her own needs in the community (Calvani & Douris, 1991; Guralnik et al., 1989). Within the large group of the nondisabled elderly, however, these measures have little ability to distinguish high levels of functioning (Guralnik et al., 1989). For this reason, two other functional indicators were included in preliminary analyses: use of adaptive equipment (crutches, canes, wheelchairs, walkers, bathroom grab bars or shower/tub benches) and a mobility scale described below.

Mobility scale. A scale of self-described functional mobility was created by combining responses to four items in the FHQ that asked respondents to report the degree of difficulty they would have (1) walking to the bathroom, (2) walking up a flight of stairs, (3) walking a block, and (4) running the length of a football field. Except for the variable "walking a block" these items are part of the Duke-UNC Health Profile (Parkerson et al., 1981) a 63-item measure of functional health status. Frequencies and crosstabulations of responses to the four items were analyzed, and a scale with a scoring range of 0 (no difficulty) to 5 (severe impairment) was developed. As expected, crosstabulations between mobility, neuromuscular health impairments, and performance variables demonstrated strong associations between problem health and performance indicators and mobility impairments.

Model Development

While single falls can result in injury, they are difficult to predict. Persons experiencing multiple falls have more opportunity to injure themselves; identification of risk factors for two or more falls is therefore more likely to be clinically useful in determining those at risk for injury. For this reason, outcomes for the study included (1) whether or not a person fell during the study period, (2) the number of falls, and (3) whether or not the fall resulted in injury. The same predictor variables, for the most part indicators of postural control difficulties, were used to determine risks of experiencing a fall, multiple falls, or a fall with injury.

Correlations among predictor variables and between predictors and the outcome variables were examined in order to identify items that should be included in the final model. Logistic regression was used to identify factors that contributed to fall risk; multiple regression was used to see if those same factors contributed to risk of multiple falls and injury falls. Conditions affecting motor and sensory function, medications, and performance indicators were used in preliminary analyses. Motor conditions, including arthritis, hip, knee, and back problems, were not significantly associated with any of the outcome variables and were dropped from the model. The use of pain medications, highly correlated with these conditions, was not a significant substitute. Correlations between these factors and mobility and adaptive equipment use were high, suggesting that performance indicators might better describe the degree of underlying impairment. Recent vision problems, high blood pressure, circulatory problems, lung problems, and diabetes were sensory conditions eliminated after tests for association with falls and fall injuries; antihypertensives, cardiac medications and hypoglycemics were also eliminated from the final model. Although the item "recent hearing problems" was associated with all three outcomes, the low number of responses to this item caused it to be eliminated from further analysis. Weak associations between ADLS, IADLS, and fall outcomes were detected; since the response to these items was low, the results difficult to interpret, and the correlation between these activities and mobility and adaptive equipment use high, ADLS and IADLS were also eliminated from the final model.

Items used in the final equations to identify risk of falls, multiple falls and injury falls were categorized as health conditions, performance indicators, medications, and nonspecific indicators (age and gender), and were grouped according to the postural control components most probably affected. Osteoporosis and foot problems (health conditions/motor components), heart trouble and memory problems (health conditions/sensory components), Parkinson's Disease and stroke (health conditions/sensorimotor components), use of adaptive equipment, mobility impairment, and prior falls (performance indicators/sensorimotor components), thyroid, eye medications and psychotropic drugs (medications/sensory components), and age and gender (nonspecific indicators) were included in all equations. Length of time in the study was included to control for its effect on the outcomes.

Results

Falls

Forty-five per cent of the sample (1196 people) reported at least one fall during the study period.

Fallers were more likely to be older $\chi^2(1, \underline{n}=2683)=$ 11.77, $\underline{p}=.001$, and female $\chi^2(1, \underline{n}=2683)=$ 16.66, $\underline{p}=.000$. Factors that contributed to fall risk are listed in Table 1. Significant predictors of fall risk included health conditions with sensory effects (memory, heart trouble), motor effects (foot trouble) and sensorimotor effects (Parkinson's Disease, stroke). Use of adaptive equipment and a recent pre-baseline fall, performance indicators with sensorimotor effects, were also predictors; psychotropic drug use, with primarily sensory effects, also identified fallers. Significant demographic items included greater age and female gender. Factors that did not significantly differentiate fallers from nonfallers included osteoporosis, a health condition with motor effects; mobility impairment, a performance indicator of sensorimotor difficulties; and thyroid and eye medications, drugs with primarily sensory effects.

Multiple Falls

Of those who fell, 44.5% (519 people) reported two or more falls during the study period. Multiple regression was used to identify factors that contributed to the risk of two or more falls; predictors employed in the equation to identify fallers were used again to identify those reporting multiple falls. The log of the number of falls was used as the dependent variable, as a few fallers reported numerous falls. Factors found to be significant predictors of multiple fall risk included sensory condition indicators (memory problems, use of eye medications or psychotropics), motor condition indicators (foot problems), sensorimotor condition indicators (Parkinson's Disease, stroke), and performance indicators (a recent fall, adaptive equipment use) (see Table 2). Female gender was the only demographic variable that identified multiple fallers. Osteoporosis, heart problems, mobility impairment, use of thyroid medications and age were not associated with multiple falls.

Injury Falls

Of those who fell during the study period, 61% (736 people) reported an injury fall. Over half of those (54%) reported a medical care contact because of the fall. Multiple regression, using the same predictors employed in the above equations, was used to identify factors that contributed to the risk of an injury fall. The log of the number of injury falls was used as the dependent variable as a few fallers reported a number of injury falls. Predictors of injury falls are listed in Table 3. Health conditions with motor effects that predicted a fall with injury included osteoporosis and foot problems; Parkinson's Disease, with sensorimotor effects, was also associated with an injury fall. The sensorimotor performance indicators associated with fall injury included report of a recent fall, and mobility impairment. Eye medications and psychotropics, with sensory effects, were also associated with an injury fall. Demographic predictors included female gender and greater age. Use of adaptive equipment, heart trouble, memory problems, use of thyroid medications, and stroke were not associated with injury falls.

Commonalities and Differences

Variables that predicted falls, multiple falls and injury falls are compared in Table 4. Some of the indicators associated with frequent falls were also associated with injury falls, including reports of foot problems (motor), Parkinson's Disease, a pre-baseline fall (sensorimotor), use of eye medications, use of psychotropic drugs (sensory), and female gender. Osteoporosis (motor), mobility impairment (sensorimotor) and advanced age were associated with injury falls, but not with multiple falls, while reports of memory problems (sensory), and use of adaptive equipment and previous stroke (sensorimotor) were associated with multiple falls but not injury falls. Reported heart trouble was only associated with falling; age was weakly associated with both falls and injury falls, but not fall frequency; and memory problems and stroke were associated with both falls and number of falls, but not with fall injuries.

Discussion

Almost half the participants in this study reported at least one fall during the two year period. This rate is higher than those found in other studies that report fall rates per year. It is known that at least one-third of community dwelling persons over the age of 65 fall at least once a year, and the rate is thought to increase above this age (Blake et al., 1988; Campbell et al, 1981; Tinetti, Speechley & Ginter, 1988; Waller, 1985). Age was significantly but weakly associated with falls in the present study.

Estimates of rates of injury falls that require medical care range from 10-15% (Tinetti & Speechley, 1989; Sattin et al., 1990). Rates of reported fall-related medical contact in this study (25%) are higher than this, perhaps because participants were HMO members used to contacting providers.

Although falls have been identified as serious health problems since the early studies of Droller (1955) and Sheldon (1960), the epidemiology of falls is not clear (Campbell et al., 1990; Cummings et al., 1985). Non-injury falls are rarely witnessed, so rates are of necessity based on self-report. Since in this study, reports of fall-related medical care were not checked against medical records, the estimates of fall-related injuries and medical care contacts should be interpreted with caution.

A number of self-reported health conditions and performance indicators associated with motor and sensory components of postural control (foot problems, use of eye medications, use of psychotropics, Parkinson's Disease, and a recent fall), were found to be associated with both multiple falls and injury falls among this noninstitutionalized elderly population. Advanced age, mobility impairment and osteoporosis were associated with injury, but not multiple falls, suggesting that not all of the factors associated with frequent falls can predict injury.

Some of the predictors identified had stronger associations with falls and fall-injuries than did others. Parkinson's Disease was one of these factors. It is well known to both providers and those with the disease that Parkinson's is associated with frequent falls. In the past, it was thought that the frequent falls associated with Parkinson's did not necessarily lead to injury; that is, it was thought that people with the condition may have learned to fall in a way that avoided injury. Recent evidence (Johnell et al., 1992), however, suggests that this is not the case; on the contrary, those with the disease have an increased risk of fracture. The present study also found a strong association between the disease and fall injuries, although the degree of injury is unknown.

The use of eye medications also was moderately associated with multiple falls and fall injuries.

Vision problems have been implicated in most major studies of fall risk, but a reminder to providers and consumers of the increased risk of a fall injury for those using eye preparations seems warranted. The use of psychotropic drugs was also associated with falls and fall-injuries, although the association with injuries was weaker. Whether the drugs or the underlying conditions or both are associated with postural control problems, persons receiving these prescription drugs are at risk for fall-injuries.

Mobility impairment and use of adaptive equipment are variables describing similar phenomena, although use of equipment such as a wheelchair may indicate more severe mobility impairment. In this study, equipment use was associated with falls and number of falls, but not significantly associated with injuries, while mobility was only weakly associated with injuries. These findings suggest that those with severe mobility impairment may have less opportunity to injure themselves in a fall, either because of restricted movement, or perhaps because of home help that intervenes to prevent fall injuries. Use of equipment to enhance mobility may also prevent fall injuries.

Fall injury prevention training could be of use to this population when equipment is issued.

Reported foot problems were associated with falls, multiple falls, and a fall-related injury. While responses to this item did not indicate what type of foot problems were involved, the risk of fall injuries should be considered when foot problems are encountered.

The finding that those who reported problems with memory tended to fall more frequently is difficult to interpret. Most of these individuals did not rely on surrogates to fill out the questionnaire, so their reports of fall frequency may not be accurate; if underreporting occurred, the association with falling may be even higher.

Report of a fall in the period 6 months prior to baseline was strongly associated with falls and multiple falls during the study period, and less strongly with injury falls. As an indicator of underlying postural difficulties, this item may be the most useful of all in identifying those who might benefit from further assessment.

Females in this and a number of other studies tended to have more falls, fell more often, and experienced more fall-related injuries than their male counterparts. This finding contrasts with the IOM review that found strong evidence that males over age 80 were more likely to fall (Berg & Cassells, 1990). Although there is suspicion among some researchers that men may have underreported their falls in some studies (Campbell et al., 1989), the conflicting findings suggest that further study of gender influences on postural mechanisms is warranted.

Risk factors identified from responses to this general survey are similar to those identified in other studies that used comprehensive medical, functional and environmental assessments. It may be that among those who are able to provide accurate information, self-reports are as useful as detailed examinations in identifying those who would benefit from further fall risk assessment and targeted intervention.

Response options in the health status survey used in this analysis did not allow for descriptive detail of the problems, so it is impossible to draw more than general links between the health conditions and postural control problems. It is not clear what the range of problems experienced by those who indicated the presence of foot, heart, or memory problems might have been, and although the scale of mobility impairment was developed in an attempt to better describe the degree of disability caused by these conditions, items in the scale were not specific enough to link to components of postural control. Missing responses to some survey items also may have influenced the results; for example, responses to questions about recent hearing and vision problems were not used because of missing data, although these certainly contribute to difficulties with postural mechanisms.

The health status survey used for this analysis was not specifically designed to identify factors associated with postural control problems, and it may be that more specific indicators of balance difficulties would demonstrate a stronger relationship between factors that predict fall frequency and fall-related injuries.

Given the limitations, with both healthcare cost containment and injury-related costs on the rise, it seems useful to continue searching for cost-effective methods of identifying those who would benefit from further fall risk assessment and intervention. Findings from this study suggest that there are some screening questions that can be used by practitioners in all settings to identify those at risk. For example, patients who report recent falls could benefit from further assessment before a fall results in serious injury; patients starting psychotropic or eye medications could benefit from further assessment and education since these drugs are associated with multiple and injury falls; those who report a history of stroke, foot problems, memory problems, or Parkinson's Disease might require further balance and fall history assessment before interventions are initiated, and those who receive assistive devices or demonstrate mobility problems might require focused assessment and instruction in fall prevention and recovery. For persons with osteoporosis, interventions to prevent falls would be appropriate, as they are at high risk of injury.

As more information becomes available about the mechanisms of postural control and performance indicators that can identify problems with specific postural components, survey questions can be designed to better elicit information about postural difficulties and their relationship to fall-injuries. This study provides some evidence that self-report survey can be used to identify those at risk.

The findings are useful for both health care practitioners and consumers, for they show that survey responses can identify persons who would benefit from further evaluation, and they suggest that persons with certain health conditions, mobility impairments, or those using certain medications (presumably people already in contact with health care providers) might benefit from targeted interventions.

TABLE 1
A logistic model to identify items associated with components of postural control that predict falls

VARIABLE	PARAMETER ESTIMATE (-3.38* INTERCEPT)
MOTOR COMPONENTS:	
OSTEOPOROSIS	.13
FOOT PROBLEMS	.21*
SENSORY COMPONENTS:	
HEART TROUBLE	.19*
MEMORY PROBLEMS	.31*
THYROID DRUGS	.03
EYE MEDICATIONS	.52
PSYCHOTROPIC DRUGS	.32*
SENSORIMOTOR COMPONENTS	
PARKINSON'S DISEASE	.94*
STROKE	.50*
ADAPTIVE EQUIPMENT	.26*
MOBILITY IMPAIRMENT	.20
PRIOR FALLS	.65*
NONSPECIFIC INDICATORS	
AGE	.01*
FEMALE GENDER	.27*

CHI-SQUARE (15, N=2611) = 172.36**
*P <.05 **P <.01

TABLE 2
Identification of items associated with postural control that predict multiple falls (log of the number of falls as the outcome)

VARIABLE	PARAMETER ESTIMATE (-0.32 INTERCEPT)
MOTOR COMPONENTS:	
OSTEOPOROSIS	.06
FOOT PROBLEMS	.09**
SENSORY COMPONENTS:	
HEART TROUBLE	.03
MEMORY PROBLEMS	.10**
THYROID DRUGS	.05
EYE MEDICATIONS	.19*
PSYCHOTROPIC DRUGS	.14**
SENSORIMOTOR COMPONENTS	
PARKINSON'S DISEASE	.46**
STROKE	.12*
ADAPTIVE EQUIPMENT	.10**
MOBILITY IMPAIRMENT	.00
PRIOR FALLS	.20**
NONSPECIFIC INDICATORS	
AGE	.00
FEMALE GENDER	.05*

F = 16.099**
Adjusted R-Square = .0798
N = 2611

**P* <.05 ***P* <.01

TABLE 3
Identification of items associated with components of postural control that predict injury falls (log of the number of injury falls as the outcome)

VARIABLE	PARAMETER ESTIMATE (-.48** INTERCEPT)
MOTOR COMPONENTS:	
OSTEOPOROSIS	.08*
FOOT PROBLEMS	.07**
SENSORY COMPONENTS:	
HEART TROUBLE	.02
MEMORY PROBLEMS	.02
THYROID DRUGS	.03
EYE MEDICATIONS	.12*
PSYCHOTROPIC DRUGS	.09**
SENSORIMOTOR COMPONENTS	
PARKINSON'S DISEASE	.20**
STROKE	.02
ADAPTIVE EQUIPMENT	.04
MOBILITY IMPAIRMENT	.01*
PRIOR FALLS	.07**
NONSPECIFIC INDICATORS	
AGE	.01*
FEMALE GENDER	.10**

F = 15.297**
Adjusted R-Square = .0759
N = 2611

*P <.05 **P <.01

TABLE 4
A comparison of items associated with postural control and three outcomes: falls, multiple falls, and an injury fall

VARIABLE	FALL N=2611	MULTIPLE FALLS N=2611	INJURY FALL N=2611
MOTOR COMPONENTS:			
OSTEOPOROSIS	NO	NO	YES
FOOT PROBLEMS	YES	YES	YES
SENSORY COMPONENTS:			
HEART TROUBLE	YES	NO	NO
MEMORY PROBLEMS	YES	YES	NO
THYROID DRUGS	NO	NO	NO
EYE MEDICATIONS	NO	YES	YES
PSYCHOTROPIC DRUGS	YES	YES	YES
SENSORIMOTOR COMPONENTS			
PARKINSON'S	YES	YES	YES
STROKE	YES	YES	NO
ADAPTIVE EQUIPMENT	YES	YES	NO
MOBILITY IMPAIRMENT	NO	NO	YES
PRIOR FALLS	YES	YES	YES
DEMOGRAPHICS			
AGE	YES	NO	YES
FEMALE GENDER	YES	YES	YES

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APPENDIX A

AGE COMPARISON BETWEEN RESPONDENTS AND NONRESPONDENTS

Appendix A

Comparison of age categories of respondents and nonrespondents

AGE	<65	65-69	70-74	75-79	80+	TOTAL
NO FHQ	1.01%	23.17%	31.50%	21.75%	22.56%	15.5%
FHQ	1.08%	29.56%	32.24%	21.39%	15.73%	84.5%

$\chi^2(4, \underline{n}=3175) = 17.6, \underline{p}<.001$

APPENDIX B
COMPARISON OF FALL RATES BETWEEN RESPONDENTS AND NONRESPONDENTS

Appendix B

Fall rates of FHQ nonrespondents in comparison with respondents

RESPONSE STATUS	NO FALL	FALL
NO FHQ	365 74.19%	127 25.81%
YES FHQ	1487 55.42%	1196 44.58%
TOTAL	1852 58.33%	1323 41.67%

$\chi^2(1, \underline{n}=3175) = 60.22, \underline{p}<.000$

APPENDIX C:
DISTRIBUTION OF GENDER BY AGE GROUP

Appendix C

Number of women and men in each age group

AGE	<65	65-69	70-74	75-79	80+	ROW TOTAL
WOMEN	19 65.52%	484 61.03%	538 62.20%	352 61.32%	283 67.06%	1676 62.47%
MEN	10 34.48%	309 38.97%	327 37.80%	222 38.68%	139 32.94%	1007 37.53%
TOTAL	29 1.08%	793 29.56%	865 32.24%	574 21.39%	422 15.73%	2683 100%

$\chi^2(4, \underline{n}=2683) = 4.95, \underline{p}=.292$

APPENDIX D:

MOBILITY IMPAIRMENT SCALE WITH FREQUENCIES

Mobility Scale

SCORE	SELF-REPORTED FUNCTION
5 (7.6%)	SOME OR A LOT OF TROUBLE WALKING TO THE BATHROOM A LOT OF TROUBLE CLIMBING STAIRS AND SOME OR A LOT OF TROUBLE WALKING A BLOCK
4 (9.1%)	A LOT OF TROUBLE WITH STAIRS AND NO TROUBLE OR ANSWER TO BLOCK A LOT OF TROUBLE WITH STAIRS AND NO TROUBLE WITH OR ANSWER TO WALKING TO BATHROOM A LOT OF TROUBLE WALKING A BLOCK AND NO ANSWER TO OR TROUBLE WITH STAIRS A LOT OF TROUBLE WALKING A BLOCK AND NO ANSWER WALKING TO BATHROOM SOME OR A LOT OF TROUBLE WALKING A BLOCK AND SOME TROUBLE WITH STAIRS
3 (24.2%)	SOME TROUBLE WITH STAIRS AND NO ANSWER TO OR TROUBLE WITH BATHROOM SOME TROUBLE WITH STAIRS AND NO ANSWER TO OR TROUBLE WITH A BLOCK SOME TROUBLE WITH A BLOCK AND NO ANSWER TO OR TROUBLE WITH STAIRS SOME TROUBLE WITH BLOCK AND NO ANSWER TO OR TROUBLE WITH BATHROOM SOME TROUBLE WITH BLOCK AND NO ANSWER TO STAIRS AND NO TROUBLE WITH BATHROOM
2 (16.2%)	A LOT OF TROUBLE RUNNING 100 YARDS AND NONE WITH STAIRS AND NONE WITH BATHROOM AND NONE WITH A BLOCK
1 (26.1%)	SOME TROUBLE RUNNING 100 YARDS AND NO ANSWER TO STAIRS AND NO TROUBLE WITH BLOCK AND NONE WITH BATHROOM NO TROUBLE WITH STAIRS, NONE WITH A BLOCK, AND NONE WITH BATHROOM AND NO ANSWER TO RUNNING 100 YARDS
0 (16.7%)	NO TROUBLE RUNNING, CLIMBING STAIRS, WALKING A BLOCK OR TO THE BATHROOM

APPENDIX E
FREQUENCY OF MEDICATION USE BY CATEGORY

Appendix E

FREQUENCY OF MEDICATION USE BY CATEGORY

DRUG CATEGORY	NUMBER USING ONE OR MORE DRUGS	PERCENT USING ONE OR MORE DRUGS
CARDIAC MEDICATIONS	798	31.8%
ANTIHYPERTENSIVES	1045	38.9%
PAIN MEDICATIONS	964	35.9%
SEDATIVE/HYPNOTICS	195	7.3%
EYE MEDICATIONS	43	1.6%
INSULIN	40	1.4%
ORAL HYPOGLYCEMICS	86	3.2%
THYROID MEDICATIONS	258	9.6%

APPENDIX F
FREQUENCY OF HEALTH CONDITIONS WITH MOTOR, SENSORY AND MIXED EFFECTS

Appendix F

FREQUENCY OF HEALTH CONDITIONS WITH MOTOR EFFECTS

HEALTH CONDITION	FREQUENCY	PERCENT OF RESPONDENTS
ARTHRITIS	1233	46%
OSTEOPOROSIS	199	7.4%
HIP PROBLEMS	373	13.9%
BACK PROBLEMS	778	29%
KNEE PROBLEMS	604	22.5%
FOOT PROBLEMS	551	20.5%

FREQUENCY OF HEALTH CONDITIONS WITH SENSORY EFFECTS

HEALTH CONDITION	FREQUENCY	PERCENT OF RESPONDENTS
DEAFNESS	365	13.6%
BLINDNESS	47	1.8%
HEART PROBLEMS	625	23.3%
CHRONIC COUGH	169	6.3%
MEMORY LOSS	272	10.1%
LOW BLOOD PRESSURE	82	3.1%
HIGH BLOOD PRESSURE	992	37%
CIRCULATION PROBLEMS	490	18.3%
LUNG/BREATHING PROBLEMS	296	11%
DIABETES	186	6.9%

FREQUENCY OF HEALTH CONDITIONS WITH MIXED EFFECTS

HEALTH CONDITION	FREQUENCY	PERCENT
STROKE	87	3.2%
PARKINSON'S	33	1.2

APPENDIX G:
FREQUENCY AND SUMMATION OF ADAPTIVE EQUIPMENT USE

Appendix G

FREQUENCY OF EQUIPMENT USE

EQUIPMENT	FREQUENCY	PERCENT
CRUTCHES	24	0.9%
WHEELCHAIR	23	0.9%
WALKER	65	2.4%
CANE	283	10.5%
GRAB BARS	325	12.1%
BATH BENCH	117	4.4%

SUM OF EQUIPMENT USE

NUMBER OF ITEMS USED	FREQUENCY	PERCENT
0	2131	79.4%
1	366	13.6%
2	121	4.5%
3	42	1.6%
4	15	0.6%
5	5	0.2%
6	3	0.1%
TOTAL USERS	522	20.6%

APPENDIX H
FREQUENCY AND SUM OF NEEDS FOR HELP WITH ADLS

Appendix H

FREQUENCY OF NEEDS FOR HELP WITH INDIVIDUAL ADLS

ADL	FREQUENCY	PERCENT
EATING	12	0.5%
DRESSING	35	1.4%
BATHING	36	1.4%
BED TRANSFERS	50	1.9%
TOILET TRANSFERS	13	0.5%

SUM OF ADL HELP NEEDS

NUMBER OF ADLS	FREQUENCY	PERCENT
0	2516	96.4%
1	65	2.5%
2	13	0.5%
3	7	0.3%
4	6	0.2%
5	2	0.1%
TOTAL REQUIRING HELP	93	3.6%

APPENDIX I
FREQUENCY AND SUM OF NEEDS FOR HELP WITH IADLS

Appendix I

FREQUENCY OF HELP NEEDED FOR IADLS

IADL	FREQUENCY	PERCENT
LAUNDRY	151	6%
MEAL PREP	122	4.8%
TAKING MEDICATIONS	56	2.2%
MONEY MANAGEMENT	97	3.8%
PHONE USE	64	2.5%
SHOPPING	263	10.3%
HOUSEHOLD CHORES	218	8.6%
GOING PLACES	452	17.6%

SUM OF IADLS

NUMBER OF IADLS	FREQUENCY	PERCENT
0	2003	77%
1	263	10.1%
2	141	5.4%
3	68	2.6%
4	50	1.9%
5	30	1.2%
6	18	0.7%
7	16	0.6%
8	13	0.5%
TOTAL NEEDING HELP	599	23%

APPENDIX J
FURTHER DISCUSSION OF POSTURAL CONTROL MECHANISMS

POSTURAL STRATEGIES

Three strategies are used to maintain balance: ankle, hip, and stepping strategies. The ankle strategy rotates the body about the ankle joints in an effort to move the center of mass; it is normally used in response to small perturbations to equilibrium, when the support surface is firm. The hip strategy produces large and rapid motions at the hip joints and requires large, accurately coordinated movements of the trunk and neck to stabilize the head; it is normally used in response to larger, faster perturbations or when the support surface is compliant or smaller than the feet. The stepping strategy, consisting of a series of steps or hops, requires flexion at the knee, ankle and hip to lower the center of gravity in order to bring the support base back into alignment; it is normally used in response to very large or fast perturbations that are of sufficient magnitude to displace the center of body mass outside the base of support of the feet (Shumway-Cook & Horak, 1990; Woollacott & Shumway-Cook, 1990).

Coordination of the postural responses depends on the correct timing of contractile activity among the involved muscles; the appropriateness of the response must be initiated in a timeley manner to maintain adequate control of the position of the center of gravity (Horak, Shupert & Mirka, 1989). Conditions affecting involved muscles or nerve pathways can greatly affect postural movement coordination; there is evidence that aging itself affects muscle response (Grimby, 1990; Woollacott, 1990). Pathologies such as neuropathies that slow central processing time or nerve conduction time in efferent and afferent pathways can also affect response time (Horak, Shupert & Mirka, 1989).

The coordinated postural responses must be appropriately scaled to the velocity and amplitude of the perturbation; underresponse may result in a fall toward the disturbance, while overresponse may result in a fall in the opposite direction (Horak, Shupert & Mirka, 1989). Cerebellar difficulties, which are not always noted on physical examination, or problems encoding the sensory input, may seriously affect the ability to scale postural adjustments and responses. Prior experience and practice also determine the appropriateness of automatic postural responses; subtle cerebellar signs in the elderly may be due to deficits in the motor learning component of postural control (Horak, Shupert & Mirka, 1989).

Postural stability is limited by the body's biomechanics, including joint mobility and the quality of muscle strength; severe losses of strength or joint mobility may result in inability to perform certain postural movements or in postural misalignment. If the misalignment places the center of gravity near the limits of its support base, small amounts of sway may require a hip or stepping strategy for balance recovery, or may result in disequilibrium and falls (Horak, Shupert & Mirka, 1989). Restrictions in joint mobility resulting from arthritis, and muscle weakness resulting from a number of possible contributing pathologies are examples of age-related impairments affecting the body's biomechanics.

There is some evidence that inappropriate use of postural strategies may be due to perceived rather than actual changes in stability limits in elders who do not demonstrate biomechanical problems. Whether stability limits are narrowed by fear of falling or biomechanical pathologies, narrow limits result in abnormal use of movement strategies; the individual relies on hip or stepping strategies for any displacement, and falls are more likely, especially on slippery surfaces (Horak, Shupert & Mirka, 1989).

Sensory and motor processes interact closely in postural control; the postural strategy used depends on both the mechanical constraints of the task and the availability of sensory information (Horak, Nashner & Diener, 1990). Peripheral sensory information about the position of the center of gravity includes somatosensory information about the motion of the body with respect to the support surface and the motion of body segments with respect to each other, visual information about the motion of the body with respect to the external environment, and vestibular information about head position (Horak, Shupert & Mirka, 1989). Spinal cord, brainstem and cortical mechanisms organize and interpret this information and allow selection of postural responses appropriate to the environmental context (Horak, Shupert & Mirka, 1989). Central or peripheral sensory system pathologies can affect one or more of the sensory components of postural control.

Visual impairments, reduced vibration sense at the ankle, and vestibular degeneration are common sensory impairments that are thought to be age-related, but they may be due to undetected age-related pathologies. Healthy adults rely primarily on somatosensory inputs for balance adjustment when all inputs are available; it is possible that age-related decline of the vestibular system does not affect function until the system must compensate for sway in isolation from visual and somatosensory inputs (Woollacott, 1990; Woollacott & Shumway-Cook, 1990). In the absence of vestibular inputs, there is increased reliance on visual information for spatial orientation (Shumway-Cook & Horak, 1990). The contribution of visual feedback may also increase as proprioceptive feedback declines with age (Tobis et al., 1990). Peripheral vision, which is reduced with aging, is thought to be particularly important for stabilization of sway. Adaptive processes, such as walking slowly, allow more accurate use of diminished visual and somatosensory information; but age-related eye diseases such as cataracts, glaucoma and macular degeneration may compromise these compensatory strategies (Daleiden & Lewis, 1990; Maguire, 1990).

Elderly people are subject to many other conditions that can affect peripheral sensory function. Diabetes can result in peripheral neuropathies that reduce or eliminate sensation in the legs and feet, and vascular changes that affect vision and vestibular function (Horak, Shupert & Mirka, 1989). Cardiovascular conditions can have the same effects on both peripheral and central mechanisms by affecting cerebral blood flow, blood oxygen levels, and peripheral flow (Jonsson & Lipsitz, 1990a, 1990b);

respiratory problems affect sensory function through similar mechanisms.

Dysfunction in the central nervous system mechanisms responsible for integrating, interpreting, and acting upon sensory information increases the individual's risk of falling, especially in unusual sensory environments. The ability to select and weigh alternative orientation references adaptively is viewed as a critical factor in postural control in the elderly. Those unable to quickly select appropriate sensory references are especially at risk for falls when the sensory environment changes suddenly (Horak et al., 1989; Horak, Nashner & Diener, 1990; Shumway-Cook & Horak, 1990).

Any disruption in the ability to coordinate and move muscles and joints also compromises stability, as postural control also depends on the ability to select, match and execute an adequate motor response quickly and effectively. Inappropriate motor responses, whether due to motor difficulties, distortions in sensory information, or a combination of factors, result in falls (Horak, Shupert & Mirka, 1989).