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Obesity Influences Transitional States of Disability in Older Adults With Knee Pain

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Abstract

Objectives—This study employed relatively new statistical methods to understand how many states are needed to describe disability in older adults with knee pain, describe the relative probability of transitioning between states over time, and examine whether obesity influences the probability of transitioning between states.

Design—Prospective epidemiologic study of older adults with knee pain.

Setting—Community.

Participants—The participants, 245 women and 235 men, were 65 years or older, had chronic knee pain on most days, and had difficulty with at least 1 mobility-related activity caused by knee pain.

Interventions—Not applicable.

Main Outcome Measure—The primary instrument, the Pepper Assessment Tool for Disability, evaluated self-reported difficulty with mobility, basic activities of daily living (ADLs), and instrumental activities of daily living (IADLs).

Results—The Hidden Markov Model yielded 6 states reflecting changes in mobility, ADLs, and IADLs. There is evidence that loss in more demanding mobility-related activities such as stair climbing is an early sign for the onset of disability and that functional deficits in the lower extremities are critical to the early loss of ADLs. Overall the trend is for older adults to experience greater progression than regression and for obesity to be important in understanding severe states of disability.

Conclusions—These data provide a strong rationale for characterizing disability on a continuum and underscore the fluid nature of disability in older adults. As expected, lower-extremity function

plays a key role in the disablement process; obesity is also particularly relevant to understanding severe states of disability.

Keywords

Aged; Obesity; Rehabilitation

At the turn of the century,¹ 7 million older adults in the United States were chronically disabled because of self-reported limitations in basic ADLs such as walking indoors or getting into and out of a chair. When coupled with difficulties that occur in more advanced activities such as walking several blocks or in completing instrumental tasks that create the infrastructure of social roles, the burden of disability on society is daunting.² Until recently, disability was conceptualized much like other chronic health problems, a progressive disorder that was irreversible.^{3,4} However, Gill and colleagues⁴⁻⁶ have shown that older adults actually move in and out of disability, suggesting that it is best conceptualized as a state, not a trait. Because statistical methods have been developed to understand transitions between states better, the current study applied these methods to data from a 30-month prospective epidemiologic study of older adults with knee pain (OASIS).⁷

The first empirical evidence that disablement is a dynamic process was provided by Verbrugge et al,³ who followed persons aged 55 years or older hospitalized for hip fracture, cerebral vascular events, diabetes, chronic obstructive pulmonary disease, or congestive heart failure. Using a variety of both objective and subjective indices of disability, they found substantial within-individual variability in trajectories the year after hospital discharge, concluding that disability outcomes "... are very dynamic over a year's time for persons with serious chronic illness." (p 104) In recent years, Gill and colleagues⁴⁻⁶ have published several studies on the dynamic nature of ADL disability using a prospective community cohort of persons age 71 years or older whose disability status was assessed monthly. In one of the early publications, Gill and Kurland⁴ examined the transition to disability over a 3-year period in 580 older adults who, at time 0, were nondisabled. The primary outcome was time to the onset of ADL disability, which was defined as requiring help with completing any 1 of 4 tasks: bathing, dressing, walking inside the house, or transferring from a chair. In the year prior to being classified as nondisabled, 55 participants had been disabled for a single month, 8 had been disabled for a single episode of 2 months, 18 had experienced chronic disability of 3 months or more, and 11 had some other pattern of short-term disability. During the 3 years of follow-up, roughly 20% of the sample experienced chronic disability, while the remaining participants had only a short-term experience with disability. Clearly, ADL disability is not an invariant condition.

A second article by Hardy and Gill⁶ examined the rate of and time to recovery of independent functioning among older adults who became newly disabled. During a median follow-up of 51 months, 56% of the sample experienced a new ADL disability. Of this group, 82% recovered within 1 year from the onset of their event; that is, they did not need any help with any of the 4 ADLs mentioned. In addition, 57% maintained their independence for at least 6 months. On the other hand, whereas 60% of those participants

who experienced disability for 3 months or more also recovered to an independent state, only a third of this group remained disability-free for at least 6 months.

Finally, Gill et al⁵ recently examined the prospective transition to physical frailty, defined as meeting at least 3 of the following criteria: weight loss, exhaustion, muscle weakness, and slow walking speed. Of particular interest to the current study is the fact that during an 18-month observational period, 43.3% of the sample transitioned to states of greater frailty, and 23% transitioned to states of lesser frailty. However, the probability of transitioning from a frail to a nonfrail state was less than 1%.

The model of disability employed in the current research is consistent with the World Health Organization's International Classification System of Impairments, Disability, and Handicaps,⁸ which makes a distinction between activity and participation domains. In a recent validation study⁹ of a self-report measure that has been used for more than 15 years by our aging center, the Pepper Assessment Tool for Disability,^{7,10,11} we demonstrated that the items clustered into 3 distinct subscales. These included basic ADLs, mobility, and IADLs, with the first 2 subscales falling into the activity domain of disability and IADLs representing the participation domain. It is also interesting to note that these subscales capture the 3 components of self-maintenance that were originally identified by Katz.¹²

As older adults lose function, they become less active and gain weight.¹³ Holm et al¹⁴ point out that overweight and obese adults have more joint and mobility problems than people within the healthy weight for height range. Consistent with this position are cross-sectional data from the Women's Health and Aging Study¹⁵ demonstrating that obesity is a distinctive risk factor for increased risk of mobility limitations through the negative effect that obesity has on intensifying pain. Using the Cardiovascular Health Study Cohort, Visser et al¹⁶ examined the relationship between body composition and mobility-related disability in 2714 women and 2095 men age between 65 and 100 years. In cross-sectional analyses, they found that the OR for disability in the highest quintile of fat mass was 3.04 for women and 2.77 for men compared with those in the lowest quintile. In longitudinal analyses, fat mass at baseline was predictive of mobility disability 3 years later with ORs of 2.83 for women and 1.72 for men in the highest quintile of fat mass. Interestingly, this increased risk was independent of age, physical activity, chronic disease, or other potential confounders. Finally, in a cross-sectional study of older adult women, obesity was found to be significantly associated with frailty even after controlling for covariates.¹⁷

Given the importance of transitional states to the concept of disability and the role that obesity plays in the disablement process, our objective in this investigation is to use an HMM to understand how many states are needed to describe disability in older adults with knee pain, describe the relative probability of transitioning between states over time, and examine whether obesity influences the probability of transitioning between states.¹⁸

METHODS

Participants

The OASIS was a prospective epidemiologic study of knee pain in older adults.⁷ The 480 participants, 245 women and 235 men, were 65 years old or older; had chronic knee pain on most days; and had difficulty with at least 1 mobility-related activity caused by knee pain such as walking a quarter of a mile, climbing stairs, getting in and out of a car, lifting and carrying groceries, and performing activities such as shopping, cleaning, or self-care. The sample was 82.5% white and 13% black; approximately 30% of the participants were college graduates or above. BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). Of the sample, 57% had a BMI below 30, 28% had a BMI 30 or higher but less than 35, and 15% had a BMI of 35 or higher. We used these 3 categories because a BMI below 30 is considered nonobese, whereas a BMI from 30 to 35 represents class I obesity, and greater than 35 captures class III and class IV obesity, with 13 participants falling into the class IV category of 40 or higher. The article by Miller et al⁷ provides a complete description of participant characteristics.

Measurement of Disability: The Pepper Assessment Tool for Disability

The Pepper Assessment Tool for Disability is a self-administered questionnaire designed to assess major components of disability among older adults: ADLs, mobility, and IADLs. ADLs represent very basic activities such as self-care and those that involve transferring from 1 position to another (eg, getting in and out of bed). Mobility has to do with transporting oneself from 1 location to another using lower-extremity function and includes activities such as walking a block or climbing stairs. Finally, IADLs reflect more complex abilities related to participation in social roles and include tasks such as doing light house work, visiting relatives, or being able to manage money. Originally developed for the Fitness Arthritis and Seniors Trial, a 2-site clinical trial of 480 older adults age 60 years or older with osteoarthritis of the knee, the Pepper Assessment Tool for Disability has 19 items drawn from a universe of content. Responses are made on a 5-point Likert scale using the past month as a frame of reference. Respondents are asked how hard it is to do each activity because of their health using a Likert scale ranging from 1 (usually do with no difficulty) to 5 (unable to do), with a sixth option offered if participants are unable to do an activity for some reason unrelated to their health (eg, a participant does not prepare his/her own meals). Based on a recent psychometric study, the Pepper Assessment Tool for Disability yields a total score and 3 subscale scores: basic ADLs, mobility, and IADLs.⁹ All scales have good reliability and validity.⁹

For the purpose of this study, we simplified the analysis and presentation by creating a discrete variable from the Likert response for each of the 19 items: no disability (a response of 1) and disability (a response of 2–5). In presenting the data, we have clustered the items for each subscale to assist with interpretation of the results. The Pepper Assessment Tool for Disability was collected at baseline and again at the 2 follow-up assessment visits, at 15 and 30 months.

Statistical Analysis

To account for the heterogeneity in the disability profiles of the study population over time, we applied a statistical methodology called HMM.¹⁸ Like the latent class model, HMM provides a structural analysis of the profiles of the participants in terms of their responses to the items on the Pepper Assessment Tool for Disability measure. One can envision the latent class model as a means of grouping participants with similar response patterns into a finite number of so-called *latent classes* for cross-sectional data, whereas the HMM expands this notion of latent class to allow the longitudinal analysis of patterns over time.

Briefly, the HMM conceptualizes the disablement process as 2 distinct but parallel processes: a sequence of multiple indicators of disability that is driven by an underlying sequence of latent disability states, of which the state at time (t+1) depends only on the state at t and not on the history prior to time t. Accordingly, the HMM produces 3 sets of estimated parameters. First, applying HMM on the longitudinal data set resulted in an empirically justifiable set of disability states, each characterized by the multiple items on the Pepper Assessment Tool for Disability. The number of states is determined by a goodness-of-fit criterion, the Bayesian Information Criterion.¹⁹ Each participant can be classified as a member of any 1 of the several disability states at any given time point, and it is assumed that the number and structure of the states is constant across time. Second, the HMM provides estimates of the prevalence of each latent state at a given time point. Finally, the HMM produces estimates for the transition probabilities from one state to another at any given time point except the last one. The HMM was implemented in a specialized program written in MATLAB.^a Technical details are provided by Rijmen et al.²⁰

Missing values existed at both the visit and the item levels. At the visit level, 44 participants (10%) missed the 15-month visit, and a total of 77 participants (16%) missed the 30-month visit, whereas at the item level, the total percent of missing items was 0.6%, 9.7%, and 17.0% at the 3 time points, respectively. While using only observations with complete data is a convenient way to handle missing values, this method could drastically reduce the overall sample size, lower the power of the analysis, and lead to bias when data are not missing at random. To preserve partially available participant data, we used the method of multiple imputation²¹ to create 5 imputed values for each missing data point. The multiple imputation procedure made use of the correlation structure between all available variables, both across items and across time points, to provide the best guess of the missing value. The variation across the imputed data sets was calculated within the profile of each state (see Results and fig 1). The multiple imputation scheme was implemented through the program PROC MI.^b

RESULTS

Objective 1: States That Capture the Progression of Disability

The HMM yielded 6 distinct states according to the Bayesian Information Criterion; however, these states are not sequentially ordered. The prevalence rates for each state at

^aMathworks, 3 Apple Hill Dr, Natick, MA 01760.

^bSAS, 100 SAS Campus Dr, Cary, NC 27513.

baseline, 15 months, and 30 months were as follows: state 1 was equal to 16%, 19%, and 15%; state 2 was equal to 20%, 17%, and 14%; state 3 was equal to 10%, 12%, and 14%; state 4 was equal to 25%, 19%, and 18%; state 5 was equal to 23%, 22%, and 24%; and state 6 was equal to 6%, 11%, and 15%. Figure 1 shows the disability profile of these 6 states with the states ordered from left to right by severity; that is, state 1 represents the least disabled state. Each bar shows the relative frequency with which participants had no disability for each of the 19 tasks within each state. The items in each state are grouped by domains of content as defined by the Pepper Assessment Tool for Disability: ADLs (black), mobility (red), and IADLs (green).

Inspection of the 6 disability profiles reveals several interesting patterns in the data. For example, as one would expect, the first state of disability is marked by difficulty in mobility-related tasks, with stair climbing and lifting representing the most challenging tasks that older adults face. Interestingly, this domain is followed by basic ADLs disability and then by IADLs. Within the basic ADLs domain, a considerable number of participants report difficulty transferring into and out of a chair, while most other ADLs remain intact. Finally, and perhaps somewhat unexpectedly, the loss of IADLs describes the most severe state of disability for these older adults.

Objective 2: Transitioning Probabilities Between States Over Time

Table 1 presents the transitional probability matrix for the 6 states as a function of change over time. First, examining the probability values in the diagonal, it is apparent that state 6 is the most stable. That is, older adults who have the most severe disability have a .79 probability of remaining in this state, whereas the probabilities range from .40 to .63 for the other 5 states. Note that the next 2 most stable states are 1 ($P=.60$) and 2 ($P=.63$). Second, referring back to figure 1, it is clear that state 3 signifies a considerable drop in function within the mobility domain. In this regard, it is interesting to note that the probabilities of persons in states 3 through 6 returning to states 1 or 2 are quite low: .11 for those in state 3, .14 for those in state 4, .04 for those in state 5, and .02 for those in state 6. Finally, an overall trend is for older adults to experience greater progression than regression within the disablement process. Specifically, there is more progression of disability in state 1 than regression of disability in state 6, and for the middle 2 disability states (3 and 4), the probability is higher that people will decline rather than improve in self-reported function: combined ($P=.37$ vs $P=.11$) for state 3 and ($P=.37$ vs $P=.23$) for state 4.

Objective 3: The Influence of Obesity on Transitions in Disability

Tables 2 through 4 provide the probabilities for transitioning between different disability states based on BMI classification: less than 30, 30 or higher but less than 35, and greater than 35. As illustrated, older adults who had BMIs greater than 35 had a .90 probability of remaining in this most severe state compared with a probability of .76 for those with BMIs of 35 or less. Also, the probability of remaining in the healthiest functional state, state 1, declined with increasing BMI: .62 for those less than 30, .58 for those greater than 30 but less than 35, and .52 for those greater than 35.

DISCUSSION

Results of this research support the position that disability is a dynamic process,^{3,4,6} suggesting that it should be conceptualized as a series of states rather than as a trait; moreover, the data suggest that obesity is an important moderator variable of the disablement process. To our knowledge, this is the first investigation to describe empirically the multistate nature of disability using the HMM and the 3 major classes of disability—mobility, ADLs, and IADLs—that were identified in the early 1980s by Katz¹² and recently validated in structural analyses of the Pepper Assessment Tool for Disability.⁹ An examination of the progression in disability over 30 months in older adults who had knee pain provides several insights into the disablement process.

First, as one would expect, disability begins with tasks that pose the highest physical demand—that is, items in the mobility domain. Within this domain, difficulty first appeared in items that involved stair climbing and lifting heavy objects. By state 3, patients' mobility is severely compromised, and in state 4, there are substantial deficits in basic ADLs. It is intriguing to note that, within the domain of basic ADLs disability, function is first compromised in tasks that require changing one's body position: getting into and out of a chair, car, or bed. In combination with patterns observed in the mobility domain, these data underscore the importance of maintaining a "functional reserve" in aging.²² The final domain to be compromised involves IADL disability. As expected, those items having a significant physical component such as doing light house work, participating in community activity, and caring for a family member decline earlier than do tasks that are primarily dependent on older adults' cognitive function—that is, managing money or using the telephone. Participants in OASIS were community-dwelling older adults who were cognitively intact. There is a growing body of literature suggesting that cognitive function does influence the progression of physical disability^{23,24}; however, it is equally probable that impaired physical function could lead to cognitive decline. For example, a characteristic of disability is that older adults become less socially active, a consequence that can compromise executive functioning.

Second, we would like to direct readers' attention back to the mobility domain and re-emphasize the fact that both self-reported difficulty with stair climbing and lifting heavy objects are important markers for the first state of disability that was identified in these analyses. This pattern is particularly interesting given the results of several previous studies showing that there tends to be less atrophy in the upper-body than lower-body musculature with aging^{25–27} and that the loss of muscle strength appears to develop more rapidly in lower-extremity than upper-extremity muscles.^{27–29} It has been suggested that these changes are related to greater disuse of the lower extremity than the upper extremity throughout the lifespan, particularly in relation to physical activity.³⁰ Clearly these data underscore the importance of lower-extremity function to the disablement process and emphasize the important value of lower-limb strength training in older adults.

Third, the data presented on transitional probabilities between states are consistent with previous findings suggesting that there is more progression than regression of disability, yet these data do provide clear evidence that some older adults improve with time, a finding that

is consistent with previous longitudinal observations made by Gill et al.⁵ One likely cause for such improvement is recovery from acute illness or injury. Inspection of the probability estimates between states over time reveals that there is considerable variability with respect to recovery from more severe states. For example, recall that the probability of persons in states 3 through 6 returning to either states 1 or 2 is quite low. In general, the transitional probabilities provide empirical support for the notion that the further down the slippery slope of disability one slides, the less likelihood that one will regain function. Similarly, during an 18-month observational period, Gill⁵ found that 43.3% of the sample transitioned to states of greater frailty, and just 23% transitioned to states of lesser frailty. The probability of transitioning from a frail to a nonfrail state was less than 1%.

Fourth, there are 2 findings related to obesity and disability that deserve comment. These include the fact that the probability of remaining in the healthiest functional state declined with increasing BMI, and that a person in state 6 with a BMI of 35 or higher had a very high probability of remaining in this most severe state. Previous research has linked obesity to joint pain and osteoarthritis.³¹ Furthermore, both obesity and joint pain are known determinants of disability.^{14,32} What the current data suggest is that obesity (1) increases the probability of transitioning to a more severe state of disability over time, and (2) is an inhibitory factor in recovery from severely disabled states. This is an area of study that warrants further attention in the context of physical medicine and rehabilitation.

As conceptualized by the World Health Organization,⁸ disability involves difficulty with performing discrete tasks such as the ability to climb stairs and participating in activities such as visiting friends that are embedded in various social contexts. As illustrated in this investigation for older adults with knee pain, disability is neither a trait nor a single state, but a condition that is best described as consisting of 6 states that represent increasing severity, yet are not sequentially ordered. Given the complexity of the tasks and activities that characterize any specific state, we simply ordered the states and allowed the numbers to reflect the severity of disability as opposed to providing a specific label for each state. Although these states are empirically derived, we believe that they have considerable clinical relevance within the context of physical medicine and rehabilitation. For example, knee pain is a very common condition in aging and central to disability. Using representative questions from the Pepper Assessment Tool for Disability that are central to each state would enable clinicians to assess a patient's level of disability quickly and to track it over time. This information could be quite valuable for triggering referrals to physical therapy and/or other treatment, because it is well known that the loss of function in aging has important consequences for institutionalization and the general decline of older adults' health and well being. In addition, it would be helpful to clinicians if research was conducted to determine how interventions could be tailored to provide optimal treatment for older adults who fall into these different states of disability. One of our research goals is to develop statistical models that extend HMM modeling to facilitate this type of research.

Study Limitations

Readers should keep in mind several limitations of the current study design. First, the analysis was exploratory rather than confirmatory, and no hypothesis testing was performed.

One future direction we are pursuing is the development of models that will enable investigators to test the effects of various moderating variables such as obesity on transitional states. Second, the sample was limited to older adults with knee pain. It is unclear whether this model is robust to older adults with chronic health conditions such as congestive heart failure or chronic obstructive pulmonary disease. Third, the time frame for this prospective study was 30 months, and there were only 2 follow-up assessments separated by an interval of 15 months. Longer-term prospective studies are needed with more frequent assessment intervals to evaluate how factors such as acute illness and injury might influence transitional states for disability.

CONCLUSIONS

This prospective study of older adults with knee pain identified 6 states of disability that captured the progressive loss of mobility, ADLs, and IADLs across an interval of 30 months. State 3 reflected a significant loss in mobility disability with very few participants transitioning from states 3 through 6 back to either state 1 or 2, and state 6 was the most stable state in the model. Finally, the probability of remaining in the healthiest state, state 1, declined as obesity increased in severity; participants with the most severe obesity in state 6 had the highest probability of remaining in this state. Future research is needed to examine how lifestyle interventions such as physical rehabilitation and weight loss might influence the transitional probabilities between states and to address the aforementioned limitations of the current study design.

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List of Abbreviations

ADLs	activities of daily living
BMI	body mass index
HMM	Hidden Markov Model
IADLs	instrumental activities of daily living
OASIS	Observational Arthritis Study in Seniors
OR	odds ratio

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Fig 1.

States that capture the progression of disability in older adults. The bookends at the end of each bar show the range of the probabilities estimated from each of the 5 imputed data sets. Abbreviations: CHAIR, getting in and out of a chair; BED, moving in and out of a bed; TOILET, using the toilet; CAR, getting in and out of a car; BATHE, bathing or showing; GRIP, gripping with your hands; DRESS, dressing yourself; WALKBLK, walking several blocks; WALKONE, walking 1 block; FLIGHTS, climbing several flights of stairs; CLIMBON, climbing 1 flight of stairs; LIFTOBJ, lifting heavy objects; LIFT10, lifting or carrying something as heavy as 10 pounds such as a bag of groceries; LIGHT, doing light housework; PARTACT, participating in community activities such as religious services, social activities, or volunteer work; VISITRE, visiting with relatives or friends; CAREFAM, taking care of a family member; MONEY, managing your money such as paying bills; USEPHON, using the telephone.

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Table 1

Transition Probabilities for the Entire Sample

States	State 1	State 2	State 3	State 4	State 5	State 6
State 1	0.60	0.07	0.14	0.09	0.07	0.03
State 2	0.19	0.63	0.04	0.09	0.05	0.00
State 3	0.11	0.00	0.52	0.12	0.17	0.08
State 4	0.04	0.10	0.09	0.40	0.31	0.06
State 5	0.02	0.02	0.08	0.18	0.51	0.19
State 6	0.02	0.00	0.00	0.10	0.08	0.79

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Table 2

Transition Probabilities for BMI Less Than 30

States	State 1	State 2	State 3	State 4	State 5	State 6
State 1	0.62	0.07	0.13	0.08	0.07	0.03
State 2	0.22	0.63	0.03	0.04	0.08	0.00
State 3	0.12	0.00	0.55	0.04	0.19	0.11
State 4	0.00	0.04	0.04	0.63	0.10	0.20
State 5	0.03	0.07	0.07	0.02	0.69	0.11
State 6	0.02	0.00	0.00	0.04	0.17	0.76

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Table 3

Transition Probabilities for BMI of 30 or Higher But Less Than 35

States	State 1	State 2	State 3	State 4	State 5	State 6
State 1	0.58	0.05	0.19	0.05	0.10	0.03
State 2	0.14	0.68	0.04	0.05	0.09	0.00
State 3	0.13	0.00	0.44	0.05	0.34	0.04
State 4	0.00	0.02	0.02	0.50	0.18	0.28
State 5	0.03	0.07	0.11	0.03	0.67	0.09
State 6	0.05	0.00	0.00	0.07	0.12	0.76

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Table 4

Transition Probabilities for BMI of 35 or Higher

States	State 1	State 2	State 3	State 4	State 5	State 6
State 1	0.52	0.07	0.09	0.09	0.19	0.05
State 2	0.19	0.54	0.06	0.06	0.16	0.00
State 3	0.05	0.00	0.54	0.04	0.31	0.05
State 4	0.00	0.00	0.02	0.84	0.11	0.03
State 5	0.01	0.06	0.10	0.02	0.68	0.13
State 6	0.00	0.00	0.00	0.06	0.04	0.90