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The Hierarchical Status of Mobility Disability Predicts Future IADL Disability: A Longitudinal Study on Ageing in Taiwan

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1. Introduction

As the older population grows dramatically around the world, it is important that health care providers be able to maintain people with an extended life expectancy in an active stage for as long as possible. Being independent in gross mobility functioning is an indicator of healthy and successful aging (Guralnik and Kaplan, 1989). An effective tool that is easy to use for identifying those at early stage of physical function decline is imperative for achieving this goal.

As people age, a majority of elderly individuals develop physical disability. Such development follows a hierarchical order, starting from mobility, then spreading into instrumental activities of daily living (IADL), and finally ending in basic activities of daily living (BADL) (Pinsky et al., 1987; Barberger-Gateau et al., 1995; Barberger-Gateau et al., 2000). As disability in mobility occurs at an earlier stage of the disablement process, it may be an effective indicator by which to identify older adults in an early stage of physical function decline. Identifying such older adults is imperative in order to provide timely health promotion or early intervention programs.

In the literature, mobility disability has been defined as at least one item requiring help, or being unable to perform independently using two items (climbing stairs and walking on a level surface) (Guralnik et al., 1994; Guralnik et al., 1995; Ostir et al., 1998) or three items (heavy housework, climbing stairs, and walking on a level surface) (Jette and Branch, 1981; Guralnik et al., 1994; Barberger-Gateau et al., 1995; Guralnik et al., 1995; Merrill et al., 1997; Barberger-Gateau et al., 2000; Ble et al., 2005; Yogev-Seligmann et al., 2008) in Rosow's scale (Rosow and Breslau, 1966). Using either two or three items, the disadvantage of a dichotomous mobility disability status is the inability to identify those with an intermediate status (those are becoming disabled, but are not yet disabled and thus require timely intervention).

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The use of a summed number of tasks labeled as difficult has been proposed as a way to categorize the severity of BADL disability (Hing and Bloom, 1991; Manton et al., 1993). The item-wised hierarchical structure of mobility disability has been investigated only by Wang and colleagues using two items (Wang et al., 2005) in a cross-sectional study. They reported that these hierarchies could identify participants with different physical health and performance levels. Thus the item-wise hierarchy of mobility disability is able to monitor the status of mobility disability and to identify those at the stage of decline.

By using item-wise definitions of mobility hierarchy, previous studies in Taiwan have reported that individuals with more advanced mobility disability are associated with more concurrent dependence in IADL and BADL (Chen et al., 2010; Yeh et al., 2010). We therefore predicted a longitudinal relationship between hierarchical status of mobility disability and IADL disability. However, a literature review reveals that the item-wise hierarchical status of mobility disability for identifying individuals at higher risk of further IADL decline, which often follows the development of mobility disability (Pinsky et al., 1987; Barberger-Gateau et al., 1995; Barberger-Gateau et al., 2000), has not been substantiated. Furthermore, the median age of onset and the required time for 50% of people at different levels of mobility disability to develop IADL disability have not been reported. The required length of time to develop future IADL disability after the onset of each hierarchical mobility disability status is worthwhile to ascertain so that health care providers will be able to estimate how much time they have for early interventions.

Besides the current mobility disability status that might predict future disablement, other risk factors have been reported in the literature, including age, sex, spouse status (Reynolds and Silverstein, 2003), educational level, current working status, cigarette smoking, alcohol consumption, exercise habits (Miller et al., 2000; Sarkisian et al., 2000), number of co-morbidities (Reynolds and Silverstein, 2003), self-rated health (Cornette, 2005), depressive symptoms (Sarkisian et al., 2000; Kazama et al., 2010), and cognition (Reynolds and Silverstein, 2003; Cornette, 2005; Yochim et al., 2008). These will be used, in this study, as covariates to ascertain the significance of mobility disability status in predicting future IADL disablement.

Thus, this study aimed to investigate the predictive validity of a four-level item-wise hierarchical mobility disability status for future IADL disability, using longitudinal data from a national representative sample. The specific purposes were (1) to ascertain the longitudinal relationship between hierarchies of mobility disability and IADL using the hazard ratio of the hierarchical mobility disability status in developing IADL disability across four and eight years of follow up. In order to ascertain the significant contribution of the hierarchical mobility status to IADL disability, we adjusted the potential risk factors that have been reported in the literature; and (2) to report the median age onset and the survival time for 50% of individuals to development of IADL disability (median survival time) in each hierarchical mobility disability stage.

2. Methods

Data were obtained from the 1999, 2003, and 2007 "Survey of Health and Living Status of the Elderly in Taiwan," a population-based longitudinal study with a nationally representative random sample. The sampling was conducted with a three-stage equal probability method. In the first stage, samples were stratified into administrative units; in

the second stage, blocks in the selected administrative units were defined as clusters; and in the third stage, two respondents were selected systematically from the register in each block. An elderly cohort of 4,049 individuals aged 60 or older was first interviewed in 1989 and re-interviewed every three to four years until 2007 (response rate = 88.9 - 91.8%). An additional cohort of 2642 individuals aged 50 to 66 was recruited in 1996 and re-interviewed every four years until 2007 (response rate = 81.2 - 92.1%). Full details of the survey have been published elsewhere (Hsu, 2005; Chen et al., 2010).

A total of 4,440 respondents were interviewed in the survey year 1999. For the purposes of our study, we first excluded those who were younger than 60 years old or who did not live in the community, leaving a sample size of 3,465. Another 4 and 47 respondents respectively had incomplete baseline data in mobility and other variables, such as education attainment, work status, spouse status, health lifestyle, disease status, self-rated health, BADL, and IADL, and were also excluded, further reducing the sample size to 3,414. In order to determine the risk of developing future IADL disability of each mobility disability group, we further excluded 977 individuals who already had IADL disability at baseline, leaving 2,437. Furthermore, we excluded 25 individuals due to loss of contact for follow-up and 285 individuals due to death before contributing any follow-up data on IADL in the years of 2003 and 2007. As a result, 2,127 community-dwelling older adults who had complete baseline data, were free of IADL disability at baseline, and contributed follow-up data at least once remained for further survival analysis of median age onset and the median survival time of IADL disability for each hierarchical status of mobility disability.

For Cox regression, we used the extended-model approach for covariate adjustment: Model 1 = without adjustment; Model 2 = variables in Model 1 + demographics (age, sex, education, work, and spouse status); Model 3 = variables in Models 1 & 2 + health behaviors (smoking, alcohol, and exercise); Model 4 = variables in Models 1 & 2 & 3 + health status (number of co-morbidities, self-rated health, the Center for Epidemiologic Studies Depression (CESD), and Short Portable Mental Status Questionnaire (SPMSQ)). Data on 2,127 (at eight-year follow-up) and 2,073 (at four-year follow-up, with an additional 54 samples excluded due to loss of contact for follow-up in 2003) individuals were entered into Model 1. The amount of data entered into Model 4, however, decreased dramatically because participants younger than 65 were not interviewed for their cognitive function in the survey. In total, data on cognitive function (SPMSQ) were missing for 574 (eight-year follow-up) and 557 (four-year follow-up) individuals, and data on the CESD scale were missing for 8 individuals. As a result, we excluded the data from 582 (eight-year follow-up) and 565 (four-year follow-up) individuals when running Model Four in Cox regression.

2.1 Measurements

2.1.1 Four-level hierarchy of mobility disability

This study extracted from the survey questionnaire three variables assessing gross mobility: heavy housework, climbing up 2 to 3 floors, and walking 200 to 300 m. Those reporting no difficulty in performing all three items were in the "mobility able" group, whereas those reporting difficulty performing only one item were categorized as "1 item disabled". Those reporting difficulty in any two of the three items or in all three items were treated as "2 items disabled" and "3 items disabled", respectively.

2.1.2 IADL disability status

There were five items in the instrumental activities of daily living (IADL) domain (shopping, finance, transportation, light housework, and telephone). Older adults were classified as having IADL disability if they reported any degree of difficulty or inability to perform on at least one item.

2.1.3 Covariates in Cox regressions

Covariates were included in the Cox regression models according to their values in 1999. Age was categorical data, whereas sex, current working status, smoking habit, and alcohol ingestion were dichotomous data. Education was recorded as illiteracy or no formal education, elementary school, primary or senior high school, and college or beyond. Spouse status was recorded as either living with spouse (married or living together) or living without spouse (never married, divorced, separated, or widowed).

The exercise habit was divided into inactive (less than three times a week) and active (at least three times a week). Self-rated health was divided into healthier and worsening. The number of co-morbidities was counted from the list of hypertension, diabetes, cardiac disease, stroke, cancer, and arthritis. Cognitive function was measured with the modified Taiwan version of SPMSQ using nine items (range 0-9), correct answers were coded 1, whereas errors were coded 0, thus, higher SPMSQ score means better cognition performance, individuals were categorized as having normal (6 and above) or abnormal (5 and below) cognitive function (Yen et al., 2010). Symptoms of depression were assessed with the CESD, on which each of the 10 items is scored from 0 to 3. Individuals were categorized as not having (9 and below) or having (10 and above) depressive symptoms.

2.2 Statistical analysis

The group means difference among the four hierarchical mobility disability groups was determined by analysis of variance (ANOVA) for the continuous variables and chi-square test for discrete variables. Median age difference among the four groups were investigated by Brown-Mood test. The group comparison on the depression score among the four groups was determined by using the ANOVA on the log transformed CESD score. Cox proportional hazard regression analysis was used to determine if the hierarchical mobility disability stage was a significant predictor of future IADL disability four years later (in 2003) and eight years later (in 2007) and to report its hazard ratio.

The median age onset of IADL disability of each hierarchical mobility disability group across eight years of follow up was determined by survival analysis. The survival time for 50% of participants in each hierarchical status of mobility disability to develop IADL disability (the median survival time) was determined for the whole group and separately for men and women.

3. Results

The demographic and health related information of our participants in the hierarchical mobility disability groups are summarized in Table 1. All variables showed significant differences among the four hierarchical mobility disability groups and were used as covariates in the following Cox regression analysis. The “mobility able” group was younger; had larger

percentages of men; had higher educational levels, larger percentages currently working, and spouses; smoked, drank alcohol, and exercised; and had a lower number of co-morbidities, a better perceived health status, better cognition, and lower depression symptom scores.

	Mobility Able (n=1531)	1 Item Disabled (n=359)	2 Items Disabled (n=168)	3 Items Disabled (n=69)
Age (yrs) ¥, a	70 (64, 73)	73 (67, 77)	72 (67.5, 75)	71 (68, 75)
Sex (n, %) a, e				
Men	997 (65.1%)	173 (49.2%)	58 (34.5%)	29 (42.0%)
Women	534 (34.9%)	186 (51.8%)	110 (65.5%)	40 (58.0%)
Educational level (n, %) a				
Illiterate	332 (21.7%)	116 (32.3%)	68 (40.5%)	31 (44.9%)
Elementary school	761 (49.6%)	163 (45.4%)	82 (48.8%)	31 (44.9%)
Junior or senior high school	324 (21.2%)	61 (17.0%)	15 (8.9%)	6 (8.7%)
Above college	114 (7.5%)	19 (5.3%)	3 (1.8%)	1 (1.5%)
Work status (missing data, n=7) (n, %) b, c				
No	1153 (75.3%)	320 (89.1%)	156 (92.9%)	61 (88.4%)
Yes	378 (24.7%)	39 (10.9%)	12 (7.1%)	8 (11.6%)
Spouse status (missing data, n=1) (n, %) b, c				
No	410 (26.8%)	135 (37.6%)	61 (36.3%)	27 (39.1%)
Yes	1121 (73.2%)	224 (62.4%)	107 (63.7%)	42 (60.9%)
Cigarette smoking (n, %) b, c				
No	1073 (70.1%)	289 (80.5%)	139 (82.7%)	56 (81.2%)
Yes	458 (29.9%)	70 (19.5%)	29 (17.3%)	13 (18.8%)
Alcohol consumption (n, %) a				
No	1049 (68.5%)	290 (80.8%)	141 (83.9%)	61 (88.4%)
Yes	482 (31.5%)	69 (19.2%)	27 (16.1%)	8 (11.6%)
Exercise (n, %)*, c				
No	539 (35.2%)	136 (37.9%)	75 (44.6%)	36 (52.2%)
Yes	992 (64.8%)	223 (62.1%)	93 (55.4%)	33 (47.8%)
Number of co-morbidities f (hypertension, DM, cardiac disease, stroke, cancer, arthritis)	0.7 ± 0.9	1.1 ± 1.0	1.3 ± 1.1	1.5 ± 1.2
Self Perceived Health Status (n, %) a, d				
Worse	227 (14.8%)	128 (35.6%)	79 (47.0%)	41 (59.4%)
Healthier	1304 (85.2%)	231 (64.4%)	89 (53.0%)	28 (40.6%)
Cognition_SPMSQ f	8.6 ± 0.8 (n=1081)	8.3 ± 1.1 (n=280)	8.1 ± 1.3 (n=139)	8.0 ± 1.3 (n=53)
Depression_CESD-10 a	3.4 ± 4.3 (n=1504)	5.9 ± 5.7 (n=341)	7.5 ± 6.1 (n=166)	8.6 ± 7.0 (n=64)

¥: median (q1,q3), a significant differences were found between "mobility able group and all other (1 item, 2 items, and 3 items) disabled" groups; b significant differences were found between "mobility able and 2 items disabled"; c significant differences were found between "mobility able and 3 items disabled" group; d significant differences was found between "1 item disabled and 3 items disabled groups"; e significant differences was found between "1 item disabled and 2 items disabled groups"; f no statistical significance between item 2 and item 3.

Table 1. Demographic and health-related information at baseline (year of 1999) (n=2127).

Tables 2 and 3 show the results of the Cox regression models, with significant effects of the hierarchy of mobility on developing IADL disability. As shown in Table 2, the unadjusted hazard ratios for developing IADL disability after four years, with "mobility able" as the reference group, were as follows: 2.15 for "1 item disabled", 3.09 for "2 items disabled", and 3.63 for "3 items disabled". After adjustment for potential risk factors, the hierarchical structure of hazard ratios of the four-level mobility status remained the same, though diminished in value (1.55, 1.85, and 2.19), yet they were still the strongest among the significant risk factors.

	Model 1	Model 2	Model 3	Model 4
Mobility Able	1	1	1	1
1 Item Disabled	2.15 (1.75-2.68)***	1.59(1.27-2.00)***	1.57 (1.25-1.98)**	1.55 (1.21-1.99)**
2 Items Disabled	3.09 (2.40-3.98)***	2.17 (1.67-2.83)***	2.14 (1.64-2.79)***	1.85 (1.37-2.50)***
3 Items Disabled	3.63 (2.59-5.10)***	2.61 (1.85-3.69)***	2.48 (1.74-3.52)***	2.19 (1.46-3.28)**
Age				
60-65 years		1	1	1
65-70 years		1.58 (1.09-2.29)*	1.60 (1.10-2.33)*	0.89 (0.12-6.61)
70-75 years		2.14 (1.55-2.96)***	2.19 (1.58-3.03)***	1.13 (0.15-8.29)
Over 75 years		3.24 (2.33-4.49)***	3.30 (2.37-4.59)***	1.80 (0.25-13.20)
Sex				
Men vs. Women		0.80 (0.65-0.98)*	0.79 (0.63-1.00)*	0.80 (0.62-1.03)
Educational level				
Illiterate		1	1	1
Elementary school		0.71 (0.58-0.88)**	0.72 (0.59-0.90)**	0.78 (0.62-0.99)*
Junior or senior school		0.63 (0.46-0.85)**	0.65 (0.48-0.88)**	0.72 (0.52-0.99)*
College and above		0.77 (0.43-1.07)	0.73 (0.46-1.17)	0.80 (0.49-1.31)
Work status				
Yes vs. No		0.69 (0.50-0.95)*	0.68 (0.50-0.94)*	0.76 (0.53-1.09)
Spouse status				
Yes vs. No		0.97 (0.79-1.18)	0.96 (0.79-1.17)	1.03 (0.83-1.28)
Cigarette smoking				
Yes vs. No			1.23 (0.96-1.57)	1.30 (1.00-1.69)
Alcohol consumption				
Yes vs. No			0.77 (0.60-1.00)*	0.75 (0.57-0.99)*
Exercise				
Yes vs. No			0.89 (0.73-1.08)	0.96 (0.78-1.18)
No. of co-morbidities				1.12 (1.02-1.24)*
Self rated health				
Good vs. Poor				1.03 (0.82-1.29)
SPMSQ				1.39 (0.90-2.17)
CESD-10				1.31 (1.03-1.67)*

*** <0.0001, ** <0.01, *<0.05

Table 2. Hazard ratio of each hierarchical mobility disability group to develop IADL disability across 4 years follow-up (years of 1999-2003) (n=2073).

In the final model, significant risk factors for developing IADL disability were mobility disability stage, educational level, alcohol consumption, number of co-morbidities, and depression symptom score. It should be noted that age, sex, and working status were significant risk factors in Models 2 & 3, but became insignificant in the final Model 4, with more covariates relating to health status.

Similar to those from the four-year follow-up data, the hazard ratios for developing IADL disability after eight years were also hierarchical, but they had smaller values: 1.96, 2.64, and 2.88 for the groups of "1 item disabled", "2 items disabled", and "3 items disabled", respectively (Table 3). The final model in the eight-year follow-up, when compared to the four-year follow-up data, had more covariates: sex, educational level, cigarette smoking, number of co-morbidities, and cognition.

The median age at onset for "mobility able", "1 item disabled", 2 items disabled", and "3 items disabled" group was 82, 80, 77, and 76 years of age, respectively. The median survival time is reported for each hierarchical stage of mobility disability and as follows: greater than 8 years for "mobility able", 6 years for "1 item disabled", 6 years for "2 items disabled", and 2 years for "3 items disabled" (Table 4). Inspection of the data in the four mobility disability groups revealed that it took longer period for men than for women to develop IADL disability.

Mobility disability at baseline	N	Median survival time (years)
Men		
Mobility Able	997	– (6, –)
1 Item Disabled	173	6 (2, –)
2 Items Disabled	58	6 (2, –)
3 Items Disabled	29	2 (2, 7)
Women		
Mobility Able	534	7 (4, –)
1 Item Disabled	186	6 (2, –)
2 Items Disabled	110	2 (2, 6)
3 Items Disabled	40	2 (2, –)
All		
Mobility Able	1531	8 (6, –)
1 Item Disabled	359	6 (2, –)
2 Items Disabled	168	4 (2, –)
3 Items Disabled	69	2 (2, –)

–: not defined

Table 3. The median survival time for each hierarchical status of mobility disability (8 years of follow up, 1999-2007) (n=2127).

4. Discussion

The purposes of this study were to ascertain the longitudinal relationship of developing the mobility disability and IADL disability and to report the hazard ratio, the median age onset, and the median survival time to the onset of IADL disability in each hierarchical stage of

mobility disability for use in the development of early intervention programs. In this study, we defined a four-level hierarchy of disability severity in the mobility domain by the summed number of items labeled as difficult among three items: heavy housework, climbing stairs, and walking on a level surface. Our results indicate that the hierarchy of mobility disability used in this study can significantly identify people with different demographics, health behaviors, and health status. Furthermore, this hierarchical mobility status also has a hierarchical structure in terms of the hazard ratio, the median age onset, and the median survival time to development of IADL disability.

Assessing a hierarchy of mobility disability based on the numbers of items disabled can discriminate between older adults with different levels of physical performance (Wang et al., 2005). The results of this study further substantiate the predictive validity of this hierarchy of mobility disability for future IADL disability at four years and eight years later. Individuals with more severe levels of mobility disability were at greater risk of developing IADL disability, even after adjusting for other risk factors of demographics, health behaviors, and health status. From the magnitude of hazard ratio in the final Cox model, it could be seen that the level of mobility disability appeared to be the strongest predictor of future IADL disability. To the best of our knowledge, this is the first study to examine the predictive validity of the item-wise hierarchy of mobility disability for future IADL disability based on longitudinal follow up on a nationally representative sample of the Taiwanese community-dwelling elderly.

Consistent with previous studies, demographics such as age, sex, and working status were significant risk factors in the initial Cox models (Jette & Branch, 1981; Pinsky et al., 1987; Guralnik & Kaplan, 1989), but they became insignificant in the final model due to the addition of covariates related to health status. Health status, namely number of co-morbidities, cognition, and depression symptom score, were significant risk factors in the final model. However, from the perspective of health promotion, demographics such as age and gender are non-modifiable and hence are not the focus of discussion in this study. Education and the health behaviors that were found to be significant risk factors of IADL disability in the current study, such as health status, alcohol consumption, and cigarette smoking, are in agreement with the literature (Jette & Branch, 1981; Pinsky et al., 1987; Guralnik & Kaplan, 1989) and are valuable in guiding health promotion policy or programs for people at younger ages. For example, policy for extending the years for obligatory education could help people get higher education, and that might in turn lead to better socioeconomic status and policy for health education for the publics could facilitate better health behaviors. Heightened socioeconomic status and better health behaviors could lessen the numbers of comorbidities people will develop during the process of ageing and decrease the negative impact that comorbidities might have on cognitive function and emotional health.

Surprisingly, habitual exercise was not significant in either the four or eight-year follow-up, and we propose two possibilities for this insignificance. First, our dichotomous cutting point was based on frequency of exercise per week, which did not consider exercise intensity and may fail to reflect the health benefits of exercises. Second, general exercise may be insufficient for people who already have some mobility disability, and specific training for specific impairments may be necessary, such as intervention for joint range of motion and lower leg eccentric contraction to improve the ability to climb stairs. Previous research has

suggested that heavy housework requires more muscle power, whole-body strength, balance and coordination, while climbing stairs and walking on a level surface require standing balance and lower extremity strength and velocity (Bean et al., 2008; Chen et al., 2010). Early intervention for mobility performance and stability needs to take into consideration these task-specific impairments.

The results of this study confirm the time window that health care providers have in order to reverse mobility disability and to prevent IADL disability. Our findings suggest that people with two or more items disabled in mobility develop IADL disability in 2-4 years, whereas people with one or less items disabled in mobility develop IADL disability in 6 years or longer. The survival analyses further suggested that men and women have different disablement patterns. In general, the interval for 50% of participants to develop IADL disability (median survival time) was shorter for women than that for men. Therefore, in health promotion or early intervention, the different time windows for men and women should be taken into consideration.

In this Taiwan Longitudinal Study on Ageing (TLSA) dataset, individuals were followed up every four year. The data of the year of 1999, 2003, and 2007 were used in the current study that included two follow-ups at 4 years and 8 years later. The 3rd quartile was not reported from the statistics output of the survival analysis, it is probably because the maximal follow up duration was 8-year and by that time not yet 75% of the individuals developed that certain hierarchical disability level. This study was also limited by the long interval of follow up (every four years). However, a shorter follow-up period consumes more resources. The need for a balance between the large cost and the additional information that could be gathered by a shorter follow-up period needs to be carefully considered. In addition, the population in our study was free of IADL disability at baseline, with 977 individuals excluded due to initial IADL disability. Our results should not be generalized to people who have both mobility and IADL disability. Furthermore, mobility disability is a changing condition, but our prediction of future IADL disability was based only on baseline mobility status.

5. Conclusion

The hierarchical status of mobility disability is the strongest predictor of IADL disability even after adjustments for the significant risk factors of demographics, health behaviors, and health status. Very different results of IADL disability development were found between the groups with two or more items disabled and those with one or less items disabled in mobility, which provides support for the value of hierarchical stages of mobility categorization, as opposed to the previous dichotomous definition, with any one item disabled.

People who have more disabled mobility items but are free of IADL disability initially are at higher risk of developing IADL disability than those with one or less item disabled, and the time to development is only 2-4 years. We suggest that health care providers focus on people who have two or more items disabled in mobility and that they intervene within the time window of 2-4 years in order to reverse mobility disability or to prevent IADL disability, both of which are situated in the earlier stages of the disablement process.

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