

## EXTENDED REPORTS

## Factors that modify the association between knee pain and mobility limitation in older women: the Women's Health and Aging Study

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### Abstract

**Objective**—To investigate the influence of pain severity, knee extensor muscle weakness, obesity, depression, and activity on the association between recent knee pain and limitation of usual and fast paced walking, and ability to rise from a chair.

**Methods**—A cross sectional analysis of 769 older women (mean age 77.8, range 65–101) with physical disability, but no severe cognitive impairment. Severity of knee pain in the past month was classified as none, moderate, or severe. Mobility was measured using timed performance tests. **Results**—The prevalence of recent knee pain was 53% (408/769). One third of the women with pain reported it to be severe. In general, knee pain was only significantly associated with limited mobility if severe. Obesity, activity and, to a lesser extent, depression intensified the effects of pain. Knee extensor weakness did not. Obesity was a distinctive risk factor in that it substantially increased the risk of mobility limitation, but only in women with pain. In women who had severe pain, activity (walking more than three city blocks in the past week) increased the risk of walking disability more than inactivity. Depression had a minor, but statistically significant effect on walking ability, but not the ability to rise from a chair.

**Conclusion**—In older women with recent knee pain, a high pain severity score, obesity, and activity are important factors that increase the risk of mobility limitation.

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One of the most significant threats to an older person's ability to live and function independently is loss of mobility.<sup>1,2</sup> Complaints of pain in the leg joints are common in older women,<sup>3-6</sup> and in a randomly selected sample of community dwelling older women, joint pain was the condition to which women most often attributed their mobility limitation.<sup>7</sup>

Although knee pain often results in mobility limitation, this is not always the case. Obesity,<sup>8,9</sup>

weakness of the knee extensor muscles,<sup>12-15</sup> activity levels,<sup>11</sup> and depression<sup>11,13</sup> may interact with pain and propel the development of mobility limitation. No previous studies have examined the relative importance of these factors. We used a subset of variables from the Women's Health and Aging Study<sup>14</sup> (WHAS) to investigate if, and in what way, these risk factors modify the effects of recent knee pain on mobility limitation in older women who report difficulty in activities of daily living.

### Methods

#### WHAS SAMPLING METHOD

Women were selected to represent the one third most physically disabled community dwelling women aged 65 and older. The Health Care Financing Administration (HCFA) enrolment file was used to obtain a random sample drawn from all female Medicare beneficiaries residing in 12 contiguous postal code areas in Baltimore, Maryland, USA. The HCFA file lists an estimated 98% of men and women aged over 65. The sampling technique has been described in detail by Guralnik *et al.*<sup>14</sup> In summary, an age stratified sample was drawn (65–74 years, 75–84 years, and >85 years), which yielded 6521 women. Women who were living in nursing homes, or had moved out of the area, were excluded. The remainder (5316) were asked to participate in a screening interview to establish eligibility for the study; 4137 women were located and agreed to be screened. Women were eligible for participation if they reported difficulty or inability to complete (without the assistance of another person) any of the activities in at least two of four domains:

- (1) Mobility domain (activities were walking a quarter of a mile, climbing 10 steps without resting, getting in and out of bed/chair, or heavy housework).
- (2) Upper extremity domain (activities were raising arms over head, using fingers to grasp or handle objects, or lifting and carrying 10 lb (4.54 kg)).
- (3) Basic self care domain (activities were bathing/showering, dressing, eating, or toileting).

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- (4) Higher functioning domain (activities were telephoning, light housework, meal preparation, or shopping for personal items such as medicines).

Women who had severe cognitive impairment (scored <18/30 on the Folstein Mini-Mental State Examination<sup>15</sup>) or who were currently participating in other research studies were not eligible. Of 1409 women meeting WHAS eligibility criteria, 1002 agreed to participate. There were no major disparities between eligible women who agreed to participate and those who refused.<sup>14</sup> Those who participated tended to be younger (30.2% participants were older than 85, compared with 40.8% of refusals), more often African American (28.2% of participants v 20.1% of refusals), and were more likely to have had better than a high school education (21.3% of participants v 12.8% of refusals).

One thousand and two women received a comprehensive baseline assessment between November 1992 and February 1995. This included an interview conducted by a trained interviewer and, two weeks later, a physical examination by a research nurse. A time delay between the interview and physical examination was necessary to ensure participants were not overburdened (the physical examination took just over two hours<sup>16</sup>) and that the examination could be scheduled for a convenient time. Pain assessments were completed on 991 women (98.9% of the sample), and we present data on these women.

#### INTERVIEWS AND PHYSICAL EXAMINATIONS

The interviews and physical examinations were conducted in the participants' homes. Body mass, height, depression, activity levels, and pain were assessed during the interview. Knee extensor strength and timed performance tests of mobility were measured during the physical examination, conducted by three research nurses. The interviewers and nurses were trained together, to a certified standard, and regular checks were made for quality assurance.<sup>16</sup>

#### *Assessment of pain severity*

During the interview, the women were asked, "Have you had knee pain on most days of the past month?" If the women answered "yes" they were asked to complete a validated 0–10 point visual analogue scale originally developed as part of the Western Ontario McMaster Osteoarthritis Index to assess the severity of pain while walking on a flat surface.<sup>17</sup> The duration of pain was recorded as (a) in the past month only, (b) in the past month and the past year.

#### *Assessment of depression*

During the interview depressive symptoms were assessed using the Geriatric Depression Scale (GDS).<sup>18</sup>

#### *Assessment of activity*

Activity levels were assessed as the number of city blocks walked in the week before the interview.

#### *Height (cm)*

The interviewer measured height with a stadiometer. Participants stood on a firm surface in their bare feet to have their height measured.

#### *Body mass (kg) and body mass index*

Body mass was measured during the interview with a calibrated bathroom-type digital scale, on a firm surface. Women were weighed in the standing position, wearing light indoor clothes, but no shoes, jewellery or heavy clothing. Body mass index (BMI) was calculated with the formula (weight/(height)<sup>2</sup>).

#### *Maximum isometric knee extensor strength*

Strength in both legs was measured by the research nurse during the physical examination. Women who had had knee or hip surgery in the preceding three months, had plaster casts, or who were unable to assume the testing position (for example, because they were bed bound) were excluded from the strength testing protocol. The women sat in a hard chair with the hip flexed at 90 degrees and the knee flexed at 85 degrees. A hand held dynamometer (Nicholas Manual Muscle Tester, Model #BK-7454, Fred Sammons Inc, Burr Ridge, Illinois) was placed a few inches above the ankle joint between the medial and lateral malleolus. The women were encouraged strongly to extend with maximum effort against the dynamometer using the break technique described by Bohannon.<sup>19</sup> The maximum force (recorded in kg and converted to Newtons by multiplying by 9.81) was recorded for two five second contractions on each leg. Sufficient time was allowed between contractions for recovery from fatigue. The better of the two readings from each leg were chosen, and the sum of strength in both legs was used.<sup>20</sup> A record was made if the participant mentioned any pain during testing and if the test had to be stopped owing to pain. In keeping with previous studies, absolute strength measurements were normalised for body size by dividing by body mass.<sup>21</sup> This variable was called relative strength.

#### *Walking ability*

A four metre course was marked in the participant's home by the research nurse. If they could walk, women stood with both feet on the start line and when asked to, they walked the distance at their usual pace and using their usual walking aid if appropriate. Time was recorded from the request to walk to completion of the distance. The faster of two trials is reported. The women were then asked to repeat the walking tests at their fastest possible pace. Eighty five women were tested over a three metre course owing to limitations of space, and their speed was calculated using this distance.

#### *Ability to rise from a chair*

The research nurse selected a hard armless chair from one of those in the participant's home, and recorded the height of the chair. The women were asked to rise from the chair, with their arms crossed over their chest. If

necessary they were permitted to use their arms, or the sides of the chair; this was recorded by the nurse. Analyses were adjusted for the difference between knee and chair height. Knee height was measured by the research nurse with participants in the semi-recumbent position, with the left knee and ankle bent to 90 degrees, using a Mediform sliding calliper (Medical Express, Beaverton, Oregon). The average height of the chairs was 17.5 (SD 0.6) inches (44.5 (1.5) cm).

The inter- and intratester reliability of the measures of knee extensor strength and physical performance were assessed and found to be satisfactory. The intraclass correlation for repeated strength testing procedures, measured by two nurses, was 0.91.<sup>22</sup> In a subset of 99 women, physical performance was measured weekly for six months. Measurements were stable and the intraclass correlation remained above 0.6 across a six month period in different age and disability subgroups.<sup>23 24</sup>

All participants gave their informed consent to be included in the study.

#### STATISTICAL ANALYSIS

Women who did not complete all the measures of body mass, knee extensor strength, depression, and inactivity were excluded from the analysis. Differences between women who completed the measures and those who did not, were quantified and tested for statistical significance using a  $\chi^2$  or independent sampled *t* test. Associations between age and pain severity were tested using a one way analysis of variance (ANOVA).

We examined the univariate associations between pain severity and mobility. Pain severity was coded as "none" if the women reported no pain in the past month. Women were categorised as having "moderate" pain for a visual analogue scale score of 1–6, and "severe" for a score of 7–10. Limitation in usual walking speed was defined by having a comfortable walking speed of less than 0.42 m/s or being unable to complete the test. For the fast walk, women who were slower than 0.57 m/s or unable to complete the test were defined as being limited in fast walking speed. These cut off points were chosen as previous studies have shown them to be predictive of falling and disability among community dwelling older people.<sup>1</sup> For chair rising, limitation was being unable to rise from the chair or needing to push with the arms to rise. For each category of pain severity, the percentage of women who had limited usual and fast walking, and chair rising was computed. A  $\chi^2$  test of trend was used to test for significant association between increasing pain severity and limitation of mobility. Age adjusted odds ratios and 95% confidence intervals were calculated using logistic regression (Wald method, all variables entered at once) to give the odds of mobility limitation for moderate pain versus no pain, and severe pain versus no pain (entered as dummy variables).

The univariate associations between the risk factors and pain severity were investigated. Women who had a BMI  $\geq 31.58$  were classed as obese according to a reference value derived

from an American national sample.<sup>25</sup> Women were categorised as "inactive" if they had walked fewer than three blocks (approximately 1/4 mile (400 m)), and "active" if they had walked three or more blocks in the past week. A score greater than 14 (out of a total of 30) on the GDS was used to indicate depression.<sup>18</sup> Women who had absolute or relative knee extensor strength at or below the lower quartile of the distribution were classed as having extensor weakness. These points were 172 N and  $<0.26$  respectively. A  $\chi^2$  test of trend was used to test for statistical association between increasing pain severity and, obesity, depression, absolute/relative knee extensor weakness, and inactivity respectively. Age adjusted odds ratios and 95% confidence intervals were calculated using logistic regression (as before). This gave the odds of being obese, depressed, inactive, or having extensor weakness for women with moderate pain versus no pain, and severe pain versus no pain (entered as dummy variables).

We analysed for effect modification using a stratified analysis.<sup>26</sup> Five separate analyses were carried out to establish if the associations between pain severity and mobility were modified by (a) obesity, (b) absolute knee extensor weakness, (c) relative knee extensor weakness, (d) depression, or (e) activity level. For each risk factor the procedure was to stratify the sample on the absence or presence of the risk factor (as defined previously), and within each stratum, to calculate the odds of mobility limitation for moderate pain versus no pain, and severe pain versus no pain. The odds ratios were compared qualitatively across the strata for evidence of the risk factors modifying the effect of pain on mobility.<sup>26</sup> The statistical significance of possible interactions was tested in logistic regression models which included age, pain, the risk factor, and an interaction term (pain  $\times$  risk factor). The package SPSS for Windows was used for the analysis. Significance was defined at the  $p < 0.05$  level.

## Results

#### MISSING DATA

Of the 991 women who had valid pain data, 769 (77.6%) had complete data for knee extensor strength, body mass, depression, and activity. The most common reason for incomplete data was the measure of knee extensor strength. Eight hundred and forty six women completed the strength measures in both legs. Twenty five women were physically unable to do the strength test, five women were unable to complete the test owing to pain, and 46 were unable to complete the test in both legs. In 69 others the test was not performed for various reasons.

Table 1 shows the differences between women with complete and incomplete data. Women who had incomplete data were more likely to report severe pain, to have limitation of mobility, to be inactive, and to have absolute strength  $<172$  N. These differences were statistically significant. There were no significant differences in the prevalence of relative

knee extensor weakness, depression, or obesity. Results are reported for the 769 women with complete data only.

#### PREVALENCE OF RECENT KNEE PAIN

Fifty three per cent of the women (n=408) reported knee pain (table 2). One third of the women with pain reported it to be severe. The prevalence of chronic symptoms was 81% of all women reporting pain. Slightly more women

(88.2%) with severe pain reported chronic symptoms than women with moderate pain (76.4%,  $\chi^2 = 7.8$ , p=0.005).

#### AGE BY PAIN SEVERITY

The mean age of the women was 77.8 (SD 7.7, range 65–101 years). In successive categories of pain severity, the mean age of women decreased (ANOVA, p<0.05).

#### LIMITATION OF MOBILITY BY PAIN SEVERITY

The percentage of women with limited mobility increased with successive levels of pain severity (table 2,  $\chi^2$  test for trend, p< 0.05 for all mobility tests). However, for usual paced walking and chair rising, only women with severe pain were at a statistically significant risk of limitation. For fast paced walking, women with moderate and severe pain were at a statistically significant risk of limitation, and this was greatest for women with severe pain (odds ratios and 95% confidence intervals shown in table 2).

#### OBESITY, EXTENSOR WEAKNESS, INACTIVITY, AND DEPRESSION BY PAIN SEVERITY

The prevalence and risk of obesity, weakness, inactivity, and depression increased with successive levels of pain severity (table 2). Women with moderate and severe pain were significantly more likely to be obese, to have weakness of the knee extensor muscles and depression when compared with women with no pain. Inactivity was common (>50%) in all categories of pain (including no pain), but only women with severe pain were statistically significantly more likely to be inactive than women with no pain. Table 3 shows that for the most part, each risk factor was independently associated with limited mobility.

#### ANALYSIS FOR EFFECT MODIFICATION

Table 4 shows the results of the five stratified models. Model 1 suggests that obesity was a strong effect modifier. If women were obese, the risk of limited mobility due to moderate pain was increased and became statistically significant (OR>3.4 for all mobility tests). Obesity combined with severe pain substantially increased the odds of mobility limitation (OR $\geq$ 7.1 for all mobility tests). The risk profiles were suggestive of lower body mass protecting against the disabling effects of pain. Women with severe or moderate pain, and a BMI <31.58, had no statistically significant increased risk of limited mobility compared with women with BMI $\geq$ 31.58, and no pain. Interactions between pain and obesity were statistically significant.

Models 2 and 3 suggest that neither relative nor absolute extensor strength modified the effects of pain on mobility.

Model 4 suggests that the effects of moderate and severe pain on walking were intensified in women with depression, but there was no statistically significant interaction between pain and depression. Depression had no effect on the risk of limitation in chair rising associated with knee pain.

Table 1 Numbers and characteristics of women with missing and complete data for age, pain severity, mobility limitation, and risk factors for limitation of mobility (n=991)

	Incomplete data (n)	Summary data for subjects with complete data (n=769)	Summary data for subjects with any incomplete data (n=222)
Age (mean (SD))	0	77.8(7.9)	79.4 (SD8.2)†
No pain (%)	0	52	49
Severe pain (%)	0	18	27‡
Moderate pain (%)	0	30	24
<0.42 m/s usual walk speed (%)	0	22.9	57.2¶
<0.57 m/s fast walk speed (%)	0	20.0	59.9¶
Unable to rise from chair (%)	0	15.1	54.1¶
BMI* <31.58 (%)	73	26.7	25.5
<17.5 kg absolute knee extensor strength (%)	145	25	47.4¶
<0.26 relative knee extensor strength (%)	191	25.5	34.3
GDS* >14 (%)	1	13.5	18.1
Walked <3 blocks in past fortnight (%)	75	53.6	71.4¶

\*BMI = body mass index; GDS = Geriatric Depression Scale.

†Independent sampled t test results p<0.05;  $\chi^2$  test ‡p<0.05, ¶p<0.001.

Table 2 The numbers and characteristics of women with reporting no, moderate, and severe recent knee pain for women with complete data (n= 769)

Knee pain severity	None (n=361)	Moderate (n=272)	Severe (n=136)
Age (mean(SD))	78.5 (8)	77.4 (7.8)	76.8 (7.9)†
Usual walking speed			
Mean speed (m/s)	0.66 (SD 0.27)	0.61 (SD 0.23)	0.52 (SD 0.21)‡
<0.42 m/s (%)	19.7	21.7	33.8¶
OR* (95% CI)		1.2 (0.8 to 1.8)	2.8 (1.7 to 4.5)*
Fast walking speed			
Mean speed (m/s)	1.01 (SD 0.41)	0.92 (SD 0.37)	0.83 (SD 0.38)‡
<0.57 m/s (%)	15.8	20.6	30.1¶
OR (95% CI)		1.6 (1.1 to 2.5)*	3 (1.8 to 5.0)*
Chair rise ability			
Unable (%)	13.3	14.4	21.3
OR (95% CI)		1.1 (0.7 to 1.7)	2.2 (1.3 to 3.8)*
Obesity			
Mean BMI* (SD)	26.2 (5.8)	29.4 (6.3)	31.9 (7.7)‡
BMI >31.58 (%)	15.5	30.9	47.5**
OR (95% CI)		2.4 (1.6 to 3.5)*	4.8 (3.1 to 7.6)*
Absolute strength (N)			
Mean (SD)	241 (91.2)	244 (95.2)	234 (96.1)
<172 N (%)	24.1	24.9	28.8
OR (95% CI)		1.1 (0.7 to 1.5)	1.4 (0.9 to 2.1)
Relative strength			
Mean (SD)	0.40 (0.15)	0.36 (0.15)	0.32 (0.14)‡
<0.26 (%)	19.6	26.8	38.5**
OR (95% CI)		1.4 (1 to 2.1)*	2.4 (1.6 to 3.7)*
Depression			
Mean (SD)	7.6 (5)	7.6 (5.7)	8.8 (6.3)
GDS* score $\geq$ 14 (%)	10	15.4	19.1¶
OR (95% CI)		1.6 (1 to 2.7)*	2.1 (1.2 to 3.6)*
Inactivity			
<3 blocks (%)	51	52.2	63.2¶
OR (95% CI)		1.1 (0.8 to 1.6)	1.8 (1.2 to 2.8)*

\*OR = odds ratio p<0.05; CI = confidence interval; BMI = body mass index; GDS = Geriatric Depression Scale.

†ANOVA p<0.05; ‡p<0.001. ¶ $\chi^2$  test of trend p<0.05; \*\*p<0.001.

Table 3 The univariate associations between knee pain and obesity, depression, knee extensor weakness, and inactivity in 769 older women

	Usual walking OR (95% CI)	Fast walking OR (95% CI)	Chair rising OR (95% CI)
BMI† >31.58	1.9 (1.2 to 2.9)*	2.0 (1.3 to 3.1)*	1.2 (0.7 to 1.9)
Absolute strength <172 N	4.0 (2.8 to 5.9)*	3.0 (2.0 to 4.4)*	1.9(1.2 to 2.9)*
Relative strength <0.26	4.6 (3.1 to 6.9)*	3.7 (2.4 to 5.5)*	2.7 (1.8 to 4.2)*
GDS† >14	2.2 (1.4 to 3.7)*	2.1 (1.3 to 3.5)*	2.2 (1.3 to 3.7)*
Walking <3 blocks	3.9 (2.6 to 6)*	4.8 (3 to 7.6)*	3.6 (2.2 to 6.1)*

Data are the odds ratio and (95% confidence interval). All models are age adjusted. \*p<0.05.

†BMI = body mass index; GDS = Geriatric Depression Scale.

Table 4 Effect modification owing to obesity (model 1), absolute and relative knee extensor weakness (models 2 and 3), depression (model 4), and inactivity (model 5) on the association between recent knee pain and limitation of mobility in 769 older women with physical disability

Model	Stratification variable	Comparison	Usual walking OR (95% CI)	Fast walking OR (95% CI)	Chair rising OR (95% CI)
1	Obesity	Moderate pain <i>v</i> no pain; BMI $\ddagger$ <31.58	0.8 (0.5 to 1.5)	1.2 (0.7 to 2.0)	0.9 (0.5 to 1.6)
		Moderate pain <i>v</i> no pain; BMI >31.58	3.4 (1.1 to 9.9)*	3.4 (1 to 11)*	4.2 (1 to 20)*
		Severe pain <i>v</i> no pain; BMI <31.58	1.6 (0.9 to 2.9)	1.5 (0.8 to 2.9)	1.7 (0.9 to 3.3)
		Severe pain <i>v</i> no pain; BMI >31.58	7.6 (2.6 to 23.0)* $\ddagger$	9.0 (3.0 to 29.7)* $\ddagger$	7.1 (1.5 to 33)* $\ddagger$
2	Extensor weakness, absolute strength	Moderate pain <i>v</i> no pain; strength >172 N	1.0 (0.6 to 1.8)	1.4 (0.8 to 2.1)	1.0 (0.5 to 1.9)
		Moderate pain <i>v</i> no pain; strength <172 N	1.9 (0.9 to 3.8)	2.3 (1.1 to 4.6)*	1.0 (0.4 to 2.5)
		Severe pain <i>v</i> no pain; strength >172 N	3.0 (1.6 to 5.4)*	3.2 (1.7 to 6.1)*	1.8 (0.9 to 3.9)
		Severe pain <i>v</i> no pain; strength <172 N	2.5 (1 to 5.7)*	2.6 (1.1 to 6.2)*	2.0 (1.0 to 4.0)*
3	Extensor weakness, relative strength	Moderate pain <i>v</i> no pain; strength >0.26	0.9 (0.5 to 1.6)	1.2 (0.6 to 2)	1.0 (0.6 to 1.9)
		Moderate pain <i>v</i> no pain; strength <0.26	1.9 (0.9 to 4.2)	2.6 (1.2 to 4.6)*	1.3 (0.8 to 3.6)
		Severe pain <i>v</i> no pain; strength >0.26	2.3 (1.2 to 4.2)*	2.2 (1.1 to 4.2)*	1.7 (0.9 to 3.4)
		Severe pain <i>v</i> no pain; strength <0.26	2.7 (1.2 to 6.2)*	3.7 (1.6 to 8.0)*	2.3 (1 to 5.6)*
4	Depression	Moderate pain <i>v</i> no pain; GDS $\ddagger$ <14	0.9 (0.6 to 1.6)	1.2 (0.7 to 1.9)	1.2 (0.7 to 3.8)
		Moderate pain <i>v</i> no pain; GDS >14	4.5 (1.4 to 14.2)*	5.0 (1.6 to 16.0)*	1 (0.4 to 3.8)
		Severe pain <i>v</i> no pain; GDS <14	2.4 (1.4 to 4)*	2.7 (1.6 to 4.6)*	2.0 (0.9 to 3.9)
		Severe pain <i>v</i> no pain; GDS >14	6.8 (1.7 to 27.2)*	5.0 (1.3 to 18.0)*	2.2 (0.5 to 7.4)
5	Inactivity	Moderate pain <i>v</i> no pain; walked >3 blocks	1.2 (0.5 to 3)	1.5 (0.6 to 4.3)	1.1 (0.4 to 3.4)
		Moderate pain <i>v</i> no pain; walked <3 blocks	1.1 (0.7 to 1.8)	1.4 (0.8 to 2.3)	1.0 (0.6 to 1.7)
		Severe pain <i>v</i> no pain; walked >3 blocks	5.0 (2.0 to 12.7)* $\ddagger$	4.9 (1.8 to 13.1)* $\ddagger$	4.1 (1.3 to 12.4)*
		Severe pain <i>v</i> no pain; walked <3 blocks	1.8 (1 to 3.1)*	2.2 (1.2 to 4.0)*	1.1 (0.6 to 2.7)

All models are age adjusted. \*Denotes a significant risk ( $p < 0.05$ ).  $\ddagger$ Denotes a significant interaction ( $p < 0.05$ ) in a logistic model which included age, the main effects, and an interaction term.  $\ddagger$ BMI=body mass index; GDS=Geriatric Depression Scale.

Finally, model 5 suggested that activity level had no influence on the disabling effects of moderate pain, but did modify the effect of severe pain. Women who were inactive, and had severe pain, had a small, but statistically significant, increased odds of limitation in fast and usual paced walking. The effect of activity was surprising. Much higher risks of limitation in walking were observed in women who had severe pain, but who had been active in the past few weeks. Interactions between severe pain and activity level were statistically significant.

### Discussion

The main findings are that (a) with the exception of fast paced walking, only high pain severity scores were associated with an increased risk of poor mobility; (b) obesity, activity and, to a lesser extent, depression interact with moderate and severe knee pain to increase the risk of mobility limitation; and (c) knee extensor weakness did not influence the association between pain and mobility limitation. Although we made no attempt to correlate pain with specific disease states, the high prevalence of osteoarthritis of the knee in the WHAS cohort suggests that most of the pain was due to degenerative joint disease.

There are several limitations in the study design. The analysis is cross sectional and therefore unable to infer causation. The results have to be interpreted in the context of the sampling method. Participants were selected, purposefully, to represent the one third most physically disabled women living in the community. Generalisation of the findings should be limited to groups of women with similar characteristics. We did not examine all potentially important variables, or an exhaustive supply of cut off points. In particular, we did not include pain coping skills,<sup>27 28</sup> though these are likely to be closely correlated with depression.

We included many women of advanced age, disability, and ill health, but not all were able to

complete the tests. A number of exclusions were made from the analysis because single items of data on risk factors were missing. As a result, women who had greater muscle weakness, and higher levels of disability and pain, are underrepresented in the sample.

It may seem common sense that the more severe the pain, the greater the limitation of mobility. However, few studies have investigated the relevance of severity, and may have inadvertently overlooked important aspects of the disablement process.<sup>10 27 29</sup> Lichtenstein *et al* showed pain intensity was more closely related to disability in the leg than the incidence of pain,<sup>30</sup> but these observations were not specific to the knee joint. The apparent association of the severity of pain with disability has clinical implications. Although preferable, the complete elimination of pain may not be necessary to improve mobility.

In general, moderate pain was associated with limitation in fast paced walking only. People with leg pain often adopt gait patterns that protect ligaments and other joint structures from painful movements,<sup>28</sup> including taking shorter steps and walking more slowly. We did not measure pain while performing the walking test, and there was a delay of two weeks between recording pain symptoms and walking speed. Neither of these factors was likely to have influenced our conclusions as most women had longstanding pain that would be unlikely to recover in two weeks. The analysis assumes there was no significant fluctuation in physical performance in the period between the interview and examination. We tested this assumption in a previous study and found physical performance was stable in a two week period.<sup>23 24</sup>

The inverse association between the severity of pain and age contrasts with the results of several surveys of pain in community dwelling older people.<sup>3 4</sup> Unlike previous studies, WHAS used an age stratified sampling frame

to assure that the oldest old (>85 years) were well represented. Why should younger age be more strongly associated with pain associated mobility limitation? The explanation may be that there were fewer obese women in the oldest age groups. Obesity exacerbates pain in the leg joints during weightbearing activities.<sup>31</sup> In the women studied in WHAS the prevalence of obesity decreases with advancing age,<sup>14</sup> possibly owing to a cohort effect, selective survival of non-obese disabled women into oldest age, or a decline in weight associated with age. This cannot be ascertained from cross sectional data. Another possibility is that older women do not walk as much as younger women, so that less stress is applied to irritable tissues. Previously published analyses of the WHAS baseline study have reported a trend of decreasing physical activity in the oldest women.<sup>14</sup>

There was evidence of a strong interaction between pain and obesity, with the risk of limited mobility in obese women with pain being greater than could be attributed to the purely additive effects of the two risk factors.<sup>20</sup> Verbrugge *et al* reported that obesity was a distinctive risk factor for disability in people who have arthritis (that is, that the risk factor promotes disability for arthritic people but not for those without arthritis).<sup>8</sup> We also found a similar relation in women with knee pain. Obesity was the only distinctive risk factor.

The associations between mobility, pain, and activity were surprising. Walking is recommended as being beneficial in maintaining function in people who have osteoarthritis of the knee.<sup>32</sup> Our results suggest that walking more than a mile on a severely painful knee might worsen mobility. Non-weightbearing activity, for example, swimming, might be more appropriate. Although inactivity was a risk factor for mobility limitation in people who had severe joint pain, the risk was small, but predictable, as inactivity results in a loss of physical fitness and thereby, immobility.<sup>33</sup> Optimum activity levels should be clarified by future research.

Previous research has shown knee extensor strength to be a highly prevalent, modifiable risk factor for disability in people who have osteoarthritis<sup>34 35</sup> and in elderly people without pain.<sup>36</sup> Some researchers have argued that there is a causal pathway between pain and muscle weakness mediated by reflex inhibition of knee extensor muscles,<sup>37</sup> and resulting in disability. Our data do not dispute that knee extensor strength is a determinant of mobility, but in our study group there was no suggestion that knee extensor weakness was a problem specific to or worse in women with recent knee pain. Muscle weakness is likely to be the final common pathway of many pathological and non-pathological conditions of later life. Other explanations maybe that we selected an inappropriate cut off point or summary measure to define knee extensor weakness. The cut off point we chose was equivalent to that reported by Ferrucci *et al*<sup>22</sup> as being pivotal in determining whether muscle strength was an active factor in mobility performance in older people or not. We used

the sum of extensor strength in both legs as an index of strength, as in preliminary analyses (not shown) this was more closely related to mobility than either the average strength or the strength of the weakest or strongest leg. Possibly, we were unable to detect the effects of muscle strength owing to bias arising from missing data. Also, maximality of effort was not tested using formal methods such as twitch interpolation.<sup>37</sup>

A common, often overlooked problem in analysing the importance of extensor weakness is its relation to body mass. We approached this problem by examining the effects of body mass and absolute strength separately, as well as relative strength (strength/body mass). Obese women were stronger than those who were not obese, but this was not in proportion to their body mass. In women with pain, being stronger (>172 N) was associated with a greater risk of mobility limitation than being weak. This seems biologically implausible and suggests confounding by body mass. However, relative strength might have obscured some of the effects of obesity as a woman with low strength and low body mass would have scored in a similar range to a woman with good strength and heavy body mass.

Depression is associated with and predictive of physical disability in older people.<sup>38</sup> It also has a strong relation with pain,<sup>39</sup> and several authors have suggested that it is a factor which propels the development of disability in people who have pain.<sup>11 12</sup> Our results suggest that the effect of depression is not particularly strong, or distinctive.

In conclusion, recent knee pain is a common condition in older women, but only results in significantly limited mobility when severe. Interventions that decrease the severity of pain, reduce obesity, and optimise levels of weight-bearing activity are most likely to reduce the burden of mobility disability in older women with severe pain. The study should be replicated in other groups, and with longitudinal and experimental designs to establish the wider relevance of our suggestions.

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- 1 Tinetti ME, Inouye SK, Gill TM, Doucette JT. Shared risk factors for falls, incontinence and functional dependence. *JAMA* 1995;273:1348-53.
- 2 Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med* 1995;332:556-61.
- 3 Crook J, Rideout E, Browne G. The prevalence of pain complaints in a general population. *Pain* 1984;18:299-314.
- 4 Sternberg RA. Survey of pain in the United States: the Nuprin Pain Report. *Clin J Pain* 1986;1:49-53.
- 5 Brattberg G, Thorslund M, Wikman A. The prevalence of pain in a general population: the results of a postal survey in a county of Sweden. *Pain* 1989;37:215-22.
- 6 Tennant A, Fear J, Pickering A, Hillman M, Cutts A, Chamberlain MA. Prevalence of knee problems in the population aged 55 years and over. *BMJ* 1995;310:1291-3.
- 7 Ettlinger WH, Fried LP, Harris T, Semanski L, Chultz R, Robbins J. Self reported causes of physical disability in older people: the Cardiovascular Health Study. *J Am Geriatr Soc* 1994;42:1035-44.
- 8 Verbrugge LM, Gates DM, Ike RW. Risk factors for disability among US adults with arthritis. *J Clin Epidemiol* 1991;44:167-82.
- 9 Ettlinger WH, Davies MA, Neuhaus J, Mallon K. Long term functioning in knee osteoarthritis: effects of comorbid conditions. *J Clin Epidemiol* 1994;47:747-60.

- 10 McAlindon TE, Cooper C, Kirwan JR, Dieppe PA. Determinants of disability in osteoarthritis of the knee. *Ann Rheum Dis* 1993;52:258-62.
- 11 Dekker J, Tola P, Aufdemkampe G, Winkers M. Negative affect, pain and disability in osteoarthritis patients: the mediating role of muscle weakness. *Behav Res Ther* 1993; 31:203-6.
- 12 O'Reilly SC, Jones A, Muir K, Doherty M. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. *Ann Rheum Dis* 1998;57:588-94.
- 13 Salaffi F, Cavalieri M, Nolli M, Ferraccioli G. Analysis of disability in knee osteoarthritis. Relationship with age and psychological variables but not with radiographic score. *J Rheumatol* 1991;18:1581-6.
- 14 Guralnik JM, Fried LP, Simonsick EM, Kasper JD, Lafferty ME, eds. *The Womens Health and Aging Study. Health and social characteristics of older women with disability.* Maryland, USA: National Institute of Health, 1995. (No 95-4009.) ([www.nih.gov/niha/edb/whasbook/title.htm](http://www.nih.gov/niha/edb/whasbook/title.htm))
- 15 Folstein MF, Folstein SE, McHugh PR. Mini-mental state. A practical method for the grading of cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189-98.
- 16 Simonsick EM, Maffeo CE, Rogers SK, Skinner EA, Davies D, Guralnik JM. Methodology and feasibility of a home-based examination in disabled older women: the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci* 1997;52:M264-7.
- 17 Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to anti-rheumatic drug therapy in patients with osteoarthritis of the hip and knee. *J Rheumatol* 1988;15:1833-40.
- 18 Yesavage JA, Brink TL, Rose TL, Lum O, Humang V, Adey M, *et al.* Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res* 1983;17:37-49.
- 19 Bohannon RW. The clinical measurement of strength. *Clinical Rehabilitation* 1987;1:5-16.
- 20 Brown M, Sinacore DR, Host HH. The relationship of strength to function in the older adult. *J Gerontol A Biol Sci Med Sci* 1995;50:55-9.
- 21 Bassey EJ, Fiatarone M, O'Neill E, Kelly M, Evans W, Lipsitz LA. Leg extensor power and functional performance in very old men and women. *Clin Sci* 1992;82:321-7.
- 22 Ferrucci L, Guralnik JM, Buchner D, Kasper J, Lamb SE, Simonsick EM, *et al.* Departures from linearity in the relationship between measures of muscular strength and physical performance of the lower extremities: the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci* 1997;52:M275-85.
- 23 Guralnik JM, Ferrucci L, Penninx BWJP, Kasper JD, Leveille SG, Bandeen-Roche K, *et al.* New and worsening conditions and change in physical and cognitive performance during weekly evaluations over six months: the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci* (in press).
- 24 Ferrucci L, Guralnik JM, Salive ME, Fried LP, Bandeen-Roche K, Brock DB, *et al.* Effect of age and severity of disability on short term variation in walking speed. The Women's Health and Aging Study. *J Clin Epidemiol* 1993;49: 1089-96.
- 25 Must A, Dallal GE, Dietz DH. Reference values for obesity. 85th and 95th percentiles of body mass index and triceps skinfold thickness. *Am J Clin Nutr* 1991;53:839-46.
- 26 Gordis L. *Epidemiology.* Philadelphia: Saunders, 1996.
- 27 Summers MN, Haley WE, Reveille JD, Alarcon GS. Radiographic assessment and psychologic variables as predictors of pain and functional impairment in osteoarthritis of the hip or knee. *Arthritis Rheum* 1998;31:204-9.
- 28 Keefe FJ, Caldwell DS, Queen K, Gil KM, Martinez S, Crisson JE, *et al.* Osteoarthritic knee pain: a behavioural analysis. *Pain* 1989;28:309-21.
- 29 Chang RW, Dunlop D, Gibbs J, Hughes S. The determinants of walking velocity in the elderly. An evaluation using regression trees. *Arthritis Rheum* 1995;38:343-50.
- 30 Lichtenstein MJ, Dhanda R, Cornell JE, Escalante A, Hazuda H. Disaggregating pain and its effect on physical functional limitations. *J Gerontol A Biol Sci Med Sci* 1998; 53:M361-71.
- 31 Leach RE, Baumgard S, Broom J. Obesity: its relationship to osteoarthritis of the knee. *Clin Orthop* 1973;93:271-3.
- 32 Kovar PA, Allegrante JP, Mackenzie M, Peterson GE, Gutin B, Charlson ME. Supervised fitness walking in patients with osteoarthritis of the knee. *Ann Intern Med* 1992;116: 529-34.
- 33 Buchner DM, Wagner EH. Preventing frail health. *Clin Geriatr Med* 1992;8:1-17.
- 34 Ettinger WH, Burns R, Messier SP, Applegate W, Rejeski JW, Morgan T, *et al.* A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. *JAMA* 1997;277:25-31.
- 35 O'Reilly SC, Muir KR, Doherty M. Effectiveness of home exercises on pain and disability from osteoarthritis of the knee: a randomised controlled trial. *Ann Rheum Dis* 1999; 58:15-19.
- 36 Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, *et al.* Exercise training and nutritional supplementation for physical frailty in very elderly people. *New Engl J Med* 1994;330:1769-75.
- 37 Young A. Current issues in arthrogenous inhibition. *Ann Rheum Dis* 1993;52:829-34.
- 38 Penninx BW, Guralnik JM, Ferrucci L, Simonsick EM, Deeg DJ, Wallace RB. Depressive symptoms and physical decline in community-dwelling older persons. *JAMA* 1998; 279:1720-6.
- 39 Magni G, Caldieron C, Rigatti-Luchini S, Merskey H. Chronic musculoskeletal pain and depressive symptoms in the general population. An analysis of the 1st National Health and Nutrition Examination Survey data. *Pain* 1990;43:299-307.