The disablement process: Factors associated with progression of disability and recovery in French elderly people

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Abstract
Purpose: To study the factors associated with progression, recovery and death from different grades of disability in elderly people.
Method: The sample included 3198 participants of the PAQUID (‘Personnes Âgées QUID’) cohort, aged 65 and over and community-dwellers at baseline. Subjects were re-interviewed 1, 3, 5, 8 and 10 years after baseline. A five-state Markov model was used to estimate transition intensities between four grades of disability and toward death. We used a hierarchic scale of disability, which combines basic and instrumental activities of daily living and mobility. Several explanatory variables were investigated: medical, personal and environmental factors.
Results: The factors associated with progression and/or no recovery of disability were cardiovascular diseases, stroke and diabetes, low cognition, visual impairment and dyspnoea (for pathologies and impairments), older age, female gender, low educational level (for risk factors), depression (for intra-individual factor) and being married, recent hospitalization and number of drugs (for extra-individual factors). Older age, male gender, tobacco consumption and living in an urban area were associated with mortality.
Conclusions: These findings confirm the independent contribution of each group of variables in the disablement process and stress their different impact on progression of disability or on recovery from different grades of disability.

Introduction
‘Active ageing’ is defined by the World Health Organisation (WHO) as ‘the process of optimizing opportunities for physical, social, and mental well-being throughout the life course, in order to extend healthy life expectancy, productivity and quality of life in older age’ [1]. Health and independence represent one of the three pillars on which the concept of ‘active ageing’ is based on. Considering the demographic revolution, ‘active ageing’ has become a worldwide major socio-economic and political challenge. The sizeable increase in life expectancy in recent decades is undeniably due to large improvements in medical care, but also to societal and environmental factors, such as increase in education and improvement in living conditions. The incompressible effect of old age should lead to a ceiling effect in medical progress. However, improvements are still possible in terms of disability and quality of life, by sustaining and restoring functional capacity and by maximizing older person’s social involvement and independence [2]. To organize and plan efficient policies and programmes for an ‘active ageing’, a better identification of the components of the disablement process would be very useful.

Conceptually, the disablement process of Verbrugge [2] models the impact of acute or chronic conditions on functioning of specific body systems and on people’s abilities to act. The main pathway leads from pathology to impairments, functional limitations and disability. Impairments are defined as dysfunctions and significant structural abnormalities in specific body system. Functional limitations are restrictions in performing fundamental physical and mental actions used in daily life by one’s age-sex group. Disability is experienced difficulty doing
activities in any domains of life due to a health or physical problem. Disability is not inherent in a person, but denotes a relationship between a person and her/his environment. One originality of this model is the introduction of personal and environmental factors, which speed up or slow down the pathway [2]. Thus, the risk factors are any predisposing factors that affect the presence and severity of impairment, functional limitations and disability. Intra-individual factors are factors inherent in subjects on their own. They represent the reactions of the subjects, confronted with impairment, functional limitation or disability, such as lifestyle and behaviour changes, psychosocial attributes, coping or activity accommodations. Finally, extra-individual factors are any environmental factors set up in reaction upon impairment, functional limitation or disability. They may be medical care and rehabilitation, medications, external support (personal assistance, special equipment, devices) or modifications to the environment. These factors could impact the pathway by preventing, delaying or reversing the transitions from functional independence to disability, but they can also worsen the process.

Many factors have been identified to be associated with progression of disability. Among them, the most largely studied are the medical factors, such as cardiovascular diseases [3, 4], hypertension [3], arthritis [3, 5], stroke [6, 7], chronic obstructive pulmonary disease [8, 9], cognition or dementia [10–14], diabetes [5, 15], depression [14–18], and sensory impairments [14, 16, 19, 20]. Some demographic characteristics have been also identified such as older age [5, 6, 14, 16, 20–24], female gender [6, 14, 16, 21–26], being unmarried [5, 27], low incomes [5, 14], low educational level [3, 6, 14, 28], and social isolation [14, 20, 29]. However, the impact of other personal and environmental factors has been less investigated.

Until now, a large part of the geriatric literature on disability was focused on progression and yet, disability is not an irreversible event [16, 30, 31]. Indeed, recovery from disability is possible, even among oldest old people. Hébert showed that 7.5% of subjects aged 75 years and over, regained more independence during the first year and 17.9% during the second [30].

Finally, in many studies based on the evolution of disability over time (i.e. deterioration, stability or recovery), disability was investigated as a binary variable, thus providing information on only one domain of disability. Yet, several hierarchical domains of increasing disability can be distinguished such as: mobility, instrumental and basic activities of daily living [32]. Moreover, death is a competitive event. The lower prevalence of disability often reported in older men compared to women, might be explained by their higher risk of death rather than by a lower incidence of disability. Longitudinal surveys are necessary to describe the dynamics and determinants of disability and death at older ages.

The aim of this survey was to identify the contribution of factors associated with progression and/or recovery from four hierarchic grades of disability in elderly people, taking simultaneously into account the risk of death. The analyses were based on the conceptual framework of the disablement process model, by multistate Markov models.

**Methods**

**Population and sample**

The analyses were based on the PAQUID (‘Personnes Âgées QUItD’) cohort data set. The general methodology of this prospective epidemiological survey on cerebral and functional ageing has been previously described [33, 34]. The participants, randomly selected from the electoral lists, were 65 and older at baseline and lived in the community in two French South-West areas (in Gironde and Dordogne). The initial acceptance rate was 68%. This sample was representative in terms of age and sex of the elderly community dwellers of the area [34]. Subjects were interviewed at home by a specially trained psychologist and re-interviewed 1, 3, 5, 8 and 10 years after baseline. Noted that only the participants from the Gironde area were interviewed at T1.

**Assessment of disability**

The three main dimensions usually identified in the concept of disability were investigated at each visit: basic Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL) and mobility [35, 36].

- ADL included five basic activities: bathing, dressing, toileting, transferring and eating [37]. As incontinence is an impairment rather than a disability, this item was excluded from disability staging [38].

- The ability for the five following IADL was evaluated: telephoning, shopping, transferring, managing medication and finances [39]. As suggested by Lawton, three additional activities were evaluated for women only: doing housework, meal preparation and doing the laundry.

- Mobility was measured by three items of the Rosow and Breslau scale: doing heavy housework, walking half a mile and climbing stairs [40].
For each of these three domains, a subject was considered as dependent if he could not perform at least one activity of the domain without a given level of assistance, as defined by the respective authors of the scales.

The statistical analyses were conducted on a hierarchic scale, which combines the three previous scales, as previously shown in the PAQUID study [32]. As presented in Figure 1, this indicator distinguishes four levels of increasing disability. Full independence was coded state 0; mild disability (only mobility-disability) coded state 1; moderate disability (mobility- and IADL-disability) was coded state 2; and finally severe disability (mobility- and IADL- and ADL-disability) was coded state 3. This hierarchical model fitted 99.3% of the subjects at baseline of PAQUID with a coefficient of reproducibility of 0.99 and a coefficient of scalability of 0.98 [32].

**Explanatory variables**

The explanatory variables were assessed at baseline.

- Pathologies and their clinical manifestations in terms of ‘impairments’ were grouped for the analyses. Diagnoses of cardiovascular diseases, stroke and diabetes were based on self-report and on the presence of specific treatments among the list of drugs currently taken at baseline. Cognitive impairment was defined according to the Mini-Mental Status Examination (MMSE) of Folstein [41]. A subject was considered as cognitively impaired if he obtained a MMSE score lower than 24 for the low educated subjects (as defined below) or less than 26 otherwise [42]. A visually impaired subject reported difficulties in reading or sewing due to visual problems or blindness. Dyspnoea was defined as being breathless for at least major efforts.
- ‘Risk factors’ included age, gender, educational level, tobacco and wine consumption. Age was dichotomized in 65 – 79 years vs. 80 years and older, since some studies reported striking differences in the prevalence of disability after this threshold [22]. A high educational level was defined by the possession of at least the Certificate d’Etudes Primaires (CEP), which is the French primary school diploma corresponding to about 7 years of schooling. Tobacco consumption was divided in non-smokers, current and former smokers. Three wine consumption levels were distinguished: no consumer, less than 0.25 litres of wine per day and more than 0.25 litres.
- Depressive symptomatology was the only ‘intra-individual’ factor available, evaluated by the Centre for Epidemiologic Studies Depression-scale (CES-D) [43]. Participants were classified as exhibiting a depressive symptomatology if they scored 17 and over for men and 23 and over for women [44].
- The ‘extra-individual’ factors included marital status (married subjects vs. single, divorced, or widowed) and living in a rural area (less than 2000 inhabitants). An intake of four medications or more per day, median value of the sample (considered as a ‘large’ drug consumption) and hospitalization in the previous year, represented two indicators of medical care and/or of severity of health.

**Statistical analysis**

The statistical analysis used a five-state homogeneous Markov model: the four hierarchical disability states and death (Figure 1). We assumed that transition between two non-consecutive disability states passed through the intermediate state, even if it was not actually observed due to discrete observation times. The transition intensity (\(a_{jk0}\) from state \(j\) to state \(k\)) can be considered as an ‘instantaneous risk’ of going from state \(j\) to state \(k\) [45]. The transition probability is defined as the probability of being in state \(k\) at time \(t\), given that the subject was in state \(j\) at a previous time \(s\). These probabilities do not depend

![Figure 1. Definition of states and transitions intensities of the five-state model of disability or death, with transition intensities for the model with no covariates – the PAQUID study, 1988 – 1998.](image-url)
on times $s$ and $t$ and thus, transition intensities are not time-dependent. The model was extended by introducing covariates as a proportional factor over the baseline transition intensities $\lambda_{jk}(z) = \lambda_{0j} \exp(\beta_{jk} z)$ [46]. The analyses were performed with the MKVPCI 1.0 software [47].

We firstly estimated transition intensities for a model without covariates. In order to reduce the important number of parameters, the most parsimonious representation of the effect of each covariate has been selected with adjustment for age and sex by a stepwise backward procedure ($p < 0.05$). For each covariate, we determined if they had a homogeneous effect or not on each transition with Wald tests. Ten transition intensities were estimated if the covariate had a different effect on each transition: three for progression (since $\beta_{00} \neq \beta_{10} \neq \beta_{20}$), three for regression ($\beta_{10} \neq \beta_{21} \neq \beta_{32}$) and four for death ($\beta_{0D} \neq \beta_{1D} \neq \beta_{2D} \neq \beta_{3D}$). However, a covariate could have the same effect on progression (i.e. equality of these three transition intensities: $\beta_{01} = \beta_{12} = \beta_{23}$), on regression (i.e. $\beta_{10} = \beta_{21} = \beta_{32}$) and on transitions to death (i.e. $\beta_{0D} = \beta_{1D} = \beta_{2D} = \beta_{3D}$). In accordance to the disablement process model, the four following models were successively run: pathologies and impairments, risk factors, intra- and extra-individual factors. In each model, variables were selected by a stepwise backward procedure ($p < 0.05$). Transition Intensities Ratios (TIR = exponential $\beta$) with their 95% confidence intervals were estimated. Their interpretation is similar to that of a relative risk.

### Results

**Description of the sample**

At least two assessments of disability were necessary, except for the deceased subjects for whom the baseline-assessment was sufficient. The sample included 3198 participants and their characteristics at baseline are presented in Table I.

One-quarter were aged 80 years and older, 57.3% were women and 66.2% were ‘highly’ educated. At baseline, cardiovascular problem (i.e. myocardial infarction, hypertension and/or specific treatments linked to cardiovascular diseases) and cognitive impairment were the more frequent medical conditions, with respectively 80.7 and 29.6% (Table I).

**Disability: description of functional status and transitions**

At baseline, 25.4% were fully independent, 46.1% mildly disabled, 25.3% moderately and 3.2% severely disabled. At the 10-year follow-up, 44.8% of the participants were deceased, 16.0% of the survivors were fully independent, 36.0% mildly disabled, 35.0% moderately and 13.0% severely disabled.

<table>
<thead>
<tr>
<th>Covariates</th>
<th>n = 3198</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (80 years and older)</td>
<td>798</td>
<td>24.9</td>
</tr>
<tr>
<td>Female sex</td>
<td>1833</td>
<td>57.3</td>
</tr>
<tr>
<td>High educational level</td>
<td>2117</td>
<td>66.2</td>
</tr>
<tr>
<td>Married subjects</td>
<td>1833</td>
<td>57.3</td>
</tr>
<tr>
<td>Residence in rural area</td>
<td>1121</td>
<td>35.0</td>
</tr>
<tr>
<td>Wine consumption:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No consumption</td>
<td>1391</td>
<td>43.5</td>
</tr>
<tr>
<td>Moderate consumption (&lt; 1/4 l per day)</td>
<td>1306</td>
<td>40.8</td>
</tr>
<tr>
<td>Excessive consumption (&gt; 1/4 l per day)</td>
<td>501</td>
<td>15.7</td>
</tr>
<tr>
<td>Tobacco consumption:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>2011</td>
<td>62.9</td>
</tr>
<tr>
<td>Current smoker</td>
<td>307</td>
<td>9.6</td>
</tr>
<tr>
<td>Former-smoker</td>
<td>880</td>
<td>27.5</td>
</tr>
<tr>
<td>Cardiovascular condition</td>
<td>2581</td>
<td>80.7</td>
</tr>
<tr>
<td>Stroke</td>
<td>165</td>
<td>5.1</td>
</tr>
<tr>
<td>Diabetes</td>
<td>328</td>
<td>10.2</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>948</td>
<td>29.6</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>513</td>
<td>16.0</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>239</td>
<td>7.5</td>
</tr>
<tr>
<td>Depressive symptomatology</td>
<td>438</td>
<td>13.7</td>
</tr>
<tr>
<td>Recent hospitalization</td>
<td>599</td>
<td>18.7</td>
</tr>
<tr>
<td>High drug consumption (more than 3)</td>
<td>1703</td>
<td>53.2</td>
</tr>
</tbody>
</table>

In the model with no covariates, all the TIR were significantly different from zero ($p < 0.001$). As presented in Figure 1, the transition intensities between two grades of disability were higher for progression than for recovery (e.g. between state 0 and state 1: $\beta_{01} = 8.7 \times 10^{-4}$ and $\beta_{10} = 4.3 \times 10^{-4}$). Whilst the risks of progression were higher from less severe disability grades, chances of recovery decreased with severity of disability. Finally, the transition intensities towards death increased with severity of disability.

**The components of the disablement process**

Univariate analyses (adjusted for age and gender) The factors associated with progression of disability were: older age, female gender, cardiovascular diseases (CVD), stroke, diabetes, visual and cognitive impairment, dyspnoea, depressive symptomatology, low educational level, no wine consumption, hospitalization and large drug consumption.

The factors associated with lower chance of recovery from disability were: older age, female gender, the three impairments (cognitive, visual and respiratory), depression, diabetes, hospitalization, drug consumption, being unmarried and living in a rural area.

**Multivariate analyses** In the ‘pathologies and impairments’ model (Table II), the factors associated homogeneously with disability progression (i.e. same...
impact on the risk of disability whatever the initial
disability level) were: age 80 and over (TIR = 1.9,
interpreted as relative risk), sequelea of stroke
(TIR = 1.3), CVD (TIR = 1.3), visual impairment
(TIR = 1.2) and cognitive impairment (TIR = 1.4).
The factors with a non-homogeneous effect on
progression were female gender (TIR \_0 \_1 = 1.5, i.e.
only for the transition [0→1]) and diabetes (TIR
\_1 \_2 = 1.4).

Factors homogeneously associated with lower
chances of recovery from disability were: older age
(TIR = 0.5), female gender (TIR = 0.8), visual im-
pairment (TIR = 0.7), cognitive impairment
(TIR = 0.8), and dyspnoea (TIR = 0.6). Diabetes
only limited the chance of recovery from mild
disability (TIR \_1 \_0 = 0.6).

The introduction of ‘risk factors’ (Table III) did
not change the impact of pathologies and impair-
ments on the disablement process. Education was
the only one risk factor, which remained signifi-
cantly associated with disability in the model, in
the way of a decreased homogeneous risk of
progression for the highly educated subjects
(TIR = 0.8).

When adding depressive symptomatology as an
‘intra-individual factor’, the impact of visual impair-
ment on disability progression was no longer
significant (Table IV). The negative impact of
depressive symptomatology disappeared on recovery,
but persisted on progression (TIR = 1.2).

When adding the ‘extra-individual factors’, de-
pressive symptomatology was no longer significantly
associated with disability progression (Table V).
Large drug consumption was associated with an
increased risk of disability progression (TIR = 1.1)
and a decreased chance of recovery, but only towards
full independence (TIR \_1 \_0 = 0.6). Being married
was associated with a lower risk of becoming disabled
(TIR \_0 \_1 = 0.7) and with an increased chance of
recovery from moderate disability (TIR \_2 \_1 = 1.3).
Hospitalization was associated with a lower chance of
recoverying from disability (TIR = 0.8), but its dele-
terious impact on progression disappeared after
adjustment for the other components. Finally, living
in a rural area was no longer associated with a lower
chance of disability regression.

Factors associated with mortality
In the final multivariate model, older age was
associated with a higher risk of mortality
(TIR = 1.2), whereas living in a rural area
(TIR = 0.9) and female gender (TIR \_1 \_Death = 0.2
and TIR \_2 \_Death = 0.4) were associated with a lower
risk of death (Table V). Very few significant variables
remained associated with mortality in the final
model. Mortality seems to be much more associated
### Table III. Effects of explanatory variables on disability progression, regression and mortality—Multivariate analysis—‘Pathologies, impairments and Risk factors’ model— the PAQUID Study; 1988 – 1998

<table>
<thead>
<tr>
<th>Variables</th>
<th>Progression</th>
<th>Recovery</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0→1 TIR</td>
<td>1→0 TIR</td>
<td>0→D TIR</td>
</tr>
<tr>
<td></td>
<td>95%CI</td>
<td>95%CI</td>
<td>95%CI</td>
</tr>
<tr>
<td>80 or + vs. 65–79 years</td>
<td>1.9 1.7–2.1</td>
<td>1.9 1.7–2.1</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Female gender</td>
<td>1.5 1.3–1.7</td>
<td>1.3 1.1–1.6</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.0–1.3</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.3 1.2–1.4</td>
<td>1.1 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>1.1 1.0–1.3</td>
<td>1.1 1.0–1.3</td>
<td>1.0 0.8–0.9</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.2–1.5</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.6–0.9</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.2–1.5</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>High level of education</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.6–0.9</td>
</tr>
<tr>
<td>Tobacco consumption</td>
<td>0.6 0.6–0.8</td>
<td>0.6 0.6–0.8</td>
<td>0.6 0.6–0.8</td>
</tr>
<tr>
<td>Wine consumption</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.6–0.9</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
</tr>
</tbody>
</table>

TIR: Transition Intensities Ratio
95% CI: 95% Confidence Interval

### Table IV. Effects of explanatory variables on disability progression, regression and mortality—Multivariate analysis—‘Pathologies, impairments, Risk factors and Intra-individual factors’ model—the PAQUID Study; 1988 – 1998

<table>
<thead>
<tr>
<th>Variables</th>
<th>Progression</th>
<th>Recovery</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0→1 TIR</td>
<td>1→0 TIR</td>
<td>0→D TIR</td>
</tr>
<tr>
<td></td>
<td>95%CI</td>
<td>95%CI</td>
<td>95%CI</td>
</tr>
<tr>
<td>80 or + vs. 65–79 years</td>
<td>1.9 1.7–2.2</td>
<td>1.9 1.7–2.2</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Female gender</td>
<td>1.5 1.3–1.7</td>
<td>1.3 1.1–1.6</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.0–1.3</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.0–1.3</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>1.3 1.1–1.4</td>
<td>1.3 1.1–1.4</td>
<td>1.3 1.0–1.3</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.0–1.3</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.6–0.9</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>0.6 0.4–0.8</td>
<td>0.6 0.4–0.8</td>
<td>0.6 0.4–0.8</td>
</tr>
<tr>
<td>High level of education</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
</tr>
<tr>
<td>Tobacco consumption</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.6–0.9</td>
</tr>
<tr>
<td>Wine consumption</td>
<td>0.6 0.6–0.8</td>
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<td>0.6 0.6–0.8</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
<td>1.2 1.0–1.3</td>
</tr>
</tbody>
</table>

TIR: Transition Intensities Ratio
95% CI: 95% Confidence Interval
Table V. Effects of explanatory variables on disability progression, regression and mortality—Multivariate analysis—‘Pathologies, impairments, Risk factors, Intra-individual factors and Extra-individual factors’ model—the PAQUID Study; 1988–1998

<table>
<thead>
<tr>
<th>Variables</th>
<th>Progression</th>
<th>Recovery</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0→1 TIR 95%CI</td>
<td>1→2 TIR 95%CI</td>
<td>2→3 TIR 95%CI</td>
</tr>
<tr>
<td>80 or + vs. 65–79 years</td>
<td>1.9 1.7–2.1</td>
<td>1.9 1.7–2.1</td>
<td>1.9 1.7–2.1</td>
</tr>
<tr>
<td>Female gender</td>
<td>1.3 1.1–1.5</td>
<td>0.9 0.8–1.0</td>
<td>0.9 0.8–1.0</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.1–1.6</td>
<td>1.3 1.1–1.6</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.4 1.1–1.6</td>
<td>0.7 0.5–0.9</td>
<td>0.7 0.5–0.9</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.2–1.5</td>
<td>1.3 1.2–1.5</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
<td>0.8 0.8–0.9</td>
</tr>
<tr>
<td>High level of education</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
</tr>
<tr>
<td>Tobacco consumption</td>
<td>0.7 0.6–0.8</td>
<td>1.3 1.1–1.7</td>
<td>0.9 0.8–1.0</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
<td>1.1 1.0–1.2</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>0.7 0.6–0.8</td>
<td>1.3 1.1–1.7</td>
<td>0.9 0.8–1.0</td>
</tr>
<tr>
<td>4 or + drugs vs. less</td>
<td>0.7 0.6–0.8</td>
<td>1.3 1.1–1.7</td>
<td>0.9 0.8–1.0</td>
</tr>
<tr>
<td>Married</td>
<td>0.7 0.6–0.8</td>
<td>1.3 1.1–1.7</td>
<td>0.9 0.8–1.0</td>
</tr>
<tr>
<td>Rural vs. urban area</td>
<td>0.7 0.6–0.8</td>
<td>1.3 1.1–1.7</td>
<td>0.9 0.8–1.0</td>
</tr>
</tbody>
</table>

TIR: Transition Intensities Ratio
95% CI: 95% Confidence Interval
with the severity of disability rather than with the other factors investigated in these analyses.

Discussion
The present paper confirmed the validity and the usefulness of the disablement process model proposed by Verbrugge and Jette in understanding the components and determinants of disability in elderly people [2]. Indeed, our findings showed the independent impact of the groups of covariates successively introduced in the models. Our results also showed that the impact of some factors differed on disability progression and on recovery, and that some factors impact on specific transitions (such as diabetes or marital status).

Moreover, whilst most of the studies on disability explored only one domain of disability at a time, the combined use of a hierarchical indicator of disability and multi-state models had several advantages. Indeed, this methodology allowed us to study the evolution of disability over 10 years, with the possibility of reversibility and taking into account simultaneously the three domains of disability (mobility, IADL, and ADL) and the competing risk of dying. Few studies consider disability as a potentially reversible event despite strong evidence in our results (especially from the lowest grades of disability), as in others. In the Longitudinal Study On Ageing, Mor et al. showed that even from a severe disability state and despite advanced age (aged 70–79 years), 7.0% of the severely ADL disabled men and 3.5% of women recovered full independence over 6 years [48]. Restoring functional independence could become another target for ‘active ageing’, in favouring for example, better management of visual impairments, more widespread treatment for depression or increased vigilance to conditions of discharge after hospitalization. However, hospitalization and drug consumption could also be indicators of severity of health deterioration and prevention here would be more limited.

However, there are potential limitations to this study. First, the homogeneous Markov models were not time-dependent despite the risk of disability and death strongly increasing with ageing. Moreover, the covariates were not time-dependent but only recorded at baseline, as some were not identically measured at all follow-ups. Using time-dependent covariates would have considerably reduced the number of available explanatory variables. Moreover, some other covariates, well known to be significantly associated with disability were not available in the database. For instance, arthritis is a major cause of disability, but not of death. The introduction of such factors in the model could partly modify the results. The impact of other factors, such as physical activity would have been very helpful. Disability has been evaluated by self-report and not by performance testing, although some studies reported significant differences between these two types of measures [49]. Nevertheless, disability has been evaluated by three validated scales [50]. Finally, attrition is inevitable in longitudinal studies and if refusals and loss-to-follow-up are at higher risk of functional deterioration, we will have underestimated the transition to more severe disability.

Health factors of the disablement process
As in several previous studies, cardiovascular antecedents were associated with disability occurrence or evolution [3, 4], but did not decrease the chance of recovery. Stroke has been previously identified as a major determinant of disability [6, 7]. In our study, independent of the other factors, sequelae of stroke increased the risk of disability progression towards the three grades of disability, but had no significant effect on recovery or mortality. If a previous stroke does not prevent recovery of independence, rehabilitation could have a significant impact on maintaining or recovering functional autonomy in such patients [51]. It has been noted that the most severe stroke, rapidly fatal, could not have been observed. Thus, stroke survivors might be less severely disabled and their chance of reversibility would not therefore be influenced by sequelae of stroke. Yet, such subjects did appear to be frailer, since they were at higher risk of disability progression.

As reported in previous studies [6, 23], diabetes was significantly associated with disability, but its effect is not homogeneous according to the grade of disability. Diabetes impacts specifically on the mobility-disabled subjects. Indeed, these subjects were at higher risk of progression towards moderate disability (i.e. mobility- and IADL-disability) and had lower chances of recovering full independence. This independent relationship with mobility restriction might be explained by specific complications associated with diabetes, particularly for lower extremity disability. Volpato showed in the Women’s Health and Aging Study, a strong relationship of diabetes with lower extremity disability (with mobility disability, walking limitation and mobility performance score) [52]. Jagger et al. reported that a 65-year-old diabetic subject has a life expectancy shortened by 4.7 years compared to a non-diabetic person, and a disability-free life expectancy reduced by 3.8 years [53]. Diabetic subjects could represent a target group on whom actions could delay the beginning of the process, such as earlier detection, better glycaemic control, improved management of risk factors and complications associated with
diabetes. Indeed, once disabled, they are at higher risk of functional deterioration and have a lower chance of recovery, whereas fully independent diabetic subjects are not at higher risk of disability compared to the others.

Although dementia is identified as an important risk factor for disability [12], it could not be included in the present analyses, since very few demented people experienced recovery from disability and the multistate models did not converge. Since no time-dependent covariate was included in the analyses, prevalent dementia at baseline was not as informative as cognitive performance. The decline in performance appears many years before the confirmation of the diagnosis of dementia. Indeed, cognitive impairment includes a broader category of subjects, a high proportion of whom will probably be diagnosed as demented at follow-up. However, our findings provide evidence of the strong deleterious independent impact of cognitive impairment, on disability progression and on recovery. This factor is the only one of those investigated in this paper (age excepted), which impacts significantly on the six possible transitions, independent of other factors and whatever the severity of disability. Previous studies showed that cognitive impairment is related to disability onset [10, 11, 13, 16]. For Águedo-Torres, dementia and cognitive impairment are the main contributors to the development of functional dependence and to functional worsening over the 3-year follow-up [12].

The deleterious impact of poor health status on risk of disability progression seems to be much more influenced by diseases (stroke, diabetes and CVD) rather than by impairments, whereas for recovery, it is the reverse.

Dyspnoea significantly decreased the chance of recovery from disability, whereas its impact on progression did not persist in the model after adjustment for the other health covariates. The interpretation of the relationship with disability is problematic, because this impairment is not specific to a pathology. Indeed, it is associated with cardiovascular diseases, chronic obstructive pulmonary disease and obesity. However, this impairment is a symptom of CVD, itself identified as predictive factor of mobility-disability [54] and more generally of disability evolution [4, 6, 8, 16]. According to our results, the increased risk of disability progression is much more associated with CVD per se than with dyspnoea, whereas the deleterious effect of breathless still persists for recovery.

Visual impairments affect functional limitations and have been shown to be predictive of disability [15, 16, 19, 20, 55]. In our study, visual problems strongly decrease the chance of recovery from disability, independent of other factors, whereas their deleterious impact on progression becomes non-significant when taking depression into account. This result confirms the close link between these two factors and disability [20]. Rovner observed a stronger relation between disability and depression

Figure 2. Determinants of the disablement process—recap of the final model—the PAQUID Study, 1988–98.
than with vision [56] and our results show the same trend for progression, whereas for recovery, visual problems have a stronger impact than depression. These findings highlight the importance of a better management of visual impairments to enable recovery from disability and the strong association between visual impairment and depression.

**Risk factors of the disablement process**

Our findings confirmed the important role of older age on the process and on mortality largely reported previously [5, 6, 16, 20, 22, 57]. As its impact on the disablement process is independent of all the factors included in the model, its effect could reflect an incompressible effect of age, which could be due to neuromuscular fatigue, declined muscle mass, reduced muscular strength or joint stiffness, irrespective of health status and psychosocial factors.

The deleterious impact of female gender on progression reported in this paper has been observed in many studies [6, 16, 21–26]. However, our findings show that the excess risk of disability progression observed in women is significant only at the beginning of the process (i.e. from full independence to mobility-disability). Thus, men are at lower risk of becoming disabled than women, but once disabled, there are no longer gender differences. However, the excess mortality in men, especially from the mobility-disability level, could explain that once disabled, the most ‘fragile’ men died faster, whilst women survive longer despite disability. Previous studies have reported a higher life expectancy in women, but a lower disability-free life expectancy [58]. Regarding recovery, as reported by Beckett [21], we observe that independent of other factors, women have a lower chance of recovery from disability, whatever the disability level. This could be due to physiological differences (such as lower muscle strength or lower bone density for women), or lifestyle (like sedentary life and obesity),[25] which might reduce their ability to recovery from disability.

Melzer observed the independent positive impact of a higher educational level for progression but not for recovery [59], which confirm our results. Guralnik et al [6]. notes that after controlling for socio-economic and health factors, men of low level of education are at higher risk of mobility-disability, but not women. Rautio reported that highly educated women have a higher functional capacity [28]. Medical and/or psychosocial factors other than those controlled for in this paper could explain the over-risk of disability progression in low educated subjects, such as worse management of risk factors and dietary behaviours, previous exposure to occupational risk factors, inequalities in access to health services, lower perception of worsening health status, impact of health promotion and prevention and other diseases closely linked to socio-economic level.

In this paper, wine and tobacco consumption are not associated with disability. This result might be partly explained by selection by death, since some of the excessive tobacco and wine consumers, who have an excess risk of premature death, could not form part of our cohort of older persons. Another explanation might be the effect of adjustment covariates, such as pathologies. At baseline, 45.0% of subjects with CVD were wine abstainers vs. 37.3% of the others. This non-consumption might be indicative of severe health problems that have forced the subject to stop drinking. In previous studies, the effect of alcohol consumption is controversial [60–62], whereas the impact of tobacco consumption on healthy ageing is clear [61–65]. Time spent with disability would be reduced by smoking elimination, leading to a reduction of the incidence of disabling pathologies (such as lung cancer, heart disease, stroke or chronic obstructive lung disease). According to Nusselder, tobacco consumption decreases the chance of recovery from disease, increases disease severity and the incidence of comorbidity conditions and worsens the subjects frailty [63].

**Intra-individual factor of the disablement process**

Depression is considered as a prognostic factor of disability by others [15, 17, 18, 20, 66]. Depression directly affects physical independence through persistent somatic symptoms such as fatigue, affects the motivation necessary to maintain functional ability [20], is associated with unhealthy behaviours (such as tobacco, alcohol, nutritional habits, or physical inactivity) and with social isolation [29]. Depressive symptoms may also be prodromal of new medical conditions (like dementia [67]) that affect physical ability [18]. As well as the important link with vision (discussed above), some authors have reported an association between depression and cognitive impairment [20, 68]. Our findings suggest that the effect of depression on disability progression is independent of cognitive impairment, but could be linked to this impairment for recovery since once we adjusted for health and risk factors, the deleterious impact of depression on recovery became non-significant. However, as discussed earlier for visual impairment, given the important relationship between disability and vision, cognition and depression, the specific impact of each of these factors is not evident. We can however conclude that the effect of vision and cognition is stronger than depression for recovery from disability, whereas for progression, depression seems to have a stronger
effect although this effect becomes non-significant after controlling for extra-individual factors, including high drug consumption. This result may reflect the effectiveness of anti-depressants, but depression could also be a consequence of polypathology or health status severity, two factors more strongly associated with progression of disability than depression. Nevertheless, whatever the mechanism and the direction of the association with disability, these results highlight the importance of effective treatment of depression in elderly subjects to prevent or delay functional decline.

Extra-individual factors of the disablement process

The effect of marital status on disability and health is not clear, since some studies observed a protective impact of living with a partner [5, 27] while others showed the reverse [28, 69]. In this paper, being married has a protective effect, but not homogeneously according to the severity of disability. Married subjects are at lower risk of becoming disabled (i.e. progression from full independence to mild disability), but once the disablement process had begun, the protective effect of being married disappeared. Being married was also associated with a higher chance of recovery, but only from moderate disability (i.e. the mobility- and IADL-disability level). The spouse might play a more significant role in restoring IADL-ability by stimulation, rehabilitation, compensation and adaptation, than from mobility-disability (more physical disability) and from severe disability (reversibility less probable). On the other hand, the hypothesis of a reporting bias has to be considered. Indeed, the difference between what a subject can do and what he really does is perhaps clearer for subjects who live alone than those living with a partner.

Living in a rural area was associated with a lower risk of mortality, but also associated with a lower chance of recovery from disability. This effect on recovery disappeared after controlling for other factors. Subjects who lived in a rural area might have been more exposed to occupational risk factors (such as agricultural work) that may decrease the chances of recovery from disability. Older healthy retirees could go back to rural villages, whereas elderly people in poor health in rural areas could move to towns to live near relatives and medical and social services. However, this effect is relatively weak since the migration rate is low in France, especially among elderly people. Between the two last census (in 1990 and 1999), 87% of the subjects aged 65 and older lived in the town.

Hospitalization and drug consumption have been shown to reflect the effectiveness of health service utilization [27], whereas in PAQUID, as in most surveys [23, 54], they are much more an indicator of health severity, of other disabling pathologies or of polypathology. In PAQUID, hospitalization would increase the risk of disability progression, especially from mild disability. However, after controlling for the other covariates (particularly health related factors), the negative effect of a hospitalization in the previous year was no longer independently associated with progression. Pathologies and impairments thus have a stronger association with progression than does hospitalization, whereas the latter is significantly associated with lower chances of recovery independent of the other factors. Similarly, the number of drugs currently taken is associated with disability progression as reported in previous studies [70, 71], whatever the level of disability. The deleterious impact on recovery is strong but only significant towards full independence. In our findings, high drug consumption and hospitalization would constitute a more global indicator of health status than pathologies and impairments.

Conclusion

This study throws light on the dynamic process of disablement in older people and underlines the independent contribution of different groups of factors on the progression of disability and on recovery, between hierarchically related dimensions. The present study confirms the utility of the disablement process model of Verbrugge in highlighting the contribution of different groups of factors.

Older age and cognitive impairment in particular have a strongly independent effect on the process, as much for progression of disability as for recovery. This research also shows the effect of several potentially curable or preventable pathologies or impairments, such as visual impairments, dyspnoea, diabetes, cardiovascular diseases or depression on disability onset and recovery, and thus the importance of their prevention, detection and treatment. As well as physical factors, the findings on the contribution of psychosocial factors (gender, level of education or marital status) and extra-individual factors (medical care) provides useful data to target subjects at higher risk in order to prevent, stabilize or delay the disablement process and/or to aid recovery from disability.

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References


