Age and Ageing 2010; **39:** 92–98
doi: 10.1093/ageing/afp209
Published electronically 20 November 2009

Risk factors for disability in older persons over 3-year follow-up

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Abstract

Background: the identification of modifiable risk factors for preventing disability in older individuals is essential for planning preventive strategies.
Purpose: to identify cross-sectional correlates of disability and risk factors for the development activities of daily living (ADL) and instrumental ADL (IADL) disability in community-dwelling older adults.
Methods: the study population consisted of 897 subjects aged 65–102 years from the InCHIANTI study, a population-based cohort in Tuscany (Italy). Factors potentially associated with high risk of disability were measured at baseline (1998–2000), and disability in ADLs and IADLs were assessed both at baseline and at the 3-year follow-up (2001–03).
Results: the baseline prevalence of ADL disability and IADL disability were, respectively, 5.5% (49/897) and 22.2% (199/897). Of 848 participants free of ADL disability at baseline, 72 developed ADL disability and 25 of the 49 who were already disabled had a worsening in ADL disability over a 3-year follow-up. Of 698 participants without IADL disability at baseline, 100 developed IADL disability and 104 of the 199 who already had IADL disability had a worsening disability in IADL over 3 years. In a fully adjusted model, high level of physical activity compared to sedentary state was significantly associated with lower incidence rates of both ADL and IADL disability at the 3-year follow-up visit (odds ratio (OR): 0.30; 95% confidence intervals (CI) 0.12–0.76 for ADL disability and OR: 0.18; 95% CI 0.09–0.36 for IADL disability). After adjusting for multiple confounders, higher energy intake (OR for difference in 100 kcal/day: 1.09; 95% CI 1.02–1.15) and hypertension (OR: 1.91; 95% CI 1.06–3.43) were significant risk factors for incident or worsening ADL disability.
Conclusions: higher level of physical activity and lower energy intake may be protective against the development in ADL and IADL disability in older persons.

Keywords: *prevention, disability, physical activity, energy, ageing, elderly*

Introduction

Disability in activities of daily living has a strong negative effect on quality of life in older individuals and is one of the most important components in the causal pathway leading to institutionalization and mortality [1, 2]. Understanding the processes that are responsible for the age-associated decline in functional status is important in order to develop strategies to prevent or delay disability and related risk of institutionalization and mortality among older adults [3].

A number of factors have been associated the development of disability in self-care (activities of daily living, ADL) and instrumental activities of daily living (IADL), including cognitive impairment, depression, specific chronic conditions, multiple morbidity, high and low body mass index, lower extremity functional limitation, low level of physical activity, no alcohol use compared to moderate use, smoking and vision impairment [4].

The idea that the disablement process could be linked to inefficiency and dysregulation in energy expenditure is intuitively attractive and could theoretically reveal a multisystem dysregulation in older persons [5]. However, few studies have attempted to link the risk of developing new disability or worsening disability to factors that are relevant to energy intake and consumption such as nutritional profile and level of physical activity [6, 7].

We used data from the representative population-based InCHIANTI study (Invecchiare in Chianti, 'Aging in the Chianti Area') [8] to identify risk factors for new or worsening disability over a 3-year follow-up.

Methods

The study participants consisted of men and women, aged ≥65, enrolled in the InCHIANTI study, a study of risk factors for mobility disability conducted in two small towns in Tuscany, Italy. The rationale, design and data collection have been described elsewhere, and the main outcome of this longitudinal study is mobility disability [8]. Briefly, in August 1998, 1,270 persons aged ≥65 years were randomly selected from the population registry of Greve in Chianti (population 11,709) and Bagno a Ripoli (Village of Antella, population 4,704); and of 1,256 eligible subjects, 1,155 (92.0%) agreed to participate. Participants received an extensive description of the study and participated after written, informed consent. The participants were seen again for a 3-year follow-up visit (2001–03) at which time they underwent a repeated phlebotomy, laboratory testing and clinical assessment, including the administration of performance-based tests. The study protocol complied with the Declaration of Helsinki and was approved by the Italian National Institute of Research and Care on Aging Ethical Committee.

Of the 1,155 participants ≥65 years seen at enrollment, 897 (77.7%) were re-examined at the 3-year follow-up and are included in the analyses presented here. One hundred and twenty-five subjects (10.8%) died before the 3-year follow-up and 133 (11.5%) were lost to follow-up. The subjects who did not participate in the performance tests both at baseline and at the 3-year follow-up were generally older and had greater comorbidity than those who participated in the performance tests, as reported elsewhere [9].

Demographic information on educational and marital status, smoking and medication use were collected using standardised questionnaires. Smoking was assessed by self-report (current smoking versus former and never smoked, years smoked) and expressed as current smoking status and numbers of years smoked. Average daily intakes of energy (kcal) and alcohol were estimated using the European Prospective Investigation into Cancer and Nutrition food frequency questionnaire, validated in the InCHIANTI population [10]. All participants were examined by a trained geriatrician, and diseases such as hypertension, diabetes and heart disease were ascertained according to pre-established algorithms that combined information gathered from medical history, medical records, clinical examination, and blood and instrumental tests included in the study protocol [11]. The diagnosis of metabolic syndrome was established in accordance with the National Cholesterol Education Program's Adult Treatment Panel III criteria as the presence of three or more of the following: fasting blood glucose levels ≥110 mg/dl, fasting serum triglycerides ≥150 mg/dl, serum HDL cholesterol <40 mg/dl, blood pressure ≥130/85 mmHg (or the use of antihypertensive medications) and waist circumference >102 cm in men and >88 cm in women [12]. Diabetes mellitus was defined by having fasting blood glucose levels ≥126 mg/dl. Hypertension was defined as self-reported high blood pressure, use of antihypertensive medication or systolic blood pressure ≥160 mmHg or diastolic blood pressure ≥90 mmHg.

Weight was measured using a high-precision mechanical scale. Standing height was measured to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Blood samples were collected in the morning after a 12-h fast. Aliquots of serum and plasma were immediately obtained and stored at −80°C. Total cholesterol, HDL cholesterol, triglycerides and creatinine levels were determined by commercial assays (Roche Diagnostics, Mannheim, Germany), and LDL cholesterol was calculated using the Friedewald formula.

Physical examination, including assessment of muscle strength, gait and balance, was performed by trained physiotherapists. A standardised evaluation of lower extremity function was performed using the Short Physical Performance Battery (SPPB). The SPPB score was derived from performance in three objective tests: walking speed over 4 m, five timed repeated chair rises and standing balance [13, 14]. The test score ranges from 0 to 12 and lower SPPB scores predict a higher likelihood of becoming disabled, being institutionalised and dying [13, 14].

Physical activity level in the previous year was considered as an ordinal variable and scored into seven progressive grades, from 0 (hardly any physical activity) up to 7 (intense exercise many times/week) by using a modified version of a standard questionnaire [15]. Physical activity was dichotomized (absent–light vs moderate).The entire scale was also used in a secondary analyses.

Subjects were categorised as having ADL or IADL disability at the baseline when they reported need for help of another person in performing at least one ADL (ADL disability) or IADL (IADL disability) [16, 17]. At 3-year follow-up, the change in functional status (new or worsening ADL or IADL disability) was reassessed, considering both the development of new ADL or IADL disability among subjects free of ADL/IADL limitations at baseline and the increasing number of ADL/IADL limitations among those who already had ADL or IADL disability at baseline. Analyses were performed separately for ADL and IADL outcomes, considering the following dependent variables:

(1) Worsening disability (new or increased ADL/IADL) in comparison with no change in disability status between baseline and 3-year follow-up (897 subjects considered in the analysis).
(2) Incidence of disability (new ADL/IADL) in participants without ADL/IADL disability at baseline (848 subjects for incident ADL analysis and 698 for incident IADL analysis).

The explanatory variables considered were: age, gender, marital status, educational level, SPPB score, alcohol intake,

Table 1. Characteristics of subjects included in the analysis according to change (worsening or development of new disability) in ADL at 3-year follow-up. Age- and sex-adjusted means and proportions are reported

	Worsening in ADL			New ADL disability[a]		
	No (n = 800)	Yes (n = 97)	*P* value	No (n = 776)	Yes (n = 72)	*P* value
Age (mean)	73.1	83.2	<0.001	72.9	83.2	<0.001
Gender, males (%)	44.4	40.2	0.435	44.5	40.3	0.494
Living alone (%)	35.7	48.0	0.018	35.0	53.3	0.002
No formal education (%)	29.0	35.8	0.16	28.1	35.6	0.18
SPPB scores[b] (%)						
<6	3.8	36.9	<0.001	2.2	24.1	<0.001
6–10	15.3	15.6		15.1	17.0	
≥10	72.3	40.5		74.7	50.2	
Moderate/intense physical activity (%)	38.3	13.4	<0.001	39.7	16.7	<0.001
Hypertension (%)	44.2	50.6	0.24	44.7	47.2	0.68
Diabetes (%)	12.7	27.6	<0.001	12.9	17.2	0.3
Metabolic syndrome (%)	22.5	20.0	0.57	22.7	12.3	0.06
Total cholesterol (mg/dl, mean)	219.6	218.0	0.71	220.2	222.0	0.78
Energy intake (kcal/day, mean)	1,919.8	1,960.1	0.45	1,935.9	1,982	0.46
BMI (kg/m^2, mean)	27.4	26.0	0.08	27.4	25.9	0.08
Alcohol (g/day)[c] (%)						
<10	28.4	44.6	0.014	27.8	42.4	0.07
10–20	36.3	29.5		36.3	27.3	
>20	19.9	14.7		20.4	20.3	
Current smokers (%)	14.6	18.9	0.39	14.6	20.2	0.21
Years of smoking (mean)	36.7	35.7	0.7	36.4	36.1	0.74

[a]Limited to subjects free of ADL disability (ADL = 0) at baseline.
[b]Short Physical Performance Battery (SPPB); we are not reporting participants with missing data (8.3% of the whole population at baseline).
[c]We are not reporting participants with missing data (15.0% of the whole population at baseline).

smoking, physical activity, BMI, energy intake, total cholesterol, metabolic syndrome, hypertension and diabetes mellitus.

BMI and energy intake (kcal/day) were used as continuous variables, due to insufficient numbers of participants with BMI <19 (n = 5) and with energy intake <1,000 g/day (n = 16), both expression of undernutrition. We also checked for non-linearity of BMI and energy intake using the 'boxtid' option on STATA. We found that the risk of worsening ADL and developing new ADL changed linearly with BMI and energy intake, while the association between BMI, energy intake and risk of worsening IADL and development of new IADL was non-linear.

To control for differences in the age and sex distribution between participants who experienced worsening or incidence of disability and those who did not, we calculated age- and sex-adjusted means and proportions. For worsening ADL and IADL disability, we performed a direct standardisation by applying age-class and sex-specific proportions or mean values to the distribution of the whole baseline population. For new ADL or IADL, the age- and sex-specific proportions and mean values are applied to the distribution of the whole baseline population free of ADL and IADL disability at baseline.

Categorical and continuous variables were compared with two-tailed chi-square and Student t test, respectively. $P < 0.05$ was considered statistically significant.

Multivariate logistic regression analyses were used to examine the relationship between different risk factors and the disability outcome after adjusting for multiple confounders. The analysis started with a saturated model and variables were eliminated from the model in an iterative process ($P > 0.05$ for removal) until a final parsimonious model was obtained. We decided to use this strategy after considering the moderate sample size and the limited number of outcomes. The backward selection allows the retaining of adequate statistical power while balancing the equilibrium between under- and over-adjusting. The goodness of fit of the final model was checked through the Hosmer–Lemeshow test. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated from the regression coefficients. Analyses were carried out using STATA statistical package 9.2 (Stata Corporation, College Station, TX).

Results

At baseline, 49 (5.5%) of the 897 subjects had ADL disability and 199 (22.2%) had IADL disability. The characteristics of the study population as a whole and limited to participants with ADL or IADL disability at enrollment are shown in the table Appendix 1 in the supplementary data in *Age and Ageing* online. Over a 3-year follow-up, of 848 participants without ADL disability at baseline, 72 (8.5%) developed ADL disability, and among the 49 participants who already had some disability, 25 (51.9%) experienced worsening ADL disability. Of 698 participants without IADL disability at baseline, 100 (14.3%) developed new IADL disability, and of the 199 who already had some IADL

Table 2. Characteristics of subjects included in the analysis according to change (worsening or development of new disability) in IADL at 3-year follow-up. Age- and sex-adjusted means and proportions are reported

	Worsening in IADL			New IADL disability[a]		
	No (n = 693)	Yes (n = 204)	P value	No (n = 598)	Yes (n = 100)	P value
Age (mean)	72.4	80.2	<0.001	71.5	77.6	<0.001
Gender, males (%)	48.3	28.9	<0.001	51.8	29.0	<0.001
Living alone (%)	34.3	43.2	0.022	27.9	55.3	<0.001
No formal education (%)	27.5	33.5	0.1	21.2	39.5	<0.001
SPPB scores[b] (%)						
<6	5.5	25.0	<0.001	0.7	19.4	<0.001
6–10	13.1	25.2		8.7	21.9	
≥10	74.8	37.6	<0.001	86.2	51.5	
Moderate/intense physical activity (%)	41.5	8.1	<0.001	48.7	13.7	<0.001
Hypertension (%)	44.5	61.2	<0.001	44.1	71.2	<0.001
Diabetes (%)	13.9	20.8	0.017	12.5	9.0	0.316
Metabolic syndrome (%)	21.7	35.1	<0.001	20.2	27.5	0.096
Total cholesterol (mg/dl, mean)	217.7	221.1	0.35	220.4	210.4	0.632
Energy intake (kcal/day, mean)	1,912.8	1,839.4	0.11	1,998.7	1,876.8	0.051
BMI (kg/m^2, mean)	27.4	28.0	0.16	27.5	28.9	0.216
Alcohol (g/day)[c] (%)						
<10	28.5	35.9	0.18	25.5	35.7	0.125
10–20	37.2	30.2		38.7	32.0	
>20	19.4	18.8		22.1	16.9	
Current smokers (%)	14.5	18.8	0.14	16.4	16.4	0.992
Years of smoking (mean)	35.4	36.9	0.79	35.4	36.0	0.832

[a]Limited to subjects free of ADL disability (ADL = 0) at baseline.
[b]Short Physical Performance Battery (SPPB); we are not reporting participants with missing data (8.3% of the whole population at baseline).
[c]We are not reporting participants with missing data (15.0% of the whole population at baseline).

disability at baseline, 104 (52.3%) experienced worsening IADL disability.

Compared to participants who did not develop disability, those with ADL/IADL worsening and new ADL/IADL disability were significantly older (about 8–10 years of difference). Age-and sex-adjusted characteristics of participants who experienced ADL worsening (n = 97) or developed a new ADL disability (n = 72) over 3 years are reported in Table 1. Those who experienced ADL worsening or a new ADL disability were more likely to live alone and have worse SPPB performance score and lower physical activity at enrollment. Participants who experienced ADL worsening were more likely to be affected by diabetes mellitus and to have low alcohol consumption at enrollment than those whose ADL remained stable or improved (Table 1).

The characteristics of those who experienced IADL worsening (n = 204) or developed a new IADL limitation (n = 100) over the follow-up period are shown in Table 2. Participants who experienced IADL worsening or developed a new IADL limitations had worse SPPB performance score, had lower physical activity levels and were more likely to be affected by hypertension compared to those whose IADL remained stable or improved (Table 2). Participants who experienced worsening IADL disability were more likely to be affected by diabetes mellitus and by metabolic syndrome compared to controls (Table 2).

Findings of parsimonious models predicting new disability or worsening in ADL and IADL disability at the 3-year follow-up are reported in Table 3. This model was derived from an original saturated model that included all variables presented in Table 1. Variables not independently associated with the outcome were removed using backward algorithm and are not presented. Age and SPPB performance score were significant predictors of disability in all models. A moderate–intense physical activity was associated with a lower ADL and IADL disability incidence (OR: 0.30, 95% CI: 0.12–0.76 and OR: 0.18, 95% CI: 0.09–0.36, respectively) when compared with low physical activity. Results were substantially similar when worsening ADL/IADL were considered as outcomes in analyses. Using the entire scale, the findings did not substantially change: physical activity was associated with a lower ADL and IADL disability incidence (OR: 0.43, 95% CI: 0.28–0.66 and OR: 0.43, 95% CI: 0.29–0.64, respectively) and with a lower incidence rate of worsening in ADL and IADL disability (OR: 0.42, 95% CI: 0.28–0.63 and OR: 0.46, 95% CI: 0.34–0.62, respectively).

High energy intake was also associated with higher incidence rate of worsening or new ADL disability (OR: 1.09, 95% CI: 1.02–1.15; for a difference of 100 kcal/day). Hypertension was associated with worsening in ADL disability (OR: 1.91, 95% CI: 1.06–3.43).

Discussion

This study shows that older community-dwelling men and women with lower level of physical activity, higher energy

Table 3. Independent predictors of worsening or development of ADL/IADL disabilities over 3 years. Parsimonious models are presented from original fully saturated model that included all variables presented in Table 1

Worsening in ADL (n = 897)	Parsimonious model[a] OR	95% CI
Age	1.19	(1.14–1.24)
SPPB scores[b]		
≥10	1	
6–10	2.21	(1.05–4.64)
<6	19.3	(8.19–45.6)
Hypertension	1.91	(1.06–3.43)
Physical activity	0.30	(0.12–0.74)
Energy (kcal/day)	1.09	(1.02–1.15)
ADL disability at baseline	0.89	(0.69–1.16)

Development of new ADL[c] (n = 848)	Parsimonious model[a] OR	95% CI
Age	1.19	(1.14–1.25)
SPPB scores[b]		
≥10	1	
6–10	2.28	(1.05–4.94)
<6	17.0	(6.46–44.9)
Physical activity	0.30	(0.12–0.76)
Energy (kcal/day)	1.09	(1.03–1.15)

Worsening in IADL (n = 897)	Parsimonious model[a] OR	95% CI
Age	1.14	(1.10–1.18)
SPPB scores[b]		
≥10	1	
6–10	3.68	(2.24–6.02)
<6	5.70	(2.66–12.2)
Physical activity	0.18	(0.10–0.33)
Energy (kcal/day)	1.02	(0.98–1.06)
IADL disability at baseline	0.91	(0.80–1.03)

Development of new IADL[d] (n = 698)	Parsimonious model[a] OR	95% CI
Age	1.16	(1.10–1.21)
Living alone	0.54	(0.32–0.92)
SPPB scores[b]		
≥10	1	
6–10	3.20	(1.68–6.09)
<6	9.52	(1.82–49.9)
Physical activity	0.18	(0.09–0.36)
Alcohol (g/day)	1.09	(1.03–1.15)
<10	1	
10–20	0.46	(0.24–0.86)
>20	0.50	(0.21–1.19)
Energy (kcal/day)	0.99	(0.93–1.05)

[a]Logistic regression—odd ratios (OR) and 95% confidence intervals (95% CI). The saturated model includes all the variables presented in Table 1.
[b]Short Physical Performance Battery (SPPB).
[c]Limited to subjects free of ADL disability (ADL = 0) at baseline.
[d]Limited to subjects free of IADL disability (IADL = 0) at baseline.

intake and poor lower extremity performance at enrollment were at high risk of developing ADL and IADL disability over the 3-year follow-up.

Our findings are consistent with previous studies showing that older adults who reported higher levels of physical activity in midlife were more likely to maintain mobility in late life [18]. Visser *et al.* [19], analysing data from the Longitudinal Aging Study Amsterdam, found that sports participations and a high level of total physical activity were associated with smaller mobility decline after 3 years.

Conducting an extensive review of the literature, Keysor found robust evidence that sedentary older adults who become physically active had lower risk of death relative to those who remained sedentary in old age [20]. Gregg *et al.* arrived at the same conclusion analysing the study of osteoporotic fractures [21]. Our findings are also consistent with intervention trials that have shown that supervised exercise is associated with less steep decline of physical performance and, perhaps, even disability prevention (the LIFE study) [22, 23].

The causal pathways through which physical activity may prevent ADL and IADL disability are complex and likely multifactorial. The effects of measuring physical activity may be direct on muscle function, joint range of motion, balance and motor coordination. However, it has been demonstrated that individuals who increase their physical activity have reduced levels of oxidative stress and inflammation biomarkers which may prevent or slow down the development of chronic medical conditions. In addition, physical activity often promotes social interaction, avoids psychological isolation and, in turn, may prevent anxiety and depression. All these mechanisms may contribute to disability prevention.

An important and somewhat unexpected finding of this study is that lower energy intake is preventive against disability. These results are consistent with the notion that obesity is one of the most important risk factors for disability in our society. However, studies have also found that in older individuals low energy intake is a strong biomarker of deteriorated health status, which may predict a number of negative health outcomes, including frailty and mortality. It would be attracting to interpret our findings in the context of the effect of caloric restriction, which consistently demonstrated beneficial effects on functional status in animal models. Older individuals are unlikely to voluntarily restrict their caloric intake. In addition, a recent study [24, 25] of caloric restriction in humans was unable to show any significant effect of this intervention on oxidative stress, inflammation and metabolic markers of health deterioration. More likely, also given the cultural background of this population, moderate energy consumption (not overeating) is a proxy measure of healthy behaviour. Interestingly, Stuck *et al.* [4] comprehensively summarised the risk factors for functional status decline in community-living elderly people and pointed out that some of them (e.g. nutrition and low physical activity level) have been neglected in past research. The fact that the positive effect of lower caloric intake was evident while the previously described relationship between low caloric intake and mortality did not emerge is puzzling [26]. It is quite possible that these findings are strictly dependent on the characteristics of our study population, which include individuals who tend to have few nutritional problems, especially in terms of caloric intake. As previously mentioned, in this particular population, overeating and obesity may be more important than caloric malnutrition. Interestingly, hypertension was the single most important disease associated with worsening functional status in older persons. This is somewhat surprising since diabetes, chronic obstructive pulmonary disease and other chronic diseases are generally considered risk factors for disability in older persons. It is possible that the lack of a significant effect of other conditions could be attributable to limited sample size or too short follow-up.

The main limitation of this study is that participants lost to follow-up may have been systematically different from those who remained in the study; this could limit the generalization of the findings. Another important limitation is that we considered any decline (e.g. a transition from 0 to 1 disability was considered equivalent to a transition from 6 to 7) as worsening disability. In addition, in the analysis addressing worsening disability, we were not able to implement separate analyses in those who had any new disability and in those who had an increasing number of disability (having had at least one at baseline), because there were small numbers of subjects in some of these categories. However, the risk of developing disability should not be affected by different factors in individuals with no disability compared to those who already had at least one. Moreover, we were not also able to perform the analyses using the hierarchical structures of IADLs and ADLs due to small numbers of subjects. Finally, the relationships observed in the study may be due to confounders that we did not measure. The potential limitations are contrasted with many strengths of his study, including the representative population, the high participation rate and the extensive information on risk factors and diseases.

In conclusion, our results suggest that higher level of physical activity and lower caloric intake may be protective against the development in ADL and IADL disability in older persons. Further studies are needed to verify whether intervention strategies that include both increased physical activity and dietary counselling may prevent decline in physical performance and slow down the progression to disability among older adults.

Key points

- Our results suggest that higher level of physical activity may be protective against the development in ADL and IADL disability in older persons.
- An important and somewhat unexpected finding of this study is that lower energy intake is preventive against disability.
- Intervention strategies that include both increased physical activity and dietary counselling may prevent decline in physical performance and slow down the progression to disability among older adults.

Acknowledgements

Declaration of sources of funding: The InCHIANTI study baseline (1998–2000) was supported as a 'targeted project' (ICS110.1/RF97.71) by the Italian Ministry of Health and in part by the U.S. National Institute on Aging (Contracts: 263 MD 9164 and 263 MD 821336); the InCHIANTI Follow-up 1 (2001–2003) was funded by the U.S. National Institute on Aging (Contracts: N.1-AG-1-1 and N.1-AG-1-2111).

Conflicts of interest

There are no conflicts of interest.

Supplementary data

Supplementary data are available at *Age and Ageing* online.

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Received 16 February 2009; accepted in revised form 7 October 2009