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Worsening health trends of Dutch older adults are associated with, but do not completely explain changing trends in hospital admissions (1995-2009)

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Abstract

Objectives: An increase in hospital admission rates in older people may reflect improved access to health care, but also declining health trends in the older population. Due to a lack of individual-level data, the latter possibility has received little attention. The current study examines associations between health status and hospitalization rates of older adults in the Netherlands.

Design: Observational individual-level data linked with hospital register data.

Setting: Data from 1995-2009 from the nationally representative Longitudinal Aging Study Amsterdam were linked with the Dutch Hospital Discharge Register.

Participants: A total of 5681 observations of 2520 respondents, across four measurement points (each with a follow-up of 36 months; ages 65-88 years).

Outcome measures: The contribution of health, demographic, psychosocial and lifestyle characteristics to time trends in hospitalization was assessed in multivariate models.

Results: Between 1995 and 2009, the percentage with one or more overnight admissions (planned or acute) slightly increased, from 38.1 to 39.7%. This was due to an increased prevalence of acute admission only (22.2% to 27.0%). Increases in chronic diseases, functional limitations and polypharmacy accounted for part of the observed increase in overnight and acute admissions. In addition, a more than doubled prevalence of day admissions over time was observed (12.3% to 28.3%), a trend that was unrelated to changes in individual characteristics.

Conclusions: This trend study showed a contribution of declines in population health to increases in hospital admissions. As these did not provide a full explanation, health care reforms and increases in treatment possibilities in this period are likely to have contributed as well.

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Article summary

Strengths and limitations of this study

- The Longitudinal Aging Study Amsterdam is a cohort study that is representative for the Dutch older population.

- Multiple waves of data collection, within two different cohorts, were performed between 1995 and 2006, which enabled the study of health trends.

- While previous studies mostly relied on aggregated data, our study links individual-level data on health and lifestyle trends with individual-level hospital registration data.

- The coverage of the Dutch Hospital Discharge register decreased during our study period.

- Health status characteristics and hospital admission were linked per individual, but it remains to be studied if and to what extent the health status of patients at the time of their admission has changed.

Introduction

With the aging population in most Western countries, there is increasing pressure to reduce health care expenditures. Hospital care is the most costly type of care [1] and for the greater part involves older adults. Pressures for cost containment as well as the introduction of new medical technologies have resulted in a reduced length of stay in most developed countries in recent decades [2;3]. Another approach to cost containment may be prevention of hospitalization and adverse events related to hospital admissions [4], but several studies - not all [5] - show increases in hospital admission rates and hospital costs in European countries and the US over the past decades [6-9].

Both individual and societal factors may affect the utilization of hospital care [10]. Research addressing the mechanisms underlying increased use of care and increased health care expenditures showed that these are largely driven by societal changes, such as improved medical technology and more active treatment of the oldest old, and only for a small part by demographic changes [8;11].

Regarding individual factors, the prevalence of morbidity and disability - the most immediate causes of hospital admission [10;12-14] - has shifted in recent generations of older adults. Ample evidence exists of an increased prevalence of chronic diseases and comorbidity over time, both in admitted patients and in older adults in the community [3;15-18]. Research is inconclusive regarding trends in disability or in the severity of morbidity [17]. Technological developments in recent decades may have led to better treatment possibilities, and in turn, to better health, functioning and survival of older adults. Longer survival specifically in those with chronic diseases, however, leads to a higher prevalence of chronic conditions and associated hospital admission risk. Such mixed trends make it difficult to predict whether the need for hospital admission has increased or not.

Given the societal costs associated with hospital care and the burden of hospitalization on older patients themselves [4], reducing hospital admissions among older adults is an important goal. However, simply reducing the volume of hospital care should not be aimed for, when it is at the expense of poorer quality of care or an increased disease burden. In fact, reducing one type of admission (e.g. day admissions) may result in more admissions of another - more critical – type (e.g. acute admissions). Policies aiming at the prevention of hospitalization should be informed by research on underlying health trends in the older population. In addition, trends in day admissions and overnight admissions (acute or planned) should be evaluated in relation to each other.

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The current study examines recent hospital admission trends - day admissions and overnight (planned and acute) admissions. It also examines to what extent up- or downward trends can be attributed to changing health of the older population. Individual-level health and hospital data are needed for this purpose, since these are more sensitive than population means. In addition, they may provide insight in the interrelationships between various individual characteristics. We linked individual morbidity data from Dutch older adults between 1995 and 2009, obtained within a nationally representative cohort study on aging, the Longitudinal Aging Study Amsterdam, with data from the Dutch Hospital Discharge Register (DHDR), providing individual-level data on hospital admissions.

Methods

Data sources

LASA

In 1992, a random sample of older adults was drawn from the population registries of 11 municipalities in three geographical regions in the Netherlands (ages: 55-85 years; N: 3,107; co-operation rate: 62%) [19]. Follow-up measurements took place at roughly 3 years intervals in 1995-96 and 1998-99, 2001-02 and 2005-06 (Figure 1). In 2002, a new cohort was sampled (ages: 55-64 years; N: 1,002; co-operation rate: 62%). Complete medical records were available for the period 1995 to 2009, therefore LASA participants who had at least one interview between 1995-96 and 2005-06 were included. Waves will be referred to using the mid-year of each follow-up (36 months): 1997, 2000, 2003 and 2007. We selected all 2,520 adults who were aged 65 to 88 at the time of at least one wave, to compare a fixed age range which was available in each wave. Thirty six percent of these respondents were included in one wave, 23% in two waves, 21% in three waves and 20% in all four waves, leading to a total number of 5,681 observations.

DHDR

The Dutch Hospital Discharge Register (Landelijke Basisregistratie Zorg, (LBZ), previously: Landelijke Medische Registratie (LMR)) [20] registers admissions in most general and academic hospitals and some single-specialty hospitals, thus providing a nearly complete coverage of hospital admissions in the Netherlands. All admissions are registered based on a uniform registration system. The data include admission and discharge dates, extensive diagnosis and treatment information and death during admission. A study on the reliability of

admission and discharge information in the DHDR revealed that in 1999, 99% of this information was registered correctly [21].

Linkage of data sources

For the purpose of this study, Statistics Netherlands linked data from the DHDR and LASA to each other via the Municipal Population Registry (MPR). Both data sets are anonymized, so this linkage occurred on the basis of a set of identifying variables: postal code, date of birth and gender [20]. Linkage with the MPR was fully achieved for 98% of the eligible study sample. Consent forms for accessing medical records were signed by the LASA participants and the study was approved by the Medical Ethics Committee of the VU University Medical Center.

Measurements

Hospital admission within 36 months follow-up of each LASA interview was coded as not admitted (0) or admitted at least once (1). Admissions were categorized into day admission or overnight admission. Day admissions were defined as planned admissions where specialist care is given for several hours during the day. Visits to the emergency unit were not included as a day or overnight admission, unless an overnight admission followed from this visit. Overnight admissions were all admissions including at least one night. These admissions were further divided into acute or elective admissions.

To increase our understanding of which individual-level factors underlie hospital admission trends, we assessed the role of demographic, psychosocial and lifestyle factors stepwise in addition to health status factors.

Education level was measured in years. *Net monthly income* of respondents living with a partner was multiplied by 0.7, to make their income comparable with that of one-person households [22]. Also included were *level of urbanization* (categories were <500, 500-1000, 1000-1500, 1500-2500 and >2500 addresses per km^2), *marital status* (married vs. not married) and an indicator of being *institutionalized* or not.

As psychosocial variables we included *mastery*, assessed with a 5-item version of the Pearlin Mastery scale [23], *social network size* [24], the amount of *instrumental* and *emotional support received* from one's network members over the past year [24] and *social* and *emotional loneliness*, assessed with the 11-item De Jong Gierveld Loneliness Scale [25].

Smoking behavior was categorized into nonsmokers, former smokers or current smokers. If respondents had stopped more than 20 years ago, they were categorized as

nonsmokers, since studies have shown similar mortality risks for those who stopped more than 20 years ago, compared to non-smokers [26]. *Alcohol consumption* (glasses per week) was computed by multiplying the number of days per week respondents usually drank and the number of glasses each time [27]. *Body mass index* was calculated by dividing measured weight (in kilogram) by height (in meters) squared. Averaged daily minutes of *physical activity (PA)* was computed by multiplying self-reported frequency and duration of activities. This was done separately for non-sports and sports activities [28]. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.

Self-reported health factors were: a count of nine *chronic diseases* (chronic non-specific lung disease, cardiac disease, peripheral arterial disease, stroke, diabetes mellitus, arthritis, cancer, and a maximum of two other diseases that had been present for at least 3 months [29]), *functional limitations,* indicating the number of activities out of six that respondents reported to have difficulty performing [30;31], s*elf-rated health,* with responses ranging from very good (1) to poor (5)[32]. *Previous care use* was also included, defined as having had any contact with a general practitioner or a medical specialist in the previous six months.

Objective health measures were: *Physical performance,* measured with three performance-based tests (walking speed, ability to rise from a chair and putting on and taking off a cardigan) [33]. Sum scores ranged from 0 to 12, with 12 indicating the best performance. We included a measure of *polypharmacy,* i.e. whether people took five or more drugs versus four or less. *Systolic and diastolic blood pressure (BP)* measurements were performed in sitting position. If multiple BP measurements were available (waves 2001-02 and 2005-06), only the first measurement was used to make the measurements comparable across waves. *Depressive symptoms* were measured with the Center for Epidemiologic Studies Depression Scale [34], a 20-item scale covering depressive symptomatology in the past week. *General cognitive functioning* was measured with the Mini-Mental State Examination [35].

Statistical analyses

Descriptive statistics were weighted according to age and gender. Probability weights were computed by dividing 5-year age and gender strata proportions in 1997, 2000 and 2007 by proportions of the same strata in 2003. For analysis of trends, Generalized Estimating Equations (GEE) analysis was used, which corrects for the fact that individuals were included in multiple waves [36]. Binomial logit models were applied for three dichotomous outcomes:

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Having or not having within 36 months after the interview: (1) one or more day admissions, (2) one or more overnight admissions, and (3) one or more acute overnight admissions. An independent time variable represented the study years (0, 3, 7 and 10 years). All models were based on complete cases and they were age- and gender-adjusted.

Four blocks of independent variables were included to examine their contribution to time trends in hospital admission. These blocks included the demographic, psychosocial, lifestyle and health status variables that showed associations (significant at P<.20) with the outcome in age- and gender-adjusted models. The blocks were entered in order from most distal (demographic) to most proximal (physical health status) determinants [37]. Their contribution was assessed by calculating the percentages decline or improvement in the coefficient for time after including them in the regression models. If the regression coefficient of time changed more than 10% after entering a block, each variable in the block was entered separately, to assess which factor mostly accounted for the effect. Analyses were conducted using STATA 14 (StataCorp. 2015).

Results

The age- and gender-adjusted percentage of older adults with one or more hospital admissions within 36 months after their interview increased from 42.8% in 1997 to 53.4% in 2007 (Table 1). Underlying this trend is a more than doubled percentage that experienced a day admission (from 12.3 to 28.3%), and a slightly increased risk of overnight admissions over time (percentage increased from 38.1 to 39.7%). The last increase concerned only acute admissions. Acute admission risk showed a curvilinear trend: it increased in particular after the year 2003. During the study period, a sharp decrease was observed in the length of stay, both in the average stay per overnight admission and in the total hospital days (day or overnight) within a period of 36 months.

Increasing trends were observed in education and income levels, the prevalence of being married, network size, the level of support received (Table 2). The level of loneliness (both social and emotional) decreased over time. Lifestyle factors show a mixed trend: BMI increased and time spent on non-sports physical activity decreased, but the prevalence of smoking decreased and time spent on sports increased over time. Most health factors, including the number of chronic conditions, functional limitations, medication use, depressive symptoms and self-rated health showed a worsening trend. In contrast, cognitive functioning improved and systolic blood pressure decreased.

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Tables 3, 4 and 5 demonstrate the time trends (odds ratios reflect the effect per year of the study) and potential explanatory factors in those admission types that increased during the study period. The pronounced increase in day admission risk was not explained by any of the individual characteristics, which can be observed from very small changes in the odds ratio after adding the four blocks of determinants (Table 3). The significant increase in overnight admission risk disappeared after selecting those respondents who had complete information on all predictors (Table 4). Still, introducing the predictors by domain revealed several suppressive (positive percentages) and explanatory (negative percentages) effects. After taking into account these suppressors (e.g. education, sports physical activity and smoking) the increase in overnight admission was larger: their favorable health effects have to some extent prevented a larger increase in admission risk. The explanatory factors (e.g. polypharmacy, chronic disease and functional limitations) decreased the regression coefficients: they explain some of the increase in admission risk. It should be noted, however, that the odds ratios remain very small for the increase in overnight admissions. For acute overnight admissions similar results were observed (Table 5), except that the statistically significant trend now remained after including all predictors. It should be noted that contact with general practitioner or medical specialist was not included in the final models, as they can be considered a prerequisite for most hospital admissions. Similar results were obtained in models that did include these variables.

We expected that changes in one admission type would have an influence on the prevalence of others. Therefore, in the full model for *day* admission we additionally included an indicator of having one or more *overnight* admissions, and in the models for total and acute *overnight* admissions we adjusted for having one or more *day* admission (Appendix Table 1). This adjustment had only minor impact: only the increase in acute admission risk over time was attenuated after adjusting for day admission risk.

Discussion

We found a ten percent point increase in the share of older adults that experienced one or more hospital admissions within 36 months after their interview: from 43% in 1995 to 53% in 2007. A substantial contribution to this increase was made by day admissions, a type of care that shows a sharp increase in volume: the share of older adults with one or more day admissions increased from 12% to 28%. This trend in day admission risk was not explained by changes in any of the demographic, psychosocial, lifestyle or health characteristics.

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However, the increase in acute overnight admission risk did show a relationship with worsening trends in health.

This study focused on individual level characteristics, other than age and gender, which were controlled for, and not on higher level changes such as changes in general practitioner and hospital care data. Regardless, our results also reflect policy and organizational changes in medical care in the Netherlands. First, regarding the type of hospital admission, diagnostics and treatments of a wide range of diseases are increasingly being performed during day admissions instead of during overnight admissions [1;38]. Second, in response to dissatisfaction with long waiting lists, among other reasons, budgetary constraints were relaxed in 2001. In particular the marked increase we found from 2003 onwards coincides with this development. Third, in 2005 a new financing system for hospitals was introduced. The Diagnosis Treatment Combination system (DBC, similar to diagnosis-related groups (DRGs)) substantially increased the incentive for Dutch hospitals to shorten lengths of stay. Indeed, substantial decreases in length of stay of overnight admissions have been reported [6]. At the same time, this development to a patient-based payment without a fixed budget ceiling may have stimulated health care spending [39]. For example, during the study period we found an increase in the share of respondents who had contact with a medical specialist.

We have argued that increased hospital admission risk that was found relates to the above mentioned developments. Still, the finding that a larger share of older adults experience an acute overnight admission also suggests a greater need for acute care. This greater need is for example reflected in increased disease burden and the related increase in prevalence of polypharmacy. In line with these findings is a report on out-of-hours general practitioner care in the Netherlands [40], which showed that more acute cases have been presented at these units over the past decade. Improved survival particularly among older adults with chronic diseases may have led to more complex cases in recent years (as reflected in an increase of older adults with polypharmacy), possibly leading to increased acute hospital admissions. An increasing unpredictability of these events might explain why including a broad set of health factors did not fully explain this increasing trend in acute admissions. Increases in acute admissions may also be an effect of shorter length of stay, through an increasing need for readmissions. However, it appears from our results that more people experience an admission, rather than some people experiencing more admissions. Discussion is still ongoing on the extent to which decreased length of stay is associated with quality of care and readmission rates [3;41]. Finally, increases in acute admissions may have resulted from a shift of

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emergency department presentations towards the end of the day, which leads more often to an admission. The extent to which this has played a role in our study remains unsure.

Chronic diseases, functional limitations and poor self-rated health were shown to be predictive of hospitalization in previous studies [14;42;43]. All these health indicators showed worsening trends in our study, partly corroborating findings from previous research [17;18;44]. Self-rated health explained some of the increases in admission risk, which might be due to it being a proxy for health factors that are not captured by more specific measures of disease and functioning [45]. Other factors that showed an increase during the study period, which are associated with a higher risk of hospital admission and poor outcomes of hospitalization, were mean body mass index and depressive symptoms [46;47].

We acknowledge that changes in disease burden and changes in medical care are not always easily separated. For example, increased health care expenditures during the study period [11] may have resulted in or coincided with more active treatment of older adults, and a reduction in age discrimination regarding administration of treatments [8;11]. This allows longer life expectancy in particular among older adults with chronic diseases [48;49], and thus results in a higher prevalence of these diseases. Furthermore, it might be that the same health care investments that lead to increased volume of hospital care also lead to earlier diagnosis which in turn is associated with increases in treatment. However, worsening trends in self-rated health and functioning contradict this hypothesis, as they do not likely reflect better quality of care or access to hospital care over time. In addition, polypharmacy may bring about its own health risks [50].

Some limitations of this study should be mentioned. Although health status characteristics and hospital admission were linked per individual, it remains to be studied if and to what extent health status of patients at the time of admission has changed. Another trend on which we had no data concerns the emergency department presentations without an admission following, which could have provided additional insight in our results. Participation of hospitals in the DHDR was nearly 100% until 2004. Since 2005 some hospitals (temporarily) stopped participating in DHDR because of the introduction of the Diagnosis Treatment Combination registration. As a result, the estimated percentage of missing DHDR records increased from 3.9% in 2004 to 14.6% in 2009. A third limitation may be attrition of a small proportion of the sample due to frailty or selective survival, which may have caused an underestimation of health problems [19]. In a previous study on trends in chronic diseases and disability, we found these effects to be limited [51]. Finally,

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Conclusion

This study among Dutch older adults shows that acute overnight and day admissions increased between 1997 and 2007. This increase in hospital admission risk implies higher health care expenditures. Some interesting associations emerged, suggesting that improvements in lifestyle contributed to a fall in hospital admission risk, whereas the increase in disease burden contributed to an increase in hospital admission risk over time. If our findings reflect greater demand for hospital admission in the older population this has implications for health care planning as well as for older adults' wellbeing. Therefore, future studies should further address the relative contributions of changes in health policy and in population health on hospital care utilization.

Author contributions:

HG, DD and MH conceived and designed the work and contributed to acquisition for the work. HG analysed the data and drafted the manuscript. DD, RdJ, JK and MH helped interpret the data and revised the paper critically for important intellectual content. All authors approved of the version to be published, and are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests:

All authors have nothing to disclose.

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Data sharing:

No additional data available.

Table 1 Descriptives - dependent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend[b]
	%/mean(sd)	%/mean(sd)	%/mean(sd)	%/mean(sd)	
% Female gender (unweighted)	53.3	55.7	55.2	55.8	-
Mean age (range: 65-88) (unweighted)	76.0 (6.7)	75.5 (6.7)	75.2 (6.6)	74.5 (6.4)	-
N with >=1 hospital admissions	724 (42.8)	629 (42.7)	618 (47.7)	652 (53.4)	P<.001
>=1 Day admissions	207 (12.3)	253 (17.2)	299 (23.1)	345 (28.3)	P<.001
>=1 Overnight admissions	645 (38.1)	501 (34.0)	480 (37.1)	484 (39.7)	P<.05
(Acute and elective)					
>=1 Acute	375 (58.1)	305 (60.9)	296 (61.2)	330 (68.2)	P<.001
>=1 Elective	414 (64.2)	293 (58.5)	294 (61.3)	283 (58.5)	Ns
Per admitted person:	*N=724*	*N=629*	*N=618*	*N=652*	
Nr of day admissions	2.1 (2.2)	2.1 (2.4)	2.4 (3.0)	2.7 (4.8)	P<.001
Nr of overnight admissions	1.6 (1.3)	1.4 (1.4)	1.4 (1.7)	1.5 (1.6)	Ns
Nr of acute admissions	0.8 (1.0)	0.7 (0.9)	0.7 (0.9)	0.8 (1.2)	Ns
Nr of elective admissions	0.9 (1.0)	0.7 (1.1)	0.8 (1.5)	0.7 (1.0)	P<.01
Mean HLOS per overnight admission	12.8 (13.1)	11.6 (14.9)	9.7 (9.2)	7.4 (6.4)	P<.001
Total HLOS for all admissions	21.1 (26.2)	16.4 (25.0)	14.6 (18.1)	12.5 (19.8)	P<.001

[a]All outcomes are weighted to the age- and gender distribution in 2001-02

[b]In age- and gender adjusted models

Abbreviations: HLOS, Hospital length of stay

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Table 2 Descriptives- independent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend
	% / mean (sd)	% / mean (sd)	% / mean (sd)	% / mean (sd)	
Demographic variables					
Education in years (5-18)	8.8 (3.3)	9.0 (3.2)	9.2 (3.3)	9.6 (3.3)	P<.001
Net monthly income (334-2270 Euros)[b]	963 (404)	988 (393)	1027 (359)	1052 (319)	P<.001
Married	53.4	53.6	55.4	59.7	P<.001
Urbanization level (1-5)	3.2 (1.5)	3.1 (1.4)	3.0 (1.4)	3.0 (1.4)	P<.01
Institutionalised	5.1	3.8	3.8	2.8	P<.05
Psychosocial factors					
Network size (0-67)	14.1 (8.3)	14.4 (8.6)	15.0 (8.6)	16.0 (9.1)	P<.001
Received instrumental support (0-36)	14.8 (6.7)	14.6 (6.7)	15.1 (6.5)	15.7 (6.7)	P<.001
Received emotional support (0-36)	20.7 (8.3)	20.7 (7.9)	21.9 (7.9)	22.1 (7.7)	P<.001
Mastery (5-25)	17.1 (3.4)	17.2 (3.4)	17.2 (3.4)	17.3 (3.3)	Ns
Social loneliness (0-5)	1.1 (1.4)	1.1 (1.4)	1.0 (1.4)	0.9 (1.4)	P<.05
Emotional loneliness (0-6)	1.3 (1.8)	1.3 (1.8)	1.2 (1.7)	1.1 (1.7)	P<.01
Lifestyle factors					
Alcohol (0-77 glasses p/w)	7.5 (11.5)	6.8 (9.6)	7.2 (9.5)	7.6 (10.3)	Ns
Body Mass Index (kg/m^2)	26.9 (4.2)	27.3 (4.2)	27.4 (4.2)	27.5 (4.3)	P<.001
Non-smoker	60.8	66.9	67.5	68.8	P<.01
Former	19.7	17.1	17.3	17.4	Ns
Current	19.5	15.9	15.2	13.9	P<.001
Sports physical activity (min/day)	10.5 (24.1)	13.5 (29.4)	18.5 (33.2)	19.8 (31.7)	P<.001
Non-sports physical activity (min/day)	137.2 (94.3)	139.2 (95.3)	136.6 (100.1)	129.2 (98.9)	P<.01
Health factors					
Chronic diseases (0-9)	1.6 (1.2)	1.7 (1.3)	1.7 (1.2)	1.8 (1.2)	P<.001
Functional limitations (0-6)	1.6 (1.9)	1.6 (1.9)	1.7 (1.9)	1.8 (1.9)	P<.001
Self-rated health (1-5)	2.45 (1.0)	2.42 (0.9)	2.46 (0.9)	2.49 (0.9)	P<.01
Contact with general practitioner	79.1	83.8	81.5	81.1	Ns
Contact with medical specialist	50.7	51.8	53.4	53.0	P<.05
Physical performance (4-12)	7.0 (2.7)	6.8 (2.7)	7.0 (2.6)	7.4 (2.6)	Ns
Polypharmacy (>=5 vs. <5)	16.6	22.6	24.1	31.0	P<.001
Systolic blood pressure (mmHg)	153.1 (26.1)	152.6 (25.0)	148.3 (25.5)	149.6 (25.4)	P<.001
Diastolic blood pressure (mmHg)	83.3 (13.6)	83.0 (12.2)	82.4 (13.3)	82.9 (13.7)	Ns
Depressive symptoms (0-60)	8.4 (8.1)	8.7 (7.6)	9.2 (7.5)	8.6 (7.3)	P<.001
Cognitive functioning (0-30)	26.6 (3.3)	26.9 (3.1)	27.0 (3.2)	27.2 (2.7)	P<.001

[a]All descriptives are weighted to the age- and gender distribution in 2001-02; trends were age- and gender adjusted

[b]Income level of the second wave onwards was corrected for inflation (on average 2.3% per year).

Table 3. Time trend in day admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]
Time in years[b]	1.105 (1.083-1.127)***	
+Demographics[c]	1.104 (1.082-1.126)***	-1%
+Psychosocial[d]	1.101 (1.079-1.123)***	-3%
+Lifestyle[e]	1.103 (1.081-1.126)***	+2%
+Health status[f]	1.097 (1.074-1.120)***	-5%

†N=4036 observations from a total of 2010 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] Adjusted for age and gender
[c] Institutionalized, Marital status, urbanization,
[d] Network size, income, instrumental and emotional support
[e] Sports physical activity and smoking
[f] Chronic diseases, functional limitations, self-rated health, physical performance, polypharmacy, systolic and diastolic blood pressure and cognitive functioning

Table 4. Time trend in overnight hospital admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.013 (0.996-1.030)			
+Demographics	1.016 (0.999-1.034)†	+23%	Education	+15%
			Urbanization	+8%
+Psychosocial[d]	1.016 (0.999-1.034)	-0%		
+Lifestyle	1.019 (1.001-1.037)*	+19%	BMI	-6%
			Non-Sports PA	-6%
			Sports PA	+19%
			Smoking	+13%
+Health status	1.004 (0.985-1.022)	-21%	Chronic diseases	-37%
			Functional limitations	-37%
			Self-rated health	-21%
			Physical performance	-5%
			Polypharmacy (>=5 vs.<5)	-68%
			Systolic blood pressure	-5%
			Diastolic blood pressure	-5%
			Depressive symptoms	-5%

†N=3809 observations from a total of 1925 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Network size, income, mastery, instrumental support, emotional and social loneliness

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Table 5. Time trend in acute overnight admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.033 (1.014-1.052)**			
+Demographics[d]	1.036 (1.016-1.056)***	+9%		
+Psychosocial[e]	1.036 (1.017-1.056)***	+3%		
+Lifestyle	1.041 (1.020-1.061)***	+11%	Non-sports physical activity	-3%
			Sports physical activity	+6%
			Smoking	+8%
+Health status	1.031 (1.011-1.052)**	-22%	Chronic diseases	-15%
			Functional limitations	-15%
			Self-rated health	-10%
			Physical performance	-0%
			Polypharmacy (>=5 vs. <5)	-22.5%
			Depressive symptoms	-2.5%
			Cognitive functioning	-0%

†N=4103 observations from a total of 2103 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Education, urbanization,
[e] Network size, mastery, instrumental support , emotional and social loneliness

Appendix Table 1. Time trends in admission risk, adjusted for other admission types

	Day admission OR (95% CI)	Overnight admission OR (95% CI)	Acute overnight admission OR (95% CI)
Time in years[a]	1.097 (1.074-1.120)***		
+Overnight admission (yes/no)	1.098 (1.075-1.121)***		
Time in years[a]		1.004 (0.985-1.022)	
+Day admission (yes/no)		0.990 (0.972-1.009)	
Time in years[a]			1.031 (1.011-1.052)**
+Day admission (yes/no)			1.021 (1.000-1.042)*

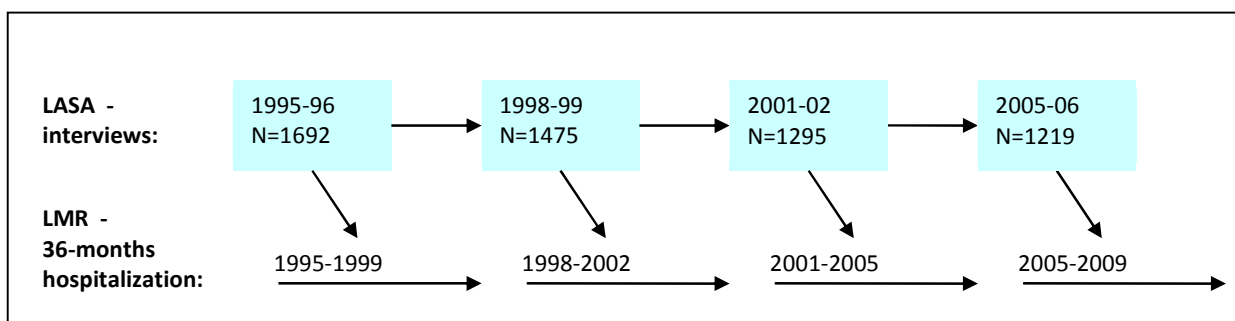*P<0.05 **P<0.01 ***P<0.001

[a] Adjusted for all covariates
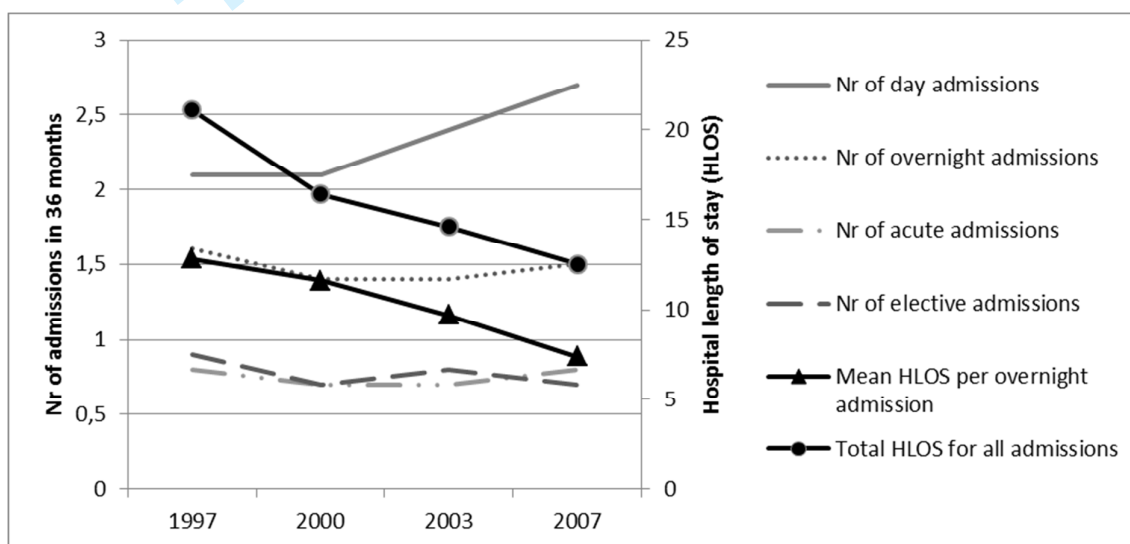
Figure 1. Study design and number of participants

Figure 2. Time trends in number of admissions and in hospital length of stay (HLOS)

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 2)
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 2)
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported (page 4-5)
Objectives	3	State specific objectives, including any prespecified hypotheses (page 5)
Methods		
Study design	4	Present key elements of study design early in the paper (page 5)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (pages 5-6)
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (page 5)
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (pages 6-7)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (pages 6-7)
Bias	9	Describe any efforts to address potential sources of bias (page 5-8, 11)
Study size	10	Explain how the study size was arrived at (page 5)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 6-7)
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (page 7-8)
		(*b*) Describe any methods used to examine subgroups and interactions (na)
		(*c*) Explain how missing data were addressed (imputation for one variable; page 7; complete cases at each wave were analysed: page 8)
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *(na, this was a trend study in which follow-up was not required. See page 11 for a discussion of the effects of frailty or selective survival)*
		(*e*) Describe any sensitivity analyses (See our results in Appendix Table 1)

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 5 and reference 19)
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (Tables 1 and 2)
		(b) Indicate number of participants with missing data for each variable of interest (we indicated the number of participants per analysis – tables 3-5)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) (page 5)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time (Table 1)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (Tables 1-5)
		(*b*) Report category boundaries when continuous variables were categorized (Tables 1-5)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (na)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (see results in Appendix Table 1)

Discussion

Key results	18	Summarise key results with reference to study objectives (page 9)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 11)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 12)
Generalisability	21	Discuss the generalisability (external validity) of the study results (page 11)

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (page 12)

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Are changing trends in hospital admissions (1995-2009) associated with changing health trends of Dutch older adults?

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Manuscripts

Are changing trends in hospital admissions (1995-2009) associated with changing health trends of Dutch older adults?

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Key words: Aged, Chronic Diseases, Hospitalization, Trends

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Abstract

Objectives: An increase in hospital admission rates in older people may reflect improved access to health care, but also declining health trends in the older population. Due to a lack of individual-level data, the latter possibility has received little attention. The current study examines associations between health status and hospitalization rates of older adults in the Netherlands.

Design: Observational individual-level data linked with hospital register data.

Setting: Data from 1995-2009 from the nationally representative Longitudinal Aging Study Amsterdam were linked with the Dutch Hospital Discharge Register.

Participants: A total of 5681 observations of 2520 respondents, across four measurement points (each with a follow-up of 36 months; ages 65-88 years).

Outcome measures: The contribution of health, demographic, psychosocial and lifestyle characteristics to time trends in hospitalization was assessed in multivariate models.

Results: Between 1995 and 2009, the percentage with one or more overnight admissions (planned or acute) slightly increased, from 38.1 to 39.7%. This was due to an increase in acute admission only (22.2% to 27.0%). Increased prevalences of chronic diseases, functional limitations and polypharmacy accounted for part of the observed increase in acute admissions. In addition, a more than doubled prevalence of day admissions over time was observed (12.3% to 28.3%), a trend that was unrelated to changes in individual characteristics.

Conclusions: This trend study showed a contribution of declines in population health to increases in hospital admissions. As these declines did not provide a full explanation, health care reforms and increases in treatment possibilities in this period are likely to have contributed as well.

Article summary

Strengths and limitations of this study

- The Longitudinal Aging Study Amsterdam is a cohort study that is representative for the Dutch older population.

- Multiple waves of data collection, within two different cohorts, were performed between 1995 and 2006, which enabled the study of health trends.

- While previous studies mostly relied on aggregated data, our study links individual-level data on health and lifestyle trends with individual-level hospital registration data.

- The coverage of the Dutch Hospital Discharge register decreased during our study period.

- Health status characteristics and hospital admission were linked per individual, but it remains to be studied if and to what extent the health status of patients at the time of their admission has changed.

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Introduction

With the aging population in most Western countries, there is increasing pressure to reduce health care expenditures. Hospital care is the most costly type of care [1] and for the greater part involves older adults. Pressures for cost containment as well as the introduction of new medical technologies have resulted in a reduced length of stay in most developed countries in recent decades [2;3]. Another approach to cost containment may be prevention of hospitalization and adverse events related to hospital admissions [4], but several studies - not all [5] - show increases in hospital admission rates and hospital costs in European countries and the US over the past decades [6-9].

Both individual and societal factors may affect the utilization of hospital care [10]. Research addressing the mechanisms underlying increased use of care and increased health care expenditures showed that these are largely driven by societal changes, such as improved medical technology and more active treatment of the oldest old, and only for a small part by demographic changes [8;11].

Regarding individual factors, the prevalence of morbidity and disability - the most immediate causes of hospital admission [10;12-14] - has shifted in recent generations of older adults. Ample evidence exists of an increased prevalence of chronic diseases and comorbidity over time, both in admitted patients and in older adults in the community [3;15-18]. Research is inconclusive regarding trends in disability or in the severity of morbidity [17;19]. Technological developments in recent decades may have led to better treatment possibilities, and in turn, to better health, functioning and survival of older adults. Longer survival specifically in those with chronic diseases, however, leads to a higher prevalence of chronic conditions and associated hospital admission risk. Such mixed trends make it difficult to formulate clear-cut hypothesis regarding trends in hospital admission. In particular if one considers the variety in types of hospital admission, such as acute vs. planned, and day vs. overnight admissions, which all address different health care needs

Given the societal costs associated with hospital care and the burden of hospitalization on older patients themselves [4], reducing hospital admissions among older adults is an important goal. However, simply reducing the volume of hospital care should not be aimed for, when it is at the expense of poorer quality of care or an increased disease burden. In fact, reducing one type of admission (e.g. day admissions) may result in more admissions of another - more critical – type (e.g. acute admissions). Policies aiming at the prevention of hospitalization should be informed by research on underlying health trends in the older population. In

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addition, trends in day admissions and overnight admissions (acute or planned) should be evaluated in relation to each other.

The current study explores recent hospital admission trends - day admissions and overnight (planned and acute) admissions. It also examines to what extent up- or downward trends can be attributed to changing health of the older population. Individual-level health and hospital data are needed for this purpose, since these are more sensitive than population means. In addition, they may provide insight in the interrelationships between various individual characteristics. We linked individual morbidity data from Dutch older adults between 1995 and 2009, obtained within a nationally representative cohort study on aging, the Longitudinal Aging Study Amsterdam, with data from the Dutch Hospital Discharge Register (DHDR), providing individual-level data on hospital admissions.

Methods

Data sources

LASA

In 1992, a random sample of older adults was drawn from the population registries of 11 municipalities in three geographical regions in the Netherlands (ages: 55-85 years; N: 3,107) with a co-operation rate (the proportion of completed interviews in the number of contacted eligible persons) of 62% [20]. Follow-up measurements took place at roughly 3 years intervals in 1995-96 and 1998-99, 2001-02 and 2005-06 (Figure 1). In 2002, a new cohort was sampled (ages: 55-64 years; N: 1,002; co-operation rate: 62%). Complete medical records were available for the period 1995 to 2009, therefore LASA participants who had at least one interview between 1995-96 and 2005-06 were included. Waves will be referred to using the mid-year of each follow-up (36 months): 1997, 2000, 2003 and 2007. We selected all 2,520 adults who were aged 65 to 88 at the time of at least one wave, to compare a fixed age range which was available in each wave. Thirty six percent of these respondents were included in one wave, 23% in two waves, 21% in three waves and 20% in all four waves, leading to a total number of 5,681 observations.

DHDR

The Dutch Hospital Discharge Register (Landelijke Basisregistratie Zorg, (LBZ), previously: Landelijke Medische Registratie (LMR)) [21] registers admissions in most general and academic hospitals and some single-specialty hospitals, thus providing a nearly complete

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coverage of hospital admissions in the Netherlands. All admissions are registered based on a uniform registration system. The data include admission and discharge dates, extensive diagnosis and treatment information and death during admission. A study on the reliability of admission and discharge information in the DHDR revealed that in 1999, 99% of this information was registered correctly [22].

Linkage of data sources

For the purpose of this study, Statistics Netherlands linked data from the DHDR and LASA to each other via the Municipal Population Registry (MPR). Both data sets are anonymized, so this linkage occurred on the basis of a set of identifying variables: postal code, date of birth and gender [21]. Linkage with the MPR was fully achieved for 98% of the eligible study sample. Consent forms for accessing medical records were signed by the LASA participants and the study was approved by the Medical Ethics Committee of the VU University Medical Center.

Measurements

Table 1 gives an overview all study variables and how they were measured. Hospital admission within 36 months follow-up of each LASA interview was coded as not admitted (0) or admitted at least once (1). Admissions were categorized into day admission or overnight admission. Day admissions were defined as planned admissions where specialist care is given for several hours during the day. Visits to the emergency unit were not included as a day or overnight admission, unless an overnight admission followed from this visit. Overnight admissions were all admissions including at least one night. These admissions were further divided into acute or elective admissions.

To increase our understanding of which individual-level factors underlie hospital admission trends, we assessed the role of demographic, psychosocial and lifestyle factors stepwise in addition to health status factors.

Education level was measured in years. *Net monthly income* of respondents living with a partner was multiplied by 0.7, to make their income comparable with that of one-person households [23]. Also included were *level of urbanization* (categories were <500, 500-1000, 1000-1500, 1500-2500 and >2500 addresses per km^2), *marital status* (married vs. not married) and an indicator of being *institutionalized* or not.

As psychosocial variables we included *mastery,* assessed with a 5-item version of the Pearlin Mastery scale [24], *social network size* [25], the amount of *instrumental* and

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emotional support received from one's network members over the past year [25] and *social*
and *emotional loneliness*, assessed with the 11-item De Jong Gierveld Loneliness Scale [26].

     Smoking behavior was categorized into nonsmokers, former smokers or current
smokers. If respondents had stopped more than 20 years ago, they were categorized as
nonsmokers, since studies have shown similar mortality risks for those who stopped more
than 20 years ago, compared to non-smokers [27]. *Alcohol consumption* (glasses per week)
was computed by multiplying the number of days per week respondents usually drank and the
number of glasses each time [28]. *Body mass index* was calculated by dividing measured
weight (in kilogram) by height (in meters) squared. Averaged daily minutes of *physical*
activity (PA) was computed by multiplying self-reported frequency and duration of activities.
This was done separately for non-sports and sports activities [29]. If the frequency or the time
spent on the activity was missing, we imputed these by substituting with gender- and activity-
specific means.

     Self-reported health factors were: a count of nine *chronic diseases* (chronic non-
specific lung disease, cardiac disease, peripheral arterial disease, stroke, diabetes mellitus,
arthritis, cancer, and a maximum of two other diseases that had been present for at least 3
months [30]), *functional limitations*, indicating the number of activities out of six that
respondents reported to have difficulty performing [31;32], s*elf-rated health,* with responses
ranging from very good (1) to poor (5)[33]. *Previous care use* was also included, defined as
having had any contact with a general practitioner or a medical specialist in the previous six
months.

     Objective health measures were: *Physical performance,* measured with three
performance-based tests (walking speed, ability to rise from a chair and putting on and taking
off a cardigan) [34]. Sum scores ranged from 0 to 12, with 12 indicating the best performance.
We included a measure of *polypharmacy,* i.e. whether people took five or more drugs versus
four or less. The number of drugs used was recorded from the medicine containers in the
home of the respondents. Since there is no agreed definition of polypharmacy [35], we based
our definition of polypharmacy on previous studies [e.g., 36;37]. *Systolic and diastolic blood*
pressure (BP) measurements were performed in sitting position. If multiple BP measurements
were available (waves 2001-02 and 2005-06), only the first measurement was used to make
the measurements comparable across waves. *Depressive symptoms* were measured with the
Center for Epidemiologic Studies Depression Scale [38], a 20-item scale covering depressive
symptomatology in the past week. *General cognitive functioning* was measured with the
Mini-Mental State Examination [39].

Statistical analyses

Descriptive statistics were weighted according to age and gender. Probability weights were computed by dividing 5-year age and gender strata proportions in 1997, 2000 and 2007 by proportions of the same strata in 2003. For analysis of trends, Generalized Estimating Equations (GEE) analysis was used, which corrects for the fact that individuals were included in multiple waves [40]. Binomial logit models were applied for three dichotomous outcomes: Having or not having within 36 months after the interview: (1) one or more day admissions, (2) one or more overnight admissions, and (3) one or more acute overnight admissions. An independent time variable represented the study years (0, 3, 7 and 10 years). All models were based on complete cases and they were age- and gender-adjusted.

Four blocks of independent variables were included to examine their contribution to time trends in hospital admission. These blocks included the demographic, psychosocial, lifestyle and health status variables that showed associations (significant at P<.20) with the outcome in age- and gender-adjusted models. The blocks were entered in order from most distal (demographic) to most proximal (physical health status) determinants [41]. Their contribution was assessed by calculating the percentages decline or improvement in the coefficient for time after including them in the regression models. If the regression coefficient of time changed more than 10% after entering a block, each variable in the block was entered separately, to assess which factor mostly accounted for the effect. Analyses were conducted using STATA 14 (StataCorp. 2015).

Results

The age- and gender-adjusted percentage of older adults with one or more hospital admissions within 36 months after their interview increased from 42.8% in 1997 to 53.4% in 2007 (Table 2). Underlying this trend is a more than doubled percentage that experienced a day admission (from 12.3 to 28.3%), and a slightly increased percentage with one or more overnight admissions over time (percentage increased from 38.1 to 39.7%). The last increase concerned only acute admissions. Acute admission showed a curvilinear trend: it increased in particular after the year 2003. During the study period, a sharp decrease was observed in the length of stay, both in the average stay per overnight admission and in the total hospital days (day or overnight) within a period of 36 months.

Increasing trends were observed in education and income levels, the prevalence of being married, network size, the level of support received (Table 3). The level of loneliness

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(both social and emotional) decreased over time. Lifestyle factors show a mixed trend: BMI increased and time spent on non-sports physical activity decreased, but the prevalence of smoking decreased and time spent on sports increased over time. Most health factors, including the number of chronic conditions, functional limitations, medication use, depressive symptoms and self-rated health showed a worsening trend. In contrast, cognitive functioning improved and systolic blood pressure decreased.

Tables 4, 5 and 6 demonstrate the time trends (odds ratios reflect the effect per year of the study) and potential explanatory factors in those admission types that increased during the study period. The pronounced increase in day admission risk was not explained by any of the individual characteristics, which can be observed from very small changes in the odds ratio after adding the four blocks of determinants (Table 4). The significant increase in overnight admission risk disappeared after selecting those respondents who had complete information on all predictors (Table 5). Still, introducing the predictors by domain revealed several suppressive (positive percentages) and explanatory (negative percentages) effects. After taking into account these suppressors (e.g. education, sports physical activity and smoking) the increase in overnight admission was larger: their favorable health effects have to some extent prevented a larger increase in admission risk. The explanatory factors (e.g. polypharmacy, chronic disease and functional limitations) decreased the regression coefficients: they explain some of the increase in admission risk. It should be noted, however, that the odds ratios remain very small for the increase in overnight admissions. For acute overnight admissions similar results were observed (Table 6), except that the statistically significant trend now remained after including all predictors. It should be noted that contact with general practitioner or medical specialist was not included in the final models, as they can be considered a prerequisite for most hospital admissions. Similar results were obtained in models that did include these variables.

We expected that changes in one admission type would have an influence on the prevalence of others. Therefore, in the full model for *day* admission we additionally included an indicator of having one or more *overnight* admissions, and in the models for total and acute *overnight* admissions we adjusted for having one or more *day* admission (Appendix Table 1). This adjustment had only minor impact: only the increase in acute admission risk over time was attenuated after adjusting for day admission risk.

Discussion

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We found a ten percent point increase in the share of older adults that experienced one or more hospital admissions within 36 months after their interview: from 43% in 1995 to 53% in 2007. A substantial contribution to this increase was made by day admissions, a type of care that shows a sharp increase in volume: the share of older adults with one or more day admissions increased from 12% to 28%. This trend in day admission risk was not explained by changes in any of the demographic, psychosocial, lifestyle or health characteristics. However, the increase in acute overnight admission risk did show a relationship with worsening trends in health.

This study focused on individual level characteristics, other than age and gender, which were controlled for, and not on higher level changes such as changes in general practitioner and hospital care data. Regardless, our results also reflect policy and organizational changes in medical care in the Netherlands. First, regarding the type of hospital admission, diagnostics and treatments of a wide range of diseases are increasingly being performed during day admissions instead of during overnight admissions [1;42]. Second, in response to dissatisfaction with long waiting lists, among other reasons, budgetary constraints were relaxed in 2001. In particular the marked increase we found from 2003 onwards coincides with this development. Third, in 2005 a new financing system for hospitals was introduced. The Diagnosis Treatment Combination system (DBC, similar to diagnosis-related groups (DRGs)) substantially increased the incentive for Dutch hospitals to shorten lengths of stay. Indeed, substantial decreases in length of stay of overnight admissions have been reported [6]. At the same time, this development to a patient-based payment without a fixed budget ceiling may have stimulated health care spending [43]. For example, during the study period we found an increase in the share of respondents who had contact with a medical specialist.

We have argued that the increased hospital admission risk that was found relates to the above mentioned developments. Still, we found that the proportion of older people who experienced an overnight admission in general did not increase, while the proportion who experienced an acute overnight admission did. This suggests that there has been a growing need for acute care over time. This need is for example reflected in increases in disease burden and in the prevalence of polypharmacy. An increase in medication prescription has been reported for older people in the UK and Italy as well [36;44]. Having a higher number of drugs prescribed was shown to be independently associated with non-elective hospital admissions [45]. A report on out-of-hours general practitioner care in the Netherlands [46] showed that more acute cases have been presented at these units over the past decade.

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Improved survival particularly among older adults with chronic diseases may have led to more complex cases in recent years (as reflected in an increase of older adults with polypharmacy), possibly leading to increased acute hospital admissions. An increasing unpredictability of these events might explain why including a broad set of health factors did not fully explain this increasing trend in acute admissions. Increases in acute admissions may also be an effect of shorter length of stay, through an increasing need for readmissions. However, it appears from our results that more people experience an admission, rather than some people experiencing more admissions. Discussion is still ongoing on the extent to which decreased length of stay is associated with quality of care and readmission rates [3;47]. Finally, increases in acute admissions may have resulted from a shift of emergency department presentations towards the end of the day, which leads more often to an admission. The extent to which this has played a role in our study remains unsure.

Chronic diseases, functional limitations and poor self-rated health were shown to be predictive of hospitalization in previous studies [14;45;48]. All these health indicators showed worsening trends in our study, partly corroborating findings from previous research [17;18;49]. Self-rated health explained some of the increases in admission risk, which might be due to it being a proxy for health factors that are not captured by more specific measures of disease and functioning [50]. Other factors that showed an increase during the study period, which are associated with a higher risk of hospital admission and poor outcomes of hospitalization, were mean body mass index and depressive symptoms [51;52].

A recent study from the UK reported that among those aged 65-84 years, disease prevalence and medication prescription increased between 2003 and 2012 [44]. The authors further reported an increase in hospital admission rate, which was small and not significant in those aged 65-84 years, but larger in those older than 85 years. They found for both age groups an increase in emergency admission. These findings are similar to what we found. At the same time, previous studies in Sweden have shown that between 1987 and 2010 both first and subsequent hospitalization (of at least two nights) occurred at older ages, which suggests a decrease in hospital admission rate [53;54]. In the US, finally, evidence was found for increased emergency department (ED) visits, but not for admission rates [55], although another study (2001-2009) did report increased admission rates [56]. It should be noted, however, that ED visits in the US may represent less acute cases as compared to the Netherlands, as ED care more often serves as a substitute for primary care in the US [57].

We acknowledge that changes in disease burden and changes in medical care are not always easily separated. For example, increased health care expenditures during the study

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period [11] may have resulted in or coincided with more active treatment of older adults, and a reduction in age discrimination regarding administration of treatments [8;11]. This allows longer life expectancy in particular among older adults with chronic diseases [58;59], and thus results in a higher prevalence of these diseases. Furthermore, it might be that the same health care investments that lead to an increased volume of hospital care also lead to earlier diagnosis which in turn is associated with increases in treatment. However, worsening trends in self-rated health and functioning contradict this hypothesis, as they do not likely reflect better quality of care or access to hospital care over time. In addition, polypharmacy may bring about its own health risks [35].

Some limitations of this study should be mentioned. Although health status characteristics and hospital admission were linked per individual, it remains to be studied if and to what extent health status of patients at the time of admission has changed. Another trend on which we had no data concerns the emergency department presentations without an admission following, which could have provided additional insight in our results. Participation of hospitals in the DHDR was nearly 100% until 2004. Since 2005 some hospitals (temporarily) stopped participating in DHDR because of the introduction of the Diagnosis Treatment Combination registration. As a result, the estimated percentage of missing DHDR records increased from 3.9% in 2004 to 14.6% in 2009. A third limitation may be attrition of a small proportion of the sample due to frailty or selective survival, which may have caused an underestimation of health problems [20]. In a previous study on trends in chronic diseases and disability, we found these effects to be limited [60].

Conclusion

This study among Dutch older adults shows that acute overnight and day admissions increased between 1997 and 2007. This increase in hospital admission risk implies higher health care expenditures. Some interesting associations emerged, suggesting that improvements in lifestyle contributed to a fall in hospital admission risk, whereas the increase in disease burden contributed to an increase in hospital admission risk over time. If our findings reflect greater demand for hospital admission in the older population this has implications for health care planning as well as for older adults' wellbeing. Therefore, future studies should further address the relative contributions of changes in health policy and in population health on hospital care utilization.

Author contributions:

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HG, DD and MH conceived and designed the work and contributed to acquisition for the work. HG analysed the data and drafted the manuscript. DD, RdJ, JK and MH helped interpret the data and revised the paper critically for important intellectual content. All authors approved of the version to be published, and are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data sharing:

No additional data available.

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Table 1. Study variables

Hospital registry (LMR) variables	Measurement/Definition	Level of measurement	Range/Categories/Unit
Outcome variables			
Hospital admission	Admitted at least once within 36 months follow-up.	Dichotomous	Yes/No
Day admission	At least one planned admission during the day within 36 months follow-up.	Dichotomous	Yes/No
Overnight admission	At least one overnight admission (planned or acute) within 36 months follow-up.	Dichotomous	Yes/No
Acute overnight admission	At least one acute overnight admission within 36 months follow-up.	Dichotomous	Yes/No
LASA variables			
Demographic variables			
Age		Continuous	65-88 years
Gender		Dichotomous	Female/male
Education in years	Categories: nine levels of education attained, recoded into education in years.	Continuous	5-18 years
Income	Net monthly income in Euros. Income level of the second wave onwards was corrected for inflation (on average 2.3% per year). Net monthly income of respondents living with a partner was multiplied by 0.7, to make their income comparable with that of one-person households.	Continuous	334-2270
Marital status	Categories: Unmarried, married, divorced, widowed.	Dichotomous	Married/not married
Urbanisation level	Data are provided by Statistics Netherlands. Categories: 5 'very highly (>2500)' 4 'highly (1500-2500)' 3 'somewhat (1000-1500)' 2 'little (500-1000)' 1 'not (<500)'.	Continuous	1-5
Institutionalised	Categories: Independent housing, residential home, nursing home – somatic, nursing home – psychogeriatric.	Dichotomous	Institutionalised/Living independently
Psychosocial factors			
Network size	Number of network members identified by the respondent in seven types of relationships.	Continuous	0-67
Received instrumental support	Four questions were asked about the relationships with a maximum of nine network members with whom contact was most frequent. Instrumental support received: how often during the previous year the respondent had received help with daily chores around the house, such as preparing meals, cleaning the house, transportation and small repairs. Emotional support received: how often, during the previous year, had they talked to their network member about personal experiences and feelings. Categories: never (0), rarely (1), sometimes (2) or often (3).	Continuous	0-36
Received emotional support		Continuous	0-36
Mastery	Pearlin Mastery scale [24].	Continuous	5-25
Social loneliness	Five items of the 11-item scale De Jong Gierveld [26]	Continuous	0-5
Emotional loneliness	Six items of the 11-item scale De Jong Gierveld [26]	Continuous	0-6
Lifestyle factors			
Alcohol intake	Self-reported number of days per week respondents usually drank*the number of glasses each time.	Continuous	0-77 glasses/week
Body Mass Index	Measured weight (in kilogram)/height (in meters) squared.	Continuous	Kg/m^2
Smoking	Self-reported smoking status. If respondents had stopped more than 20 years ago, they were categorized as nonsmokers, since studies have shown similar mortality risks for those who stopped more than 20 years ago, compared to non-smokers [26].	Nominal	Non-smoker/Former smoker/Current smoker
Sports physical activity	Self-reported frequency*duration of sports activities. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.	Continuous	Min/day

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Non-sports physical activity	Self-reported frequency*duration of non-sports activities. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.	Continuous	Min/day
Health factors			
Chronic diseases	Self-reported presence of chronic non-specific lung disease, cardiac disease, peripheral arterial disease, stroke, diabetes mellitus, arthritis, cancer, and a maximum of two other diseases that had been present for at least 3 months [30].	Continuous	0-9
Functional limitations	Self-reported number of activities out of six that respondents had difficulty performing [31;32].	Continuous	0-6
Self-rated health	Categories: very good (1), good (2), fair (3), sometimes good, sometimes bad (4), poor (5) [33].	Continuous	1-5
Contact with general practitioner	Self-reported contact with a general practitioner in the previous six months.	Dichotomous	Yes/No
Contact with medical specialist	Self-reported contact with a medical specialist in the previous six months.	Dichotomous	Yes/No
Physical performance	Time in seconds measured for three performance-based tests (walking speed, ability to rise from a chair and putting on and taking off a cardigan). Sum scores of test-specific quartiles ranged from 0 to 12, with 12 indicating the best performance. [34].	Continuous	4-12
Polypharmacy	The number of drugs used was recorded from the medicine containers in the home of the respondents. Polypharmacy was defined as having ≥5 vs. <5 drugs prescribed. [e.g. 36]	Dichotomous	≥5 vs. <5
Systolic and diastolic blood pressure	Measurements were performed in sitting position. If multiple BP measurements were available (waves 2001-02 and 2005-06), only the first measurement was used to make the measurements comparable across waves.	Continuous	mmHg
Depressive symptoms	Center for Epidemiologic Studies Depression Scale [38].	Continuous	0-60
Cognitive functioning	Mini-Mental State Examination [39].	Continuous	0-30

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Table 2 Descriptives - dependent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend[b]
	%/mean(sd)	%/mean(sd)	%/mean(sd)	%/mean(sd)	
% Female gender (unweighted)	53.3	55.7	55.2	55.8	-
Mean age (range: 65-88) (unweighted)	76.0 (6.7)	75.5 (6.7)	75.2 (6.6)	74.5 (6.4)	-
N with >=1 hospital admissions	724 (42.8)	629 (42.7)	618 (47.7)	652 (53.4)	P<.001
>=1 Day admissions	207 (12.3)	253 (17.2)	299 (23.1)	345 (28.3)	P<.001
>=1 Overnight admissions (Acute and elective)	645 (38.1)	501 (34.0)	480 (37.1)	484 (39.7)	P<.05
>=1 Acute	375 (58.1)	305 (60.9)	296 (61.2)	330 (68.2)	P<.001
>=1 Elective	414 (64.2)	293 (58.5)	294 (61.3)	283 (58.5)	Ns
Per admitted person:	*N=724*	*N=629*	*N=618*	*N=652*	
Nr of day admissions	2.1 (2.2)	2.1 (2.4)	2.4 (3.0)	2.7 (4.8)	P<.001
Nr of overnight admissions	1.6 (1.3)	1.4 (1.4)	1.4 (1.7)	1.5 (1.6)	Ns
Nr of acute admissions	0.8 (1.0)	0.7 (0.9)	0.7 (0.9)	0.8 (1.2)	Ns
Nr of elective admissions	0.9 (1.0)	0.7 (1.1)	0.8 (1.5)	0.7 (1.0)	P<.01
Mean length of stay per overnight admission (days)	12.8 (13.1)	11.6 (14.9)	9.7 (9.2)	7.4 (6.4)	P<.001
Total length of stay for all admissions (days)	21.1 (26.2)	16.4 (25.0)	14.6 (18.1)	12.5 (19.8)	P<.001

[a]All outcomes are weighted to the age- and gender distribution in 2001-02
[b]In age- and gender adjusted models

Table 3 Descriptives- independent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend
	% / mean (sd)	% / mean (sd)	% / mean (sd)	% / mean (sd)	
Demographic variables					
Education in years (5-18)	8.8 (3.3)	9.0 (3.2)	9.2 (3.3)	9.6 (3.3)	P<.001
Income	963 (404)	988 (393)	1027 (359)	1052 (319)	P<.001
Married	53.4	53.6	55.4	59.7	P<.001
Urbanization level (1-5)	3.2 (1.5)	3.1 (1.4)	3.0 (1.4)	3.0 (1.4)	P<.01
Institutionalised	5.1	3.8	3.8	2.8	P<.05
Psychosocial factors					
Network size (0-67)	14.1 (8.3)	14.4 (8.6)	15.0 (8.6)	16.0 (9.1)	P<.001
Received instrumental support (0-36)	14.8 (6.7)	14.6 (6.7)	15.1 (6.5)	15.7 (6.7)	P<.001
Received emotional support (0-36)	20.7 (8.3)	20.7 (7.9)	21.9 (7.9)	22.1 (7.7)	P<.001
Mastery (5-25)	17.1 (3.4)	17.2 (3.4)	17.2 (3.4)	17.3 (3.3)	Ns
Social loneliness (0-5)	1.1 (1.4)	1.1 (1.4)	1.0 (1.4)	0.9 (1.4)	P<.05
Emotional loneliness (0-6)	1.3 (1.8)	1.3 (1.8)	1.2 (1.7)	1.1 (1.7)	P<.01
Lifestyle factors					
Alcohol intake (0-77 glasses p/w)	7.5 (11.5)	6.8 (9.6)	7.2 (9.5)	7.6 (10.3)	Ns
Body Mass Index (kg/m^2)	26.9 (4.2)	27.3 (4.2)	27.4 (4.2)	27.5 (4.3)	P<.001
Non-smoker	60.8	66.9	67.5	68.8	P<.01
Former	19.7	17.1	17.3	17.4	Ns
Current	19.5	15.9	15.2	13.9	P<.001
Sports physical activity (min/day)	10.5 (24.1)	13.5 (29.4)	18.5 (33.2)	19.8 (31.7)	P<.001
Non-sports physical activity (min/day)	137.2 (94.3)	139.2 (95.3)	136.6 (100.1)	129.2 (98.9)	P<.01
Health factors					
Chronic diseases (0-9)	1.6 (1.2)	1.7 (1.3)	1.7 (1.2)	1.8 (1.2)	P<.001
Functional limitations (0-6)	1.6 (1.9)	1.6 (1.9)	1.7 (1.9)	1.8 (1.9)	P<.001
Self-rated health (1-5)	2.45 (1.0)	2.42 (0.9)	2.46 (0.9)	2.49 (0.9)	P<.01
Contact with general practitioner	79.1	83.8	81.5	81.1	Ns
Contact with medical specialist	50.7	51.8	53.4	53.0	P<.05
Physical performance (4-12)	7.0 (2.7)	6.8 (2.7)	7.0 (2.6)	7.4 (2.6)	Ns
Polypharmacy (>=5 vs. <5)	16.6	22.6	24.1	31.0	P<.001
Systolic blood pressure (mmHg)	153.1 (26.1)	152.6 (25.0)	148.3 (25.5)	149.6 (25.4)	P<.001
Diastolic blood pressure (mmHg)	83.3 (13.6)	83.0 (12.2)	82.4 (13.3)	82.9 (13.7)	Ns
Depressive symptoms (0-60)	8.4 (8.1)	8.7 (7.6)	9.2 (7.5)	8.6 (7.3)	P<.001
Cognitive functioning (0-30)	26.6 (3.3)	26.9 (3.1)	27.0 (3.2)	27.2 (2.7)	P<.001

[a]All descriptives are weighted to the age- and gender distribution in 2001-02; trends were age- and gender adjusted

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Table 4. Time trend in day admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]
Time in years[b]	1.105 (1.083-1.127)***	
+Demographics[c]	1.104 (1.082-1.126)***	-1%
+Psychosocial[d]	1.101 (1.079-1.123)***	-3%
+Lifestyle[e]	1.103 (1.081-1.126)***	+2%
+Health status[f]	1.097 (1.074-1.120)***	-5%

†N=4036 observations from a total of 2010 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] Adjusted for age and gender
[c] Institutionalized, Marital status, urbanization,
[d] Network size, income, instrumental and emotional support
[e] Sports physical activity and smoking
[f] Chronic diseases, functional limitations, self-rated health, physical performance, polypharmacy, systolic and diastolic blood pressure and cognitive functioning

Table 5. Time trend in overnight hospital admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.013 (0.996-1.030)			
+Demographics	1.016 (0.999-1.034)	+23%	Education	+15%
			Urbanization	+8%
+Psychosocial[d]	1.016 (0.999-1.034)	-0%		
+Lifestyle	1.019 (1.001-1.037)*	+19%	BMI	-6%
			Non-Sports PA	-6%
			Sports PA	+19%
			Smoking	+13%
+Health status	1.004 (0.985-1.022)	-21%	Chronic diseases	-37%
			Functional limitations	-37%
			Self-rated health	-21%
			Physical performance	-5%
			Polypharmacy (>=5 vs.<5)	-68%
			Systolic blood pressure	-5%
			Diastolic blood pressure	-5%
			Depressive symptoms	-5%

†N=3809 observations from a total of 1925 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Network size, income, mastery, instrumental support, emotional and social loneliness

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Table 6. Time trend in acute overnight admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.033 (1.014-1.052)**			
+Demographics[d]	1.036 (1.016-1.056)***	+9%		
+Psychosocial[e]	1.036 (1.017-1.056)***	+3%		
+Lifestyle	1.041 (1.020-1.061)***	+11%	Non-sports physical activity	-3%
			Sports physical activity	+6%
			Smoking	+8%
+Health status	1.031 (1.011-1.052)**	-22%	Chronic diseases	-15%
			Functional limitations	-15%
			Self-rated health	-10%
			Physical performance	-0%
			Polypharmacy (>=5 vs. <5)	-22.5%
			Depressive symptoms	-2.5%
			Cognitive functioning	-0%

†N=4103 observations from a total of 2103 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Education, urbanization,
[e] Network size, mastery, instrumental support , emotional and social loneliness

Figure 1. Study design and number of participants

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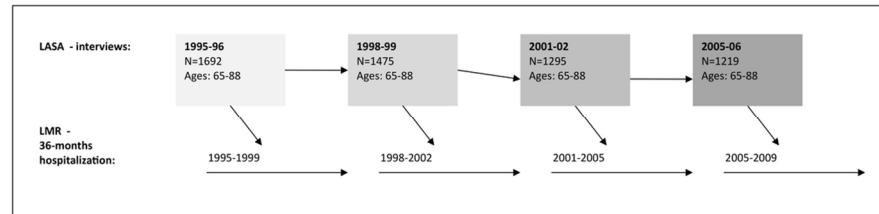
Figure 1. Study design and number of participants

110x40mm (300 x 300 DPI)

Appendix Table 1. Time trends in admission risk, adjusted for other admission types

	Day admission OR (95% CI)	Overnight admission OR (95% CI)	Acute overnight admission OR (95% CI)
Time in years[a]	1.097 (1.074-1.120)***		
+Overnight admission (yes/no)	1.098 (1.075-1.121)***		
Time in years[a]		1.004 (0.985-1.022)	
+Day admission (yes/no)		0.990 (0.972-1.009)	
Time in years[a]			1.031 (1.011-1.052)**
+Day admission (yes/no)			1.021 (1.000-1.042)*

*P<0.05 **P<0.01 ***P<0.001
[a] Adjusted for all covariates

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 2)
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 2)
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported (page 4-5)
Objectives	3	State specific objectives, including any prespecified hypotheses (page 5)
Methods		
Study design	4	Present key elements of study design early in the paper (page 5)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (pages 5-6)
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (page 5)
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (pages 6-7)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (pages 6-7)
Bias	9	Describe any efforts to address potential sources of bias (page 5-8, 11)
Study size	10	Explain how the study size was arrived at (page 5)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 6-7)
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (page 7-8)
		(*b*) Describe any methods used to examine subgroups and interactions (na)
		(*c*) Explain how missing data were addressed (imputation for one variable; page 7; complete cases at each wave were analysed: page 8)
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *(na, this was a trend study in which follow-up was not required. See page 11 for a discussion of the effects of frailty or selective survival)*
		(*e*) Describe any sensitivity analyses (See our results in Appendix Table 1)

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 5 and reference 19)
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (Tables 1 and 2)
		(b) Indicate number of participants with missing data for each variable of interest (we indicated the number of participants per analysis – tables 3-5)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) (page 5)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time (Table 1)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (Tables 1-5)
		(*b*) Report category boundaries when continuous variables were categorized (Tables 1-5)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (na)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (see results in Appendix Table 1)

Discussion

Key results	18	Summarise key results with reference to study objectives (page 9)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 11)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 12)
Generalisability	21	Discuss the generalisability (external validity) of the study results (page 11)

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (page 12)

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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A trend study on the association between hospital admissions and the health of Dutch older adults (1995-2009)

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Key words: Aged, Chronic Diseases, Hospitalization, Trends

Abstract

Objectives: An increase in hospital admission rates in older people may reflect improved access to health care, but also declining health trends in the older population. Due to a lack of individual-level data, the latter possibility has received little attention. The current study examines associations between health status and hospitalization rates of older adults in the Netherlands.

Design: Observational individual-level data linked with hospital register data.

Setting: Data from 1995-2009 from the nationally representative Longitudinal Aging Study Amsterdam were linked with the Dutch Hospital Discharge Register.

Participants: A total of 5681 observations of 2520 respondents, across four measurement points (each with a follow-up of 36 months; ages 65-88 years).

Outcome measures: The contribution of health, demographic, psychosocial and lifestyle characteristics to time trends in hospitalization was assessed in multivariate models.

Results: Between 1995 and 2009, the percentage with one or more overnight admissions (planned or acute) slightly increased, from 38.1 to 39.7%. This was due to an increase in acute admission only (22.2% to 27.0%). Increased prevalences of chronic diseases, functional limitations and polypharmacy accounted for part of the observed increase in acute admissions. In addition, a more than doubled prevalence of day admissions over time was observed (12.3% to 28.3%), a trend that was unrelated to changes in individual characteristics.

Conclusions: This trend study showed a contribution of declines in population health to increases in acute hospital admissions. As these declines did not provide a full explanation, health care reforms and increases in treatment possibilities in this period are likely to have contributed as well.

Article summary

Strengths and limitations of this study

- The Longitudinal Aging Study Amsterdam is a cohort study that is representative for the Dutch older population.
- Multiple waves of data collection, within two different cohorts, were performed between 1995 and 2006, which enabled the study of health trends.
- While previous studies mostly relied on aggregated data, our study links individual-level data on health and lifestyle trends with individual-level hospital registration data.
- The coverage of the Dutch Hospital Discharge register decreased during our study period.
- Health status characteristics and hospital admission were linked per individual, but it remains to be studied if and to what extent the health status of patients at the time of their admission has changed.

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Introduction

With the aging population in most Western countries, there is increasing pressure to reduce health care expenditures. Hospital care is the most costly type of care [1] and for the greater part involves older adults. Pressures for cost containment as well as the introduction of new medical technologies have resulted in a reduced length of stay in most developed countries in recent decades [2;3]. Another approach to cost containment may be prevention of hospitalization and adverse events related to hospital admissions [4], but several studies - not all [5] - show increases in hospital admission rates and hospital costs in European countries and the US over the past decades [6-9].

Both individual and societal factors may affect the utilization of hospital care [10]. Research addressing the mechanisms underlying increased use of care and increased health care expenditures showed that these are largely driven by societal changes, such as improved medical technology and more active treatment of the oldest old, and only for a small part by demographic changes [8;11].

Regarding individual factors, the prevalence of morbidity and disability - the most immediate causes of hospital admission [10;12-14] - has shifted in recent generations of older adults. Ample evidence exists of an increased prevalence of chronic diseases and comorbidity over time, both in admitted patients and in older adults in the community [3;15-20]. We expect that this has led to more health care utilization in recent decades. Research is inconclusive regarding trends in disability or in the severity of morbidity, but in the Netherlands disability trends have not been as favourable as in some other countries [17;21]. Technological developments in recent decades may have led to better treatment possibilities, and in turn, to better health, functioning and survival of older adults. Longer survival specifically in those with chronic diseases, however, leads to a higher prevalence of chronic conditions and associated hospital admission risk. Such mixed trends make it difficult to formulate clear-cut hypothesis regarding trends in hospital admission. In particular if one considers the variety in types of hospital admission, such as acute vs. planned, and day vs. overnight admissions, which all address different health care needs.

Given the societal costs associated with hospital care and the burden of hospitalization on older patients themselves [4], reducing hospital admissions among older adults is an important goal. However, simply reducing the volume of hospital care should not be aimed for, when it is at the expense of poorer quality of care or an increased disease burden. In fact, reducing one type of admission (e.g. day admissions) may result in more admissions of another - more critical – type (e.g. acute admissions). Policies aiming at the prevention of hospitalization

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should be informed by research on underlying health trends in the older population. In addition, trends in day admissions and overnight admissions (acute or planned) should be evaluated in relation to each other.

The current study explores recent hospital admission trends - day admissions and overnight (planned and acute) admissions. It also examines to what extent up- or downward trends can be attributed to changing health of the older population. Individual-level health and hospital data are needed for this purpose, since these are more sensitive than population means. In addition, they may provide insight in the interrelationships between various individual characteristics. We linked individual morbidity data from Dutch older adults between 1995 and 2009, obtained within a nationally representative cohort study on aging, the Longitudinal Aging Study Amsterdam, with data from the Dutch Hospital Discharge Register (DHDR), providing individual-level data on hospital admissions.

Methods

Data sources
LASA

In 1992, a random sample of older adults was drawn from the population registries of 11 municipalities in three geographical regions in the Netherlands (ages: 55-85 years; N: 3,107) with a co-operation rate (the proportion of completed interviews in the number of contacted eligible persons) of 62% [22]. Follow-up measurements took place at roughly 3 years intervals in 1995-96 and 1998-99, 2001-02 and 2005-06 (Figure 1). In 2002, a new cohort was sampled (ages: 55-64 years; N: 1,002; co-operation rate: 62%). Complete medical records were available for the period 1995 to 2009, therefore LASA participants who had at least one interview between 1995-96 and 2005-06 were included. Waves will be referred to using the mid-year of each follow-up (36 months): 1997, 2000, 2003 and 2007. We selected all 2,520 adults who were aged 65 to 88 at the time of at least one wave, to compare a fixed age range which was available in each wave. Thirty six percent of these respondents were included in one wave, 23% in two waves, 21% in three waves and 20% in all four waves, leading to a total number of 5,681 observations.

DHDR

The Dutch Hospital Discharge Register (Landelijke Basisregistratie Zorg, (LBZ), previously: Landelijke Medische Registratie (LMR)) [23] registers admissions in most general and

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academic hospitals and some single-specialty hospitals, thus providing a nearly complete coverage of hospital admissions in the Netherlands. All admissions are registered based on a uniform registration system. The data include admission and discharge dates, extensive diagnosis and treatment information and death during admission. A study on the reliability of admission and discharge information in the DHDR revealed that in 1999, 99% of this information was registered correctly [24].

Linkage of data sources

For the purpose of this study, Statistics Netherlands linked data from the DHDR and LASA to each other via the Municipal Population Registry (MPR). Both data sets are anonymized, so this linkage occurred on the basis of a set of identifying variables: postal code, date of birth and gender [23]. Linkage with the MPR was fully achieved for 98% of the eligible study sample. Consent forms for accessing medical records were signed by the LASA participants and the study was approved by the Medical Ethics Committee of the VU University Medical Center.

Measurements

Table 1 gives an overview all study variables and how they were measured. Hospital admission within 36 months follow-up of each LASA interview was coded as not admitted (0) or admitted at least once (1). Admissions were categorized into day admission or overnight admission. Day admissions were defined as planned admissions where specialist care is given for several hours during the day. Visits to the emergency unit were not included as a day or overnight admission, unless an overnight admission followed from this visit. Overnight admissions were all admissions including at least one night. These admissions were further divided into acute or elective admissions.

To increase our understanding of which individual-level factors underlie hospital admission trends, we assessed the role of demographic, psychosocial and lifestyle factors stepwise in addition to health status factors.

Education level was measured in years. *Net monthly income* of respondents living with a partner was multiplied by 0.7, to make their income comparable with that of one-person households [25]. Also included were *level of urbanization* (categories were <500, 500-1000, 1000-1500, 1500-2500 and >2500 addresses per km^2), *marital status* (married vs. not married) and an indicator of being *institutionalized* or not.

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As psychosocial variables we included *mastery,* assessed with a 5-item version of the Pearlin Mastery scale [26], *social network size* [27], the amount of *instrumental* and *emotional support received* from one's network members over the past year [27] and *social* and *emotional loneliness*, assessed with the 11-item De Jong Gierveld Loneliness Scale [28].

Smoking behavior was categorized into nonsmokers, former smokers or current smokers. If respondents had stopped more than 20 years ago, they were categorized as nonsmokers, since studies have shown similar mortality risks for those who stopped more than 20 years ago, compared to non-smokers [29]. *Alcohol consumption* (glasses per week) was computed by multiplying the number of days per week respondents usually drank and the number of glasses each time [30]. *Body mass index* was calculated by dividing measured weight (in kilogram) by height (in meters) squared. Averaged daily minutes of *physical activity (PA)* was computed by multiplying self-reported frequency and duration of activities. This was done separately for non-sports and sports activities [31]. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.

Self-reported health factors were: a count of nine *chronic diseases* (chronic non-specific lung disease, cardiac disease, peripheral arterial disease, stroke, diabetes mellitus, arthritis, cancer, and a maximum of two other diseases that had been present for at least 3 months [32]), *functional limitations*, indicating the number of activities out of six that respondents reported to have difficulty performing [33;34], s*elf-rated health,* with responses ranging from very good (1) to poor (5)[35]. *Previous care use* was also included, defined as having had any contact with a general practitioner or a medical specialist in the previous six months.

Objective health measures were: *Physical performance,* measured with three performance-based tests (walking speed, ability to rise from a chair and putting on and taking off a cardigan) [36]. Sum scores ranged from 0 to 12, with 12 indicating the best performance. We included a measure of *polypharmacy,* i.e. whether people took five or more drugs versus four or less. The number of drugs used was recorded from the medicine containers in the home of the respondents. Since there is no agreed definition of polypharmacy [37], we based our definition of polypharmacy on previous studies [e.g., 38;39]. *Systolic and diastolic blood pressure (BP)* measurements were performed in sitting position. If multiple BP measurements were available (waves 2001-02 and 2005-06), only the first measurement was used to make the measurements comparable across waves. *Depressive symptoms* were measured with the Center for Epidemiologic Studies Depression Scale [40], a 20-item scale covering depressive

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symptomatology in the past week. *General cognitive functioning* was measured with the Mini-Mental State Examination [41].

Statistical analyses

Descriptive statistics were weighted according to age and gender. Probability weights were computed by dividing 5-year age and gender strata proportions in 1997, 2000 and 2007 by proportions of the same strata in 2003. For analysis of trends, Generalized Estimating Equations (GEE) analysis was used, which corrects for the fact that individuals were included in multiple waves [42]. Binomial logit models were applied for three dichotomous outcomes: Having or not having within 36 months after the interview: (1) one or more day admissions, (2) one or more overnight admissions, and (3) one or more acute overnight admissions. An independent time variable represented the study years (0, 3, 7 and 10 years). All models were based on complete cases and they were age- and gender-adjusted.

Four blocks of independent variables were included to examine their contribution to time trends in hospital admission. These blocks included the demographic, psychosocial, lifestyle and health status variables that showed associations (significant at P<.20) with the outcome in age- and gender-adjusted models. The blocks were entered in order from most distal (demographic) to most proximal (physical health status) determinants [10]. Their contribution was assessed by calculating the percentages decline or improvement in the coefficient for time after including them in the regression models. If the regression coefficient of time changed more than 10% after entering a block, each variable in the block was entered separately, to assess which factor mostly accounted for the effect. Analyses were conducted using STATA 14 (StataCorp. 2015).

Results

The age- and gender-adjusted percentage of older adults with one or more hospital admissions within 36 months after their interview increased from 42.8% in 1997 to 53.4% in 2007 (Table 2). Underlying this trend is a more than doubled percentage that experienced a day admission (from 12.3 to 28.3%), and a slightly increased percentage with one or more overnight admissions over time (percentage increased from 38.1 to 39.7%). The last increase concerned only acute admissions. Acute admission showed a curvilinear trend: it increased in particular after the year 2003. During the study period, a sharp decrease was observed in the length of stay, both in the average stay per overnight admission and in the total hospital days (day or overnight) within a period of 36 months.

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Increasing trends were observed in education and income levels, the prevalence of being married, network size, the level of support received (Table 3). The level of loneliness (both social and emotional) decreased over time. Lifestyle factors show a mixed trend: BMI increased and time spent on non-sports physical activity decreased, but the prevalence of smoking decreased and time spent on sports increased over time. Most health factors, including the number of chronic conditions, functional limitations, medication use, depressive symptoms and self-rated health showed a worsening trend. In contrast, cognitive functioning improved and systolic blood pressure decreased.

Tables 4, 5 and 6 demonstrate the time trends (odds ratios reflect the effect per year of the study) and potential explanatory factors in those admission types that increased during the study period. The pronounced increase in day admission risk was not explained by any of the individual characteristics, which can be observed from very small changes in the odds ratio after adding the four blocks of determinants (Table 4). The significant increase in overnight admission risk disappeared after selecting those respondents who had complete information on all predictors (Table 5). Still, introducing the predictors by domain revealed several suppressive (positive percentages) and explanatory (negative percentages) effects. After taking into account these suppressors (e.g. education, sports physical activity and smoking) the increase in overnight admission was larger: their favorable health effects have to some extent prevented a larger increase in admission risk. The explanatory factors (e.g. polypharmacy, chronic disease and functional limitations) decreased the regression coefficients: they explain some of the increase in admission risk. It should be noted, however, that the odds ratios remain very small for the increase in overnight admissions. For acute overnight admissions similar results were observed (Table 6), except that the statistically significant trend now remained after including all predictors. It should be noted that contact with general practitioner or medical specialist was not included in the final models, as they can be considered a prerequisite for most hospital admissions. Similar results were obtained in models that did include these variables.

We expected that changes in one admission type would have an influence on the prevalence of others. Therefore, in the full model for *day* admission we additionally included an indicator of having one or more *overnight* admissions, and in the models for total and acute *overnight* admissions we adjusted for having one or more *day* admission (Appendix Table 1). This adjustment had only minor impact: only the increase in acute admission risk over time was attenuated after adjusting for day admission risk.

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Discussion

We found a ten percent point increase in the share of older adults that experienced one or more hospital admissions within 36 months after their interview: from 43% in 1995 to 53% in 2007. A substantial contribution to this increase was made by day admissions, a type of care that shows a sharp increase in volume: the share of older adults with one or more day admissions increased from 12% to 28%. This trend in day admission risk was not explained by changes in any of the demographic, psychosocial, lifestyle or health characteristics. However, the increase in acute overnight admission risk did show a relationship with worsening trends in health.

This study focused on individual level characteristics, other than age and gender, which were controlled for, and not on higher level changes such as changes in general practitioner and hospital care data. Regardless, our results also reflect policy and organizational changes in medical care in the Netherlands. First, regarding the type of hospital admission, diagnostics and treatments of a wide range of diseases are increasingly being performed during day admissions instead of during overnight admissions [1;43]. Second, budgetary constraints that had resulted, among other things, in long waiting lists, were relaxed in 2001. These budgetary constraints did not concern primary care, but hospital care, for the most part in-patient hospital care. In particular the shift in overnight hospital admissions, from a decrease before the year 2000 to an increase after that, coincides with this development. Third, in 2005 a new financing system for hospitals was introduced. The Diagnosis Treatment Combination system (DBC, similar to diagnosis-related groups (DRGs)) substantially increased the incentive for Dutch hospitals to shorten lengths of stay. Indeed, substantial decreases in length of stay of overnight admissions have been reported [6]. At the same time, this development to a patient-based payment without a fixed budget ceiling may have stimulated health care spending [44]. An increase in health care spending may be reflected in an increase in the share of respondents who had contact with a medical specialist during our study period.

We have argued that the increase in hospital admission risk that was found relates to the above mentioned developments. Still, we found that the proportion of older people who experienced an overnight admission in general did not increase, while the proportion who experienced an acute overnight admission did. This finding refines our hypothesis in that the increase in disease burden has only contributed to the growing use of acute hospital care over time. A report on out-of-hours general practitioner care in the Netherlands [45] indeed showed that more acute cases have been presented at these units over the past decade.

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Chronic diseases, medication use, functional limitations and poor self-rated health were shown to be predictive of hospitalization in previous studies [14;46;47]. All these health indicators showed worsening trends in our study, partly corroborating findings from previous research [17;18;48]. An increase in chronic conditions in one person (multimorbidity) is frequently accompanied by an acute event that may lead to acute hospitalization [49,50]. An increase in medication prescription has been reported for older people in the UK and Italy as well [39;51]. Having a higher number of drugs prescribed was shown to be independently associated with non-elective hospital admissions [46]. Self-rated health explained some of the increases in admission risk, which might be due to it being a proxy for health factors that are not captured by more specific measures of disease and functioning [52]. Other factors that showed an increase during the study period, which are associated with a higher risk of hospital admission and poor outcomes of hospitalization, were mean body mass index and depressive symptoms [53;54].

The increase in disease burden may be due to improved survival particularly among older adults with chronic diseases [55;56]. This trend, which is positive in itself, may have led to more complex cases in recent years. This complexity may increase the unpredictability of acute events, and thus including a broad set of health factors might not fully explain the increasing trend in acute admissions. An increase in acute admissions may also be an effect of shorter length of stay, through an increasing need for readmissions. However, it appears from our results that more people experience an admission, rather than some people experiencing more admissions. Discussion is still ongoing on the extent to which a decrease in the length of stay is associated with quality of care and readmission rates [3;57]. Finally, increases in acute admissions may have resulted from a shift of emergency department presentations towards the end of the day, which leads more often to an admission. The extent to which this has played a role in our study remains uncertain.

A recent study from the UK reported that among those aged 65-84 years, disease prevalence and medication prescription increased between 2003 and 2012 [51]. The authors further reported an increase in hospital admission rate, which was small and not significant in those aged 65-84 years, but larger in those older than 85 years. They found for both age groups an increase in emergency admission. These findings are similar to what we found. At the same time, previous studies in Sweden have shown that between 1987 and 2010 both first and subsequent hospitalization (of at least two nights) occurred at older ages, which suggests a decrease in hospital admission rate [58;59]. In the US, finally, evidence was found for an increase in emergency department (ED) visits, but not for admission rates [60], although

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another study (2001-2009) did report an increase in admission rates [61]. It should be noted, however, that both definitions of hospitalization and health care contexts differ across countries. For example, ED visits in the US may represent less acute cases as compared to the Netherlands, as ED care more often serves as a substitute for primary care in the US [62].

We acknowledge that changes in disease burden and changes in medical care are not always easily separated. For example, an increase in health care expenditures during the study period [11] may have resulted in or coincided with more active treatment of older adults, and a reduction in age discrimination regarding administration of treatments [8;11]. This allows longer life expectancy in particular among older adults with chronic diseases [55;56], and thus results in a higher prevalence of these diseases. Furthermore, it might be that the same health care investments that lead to an increase in the volume of hospital care also lead to earlier diagnosis which in turn is associated with increases in treatment. However, worsening trends in self-rated health and functioning contradict this hypothesis, as they do not likely reflect better quality of care or access to hospital care over time. In addition, polypharmacy may bring about its own health risks [37].

Some limitations of this study should be mentioned. Although health status characteristics and hospital admission were linked per individual, it remains to be studied if and to what extent health status of patients at the time of admission has changed. Another trend on which we had no data concerns the emergency department presentations without an admission following, which could have provided additional insight in our results. Participation of hospitals in the DHDR was nearly 100% until 2004. Since 2005 some hospitals (temporarily) stopped participating in DHDR because of the introduction of the Diagnosis Treatment Combination registration. As a result, the estimated percentage of missing DHDR records increased from 3.9% in 2004 to 14.6% in 2009. A third limitation may be attrition of a small proportion of the sample due to frailty or selective survival, which may have caused an underestimation of health problems [22]. In a previous study on trends in chronic diseases and disability, we found these effects to be limited [63].

Conclusion

This study among Dutch older adults shows that acute overnight and day admissions increased between 1997 and 2007. This increase in hospital admission risk implies higher health care expenditures. Some interesting associations emerged, suggesting that improvements in lifestyle contributed to a fall in acute hospital admission risk, whereas the increase in disease burden contributed to an increase in acute hospital admission risk over

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time. If our findings reflect greater demand for hospital admission in the older population this has implications for health care planning as well as for older adults' wellbeing. Therefore, future studies should further address the relative contributions of changes in health policy and in population health on hospital care utilization.

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Table 1. Study variables

Hospital registry (LMR) variables	Measurement/Definition	Level of measurement	Range/Categories/Unit
Outcome variables			
Hospital admission	Admitted at least once within 36 months follow-up.	Dichotomous	Yes/No
Day admission	At least one planned admission during the day within 36 months follow-up.	Dichotomous	Yes/No
Overnight admission	At least one overnight admission (planned or acute) within 36 months follow-up.	Dichotomous	Yes/No
Acute overnight admission	At least one acute overnight admission within 36 months follow-up.	Dichotomous	Yes/No
LASA variables			
Demographic variables			
Age		Continuous	65-88 years
Gender		Dichotomous	Female/male
Education in years	Categories: nine levels of education attained, recoded into education in years.	Continuous	5-18 years
Income	Net monthly income in Euros. Income level of the second wave onwards was corrected for inflation (on average 2.3% per year). Net monthly income of respondents living with a partner was multiplied by 0.7, to make their income comparable with that of one-person households.	Continuous	334-2270
Marital status	Categories: Unmarried, married, divorced, widowed.	Dichotomous	Married/not married
Urbanisation level	Data are provided by Statistics Netherlands. Categories: 5 'very highly (>2500)' 4 'highly (1500-2500)' 3 'somewhat (1000-1500)' 2 'little (500-1000)' 1 'not (<500)'.	Continuous	1-5
Institutionalised	Categories: Independent housing, residential home, nursing home – somatic, nursing home – psychogeriatric.	Dichotomous	Institutionalised/Living independently
Psychosocial factors			
Network size	Number of network members identified by the respondent in seven types of relationships.	Continuous	0-67
Received instrumental support	Four questions were asked about the relationships with a maximum of nine network members with whom contact was most frequent. Instrumental support received: how often during the previous year the respondent had received help with daily chores around the house, such as preparing meals, cleaning the house, transportation and small repairs. Emotional support received: how often, during the previous year, had they talked to their network member about personal experiences and feelings. Categories: never (0), rarely (1), sometimes (2) or often (3).	Continuous	0-36
Received emotional support		Continuous	0-36
Mastery	Pearlin Mastery scale [26].	Continuous	5-25
Social loneliness	Five items of the 11-item scale De Jong Gierveld [28]	Continuous	0-5
Emotional loneliness	Six items of the 11-item scale De Jong Gierveld [28]	Continuous	0-6
Lifestyle factors			
Alcohol intake	Self-reported number of days per week respondents usually drank*the number of glasses each time.	Continuous	0-77 glasses/week
Body Mass Index	Measured weight (in kilogram)/height (in meters) squared.	Continuous	Kg/m^2
Smoking	Self-reported smoking status. If respondents had stopped more than 20 years ago, they were categorized as nonsmokers, since studies have shown similar mortality risks for those who stopped more than 20 years ago, compared to non-smokers [29].	Nominal	Non-smoker/Former smoker/Current smoker
Sports physical activity	Self-reported frequency*duration of sports activities. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.	Continuous	Min/day

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Non-sports physical activity	Self-reported frequency*duration of non-sports activities. If the frequency or the time spent on the activity was missing, we imputed these by substituting with gender- and activity-specific means.	Continuous	Min/day
Health factors			
Chronic diseases	Self-reported presence of chronic non-specific lung disease, cardiac disease, peripheral arterial disease, stroke, diabetes mellitus, arthritis, cancer, and a maximum of two other diseases that had been present for at least 3 months [32].	Continuous	0-9
Functional limitations	Self-reported number of activities out of six that respondents had difficulty performing [33;34].	Continuous	0-6
Self-rated health	Categories: very good (1), good (2), fair (3), sometimes good, sometimes bad (4), poor (5) [35].	Continuous	1-5
Contact with general practitioner	Self-reported contact with a general practitioner in the previous six months.	Dichotomous	Yes/No
Contact with medical specialist	Self-reported contact with a medical specialist in the previous six months.	Dichotomous	Yes/No
Physical performance	Time in seconds measured for three performance-based tests (walking speed, ability to rise from a chair and putting on and taking off a cardigan). Sum scores of test-specific quartiles ranged from 0 to 12, with 12 indicating the best performance. [36].	Continuous	4-12
Polypharmacy	The number of drugs used was recorded from the medicine containers in the home of the respondents. Polypharmacy was defined as having ≥5 vs. <5 drugs prescribed. [38;39]	Dichotomous	≥5 vs. <5
Systolic and diastolic blood pressure	Measurements were performed in sitting position. If multiple BP measurements were available (waves 2001-02 and 2005-06), only the first measurement was used to make the measurements comparable across waves.	Continuous	mmHg
Depressive symptoms	Center for Epidemiologic Studies Depression Scale [40].	Continuous	0-60
Cognitive functioning	Mini-Mental State Examination [41].	Continuous	0-30

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Table 2 Descriptives - dependent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend[b]
	%/mean(sd)	%/mean(sd)	%/mean(sd)	%/mean(sd)	
% Female gender (unweighted)	53.3	55.7	55.2	55.8	-
Mean age (range: 65-88) (unweighted)	76.0 (6.7)	75.5 (6.7)	75.2 (6.6)	74.5 (6.4)	-
N with >=1 hospital admissions	724 (42.8)	629 (42.7)	618 (47.7)	652 (53.4)	P<.001
>=1 Day admissions	207 (12.3)	253 (17.2)	299 (23.1)	345 (28.3)	P<.001
>=1 Overnight admissions (Acute and elective)	645 (38.1)	501 (34.0)	480 (37.1)	484 (39.7)	P<.05
>=1 Acute	375 (58.1)	305 (60.9)	296 (61.2)	330 (68.2)	P<.001
>=1 Elective	414 (64.2)	293 (58.5)	294 (61.3)	283 (58.5)	Ns
Per admitted person:	*N=724*	*N=629*	*N=618*	*N=652*	
Nr of day admissions	2.1 (2.2)	2.1 (2.4)	2.4 (3.0)	2.7 (4.8)	P<.001
Nr of overnight admissions	1.6 (1.3)	1.4 (1.4)	1.4 (1.7)	1.5 (1.6)	Ns
Nr of acute admissions	0.8 (1.0)	0.7 (0.9)	0.7 (0.9)	0.8 (1.2)	Ns
Nr of elective admissions	0.9 (1.0)	0.7 (1.1)	0.8 (1.5)	0.7 (1.0)	P<.01
Mean length of stay per overnight admission (days)	12.8 (13.1)	11.6 (14.9)	9.7 (9.2)	7.4 (6.4)	P<.001
Total length of stay for all admissions (days)	21.1 (26.2)	16.4 (25.0)	14.6 (18.1)	12.5 (19.8)	P<.001

[a]All outcomes are weighted to the age- and gender distribution in 2001-02
[b]In age- and gender adjusted models

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Table 3 Descriptives- independent variables[a]

	1997 N=1692	2000 N=1474	2003 N=1295	2007 N=1220	P for trend
	% / mean (sd)	% / mean (sd)	% / mean (sd)	% / mean (sd)	
Demographic variables					
Education in years (5-18)	8.8 (3.3)	9.0 (3.2)	9.2 (3.3)	9.6 (3.3)	P<.001
Income	963 (404)	988 (393)	1027 (359)	1052 (319)	P<.001
Married	53.4	53.6	55.4	59.7	P<.001
Urbanization level (1-5)	3.2 (1.5)	3.1 (1.4)	3.0 (1.4)	3.0 (1.4)	P<.01
Institutionalised	5.1	3.8	3.8	2.8	P<.05
Psychosocial factors					
Network size (0-67)	14.1 (8.3)	14.4 (8.6)	15.0 (8.6)	16.0 (9.1)	P<.001
Received instrumental support (0-36)	14.8 (6.7)	14.6 (6.7)	15.1 (6.5)	15.7 (6.7)	P<.001
Received emotional support (0-36)	20.7 (8.3)	20.7 (7.9)	21.9 (7.9)	22.1 (7.7)	P<.001
Mastery (5-25)	17.1 (3.4)	17.2 (3.4)	17.2 (3.4)	17.3 (3.3)	Ns
Social loneliness (0-5)	1.1 (1.4)	1.1 (1.4)	1.0 (1.4)	0.9 (1.4)	P<.05
Emotional loneliness (0-6)	1.3 (1.8)	1.3 (1.8)	1.2 (1.7)	1.1 (1.7)	P<.01
Lifestyle factors					
Alcohol intake (0-77 glasses p/w)	7.5 (11.5)	6.8 (9.6)	7.2 (9.5)	7.6 (10.3)	Ns
Body Mass Index (kg/m^2)	26.9 (4.2)	27.3 (4.2)	27.4 (4.2)	27.5 (4.3)	P<.001
Non-smoker	60.8	66.9	67.5	68.8	P<.01
Former	19.7	17.1	17.3	17.4	Ns
Current	19.5	15.9	15.2	13.9	P<.001
Sports physical activity (min/day)	10.5 (24.1)	13.5 (29.4)	18.5 (33.2)	19.8 (31.7)	P<.001
Non-sports physical activity (min/day)	137.2 (94.3)	139.2 (95.3)	136.6 (100.1)	129.2 (98.9)	P<.01
Health factors					
Chronic diseases (0-9)	1.6 (1.2)	1.7 (1.3)	1.7 (1.2)	1.8 (1.2)	P<.001
Functional limitations (0-6)	1.6 (1.9)	1.6 (1.9)	1.7 (1.9)	1.8 (1.9)	P<.001
Self-rated health (1-5)	2.45 (1.0)	2.42 (0.9)	2.46 (0.9)	2.49 (0.9)	P<.01
Contact with general practitioner	79.1	83.8	81.5	81.1	Ns
Contact with medical specialist	50.7	51.8	53.4	53.0	P<.05
Physical performance (4-12)	7.0 (2.7)	6.8 (2.7)	7.0 (2.6)	7.4 (2.6)	Ns
Polypharmacy (>=5 vs. <5)	16.6	22.6	24.1	31.0	P<.001
Systolic blood pressure (mmHg)	153.1 (26.1)	152.6 (25.0)	148.3 (25.5)	149.6 (25.4)	P<.001
Diastolic blood pressure (mmHg)	83.3 (13.6)	83.0 (12.2)	82.4 (13.3)	82.9 (13.7)	Ns
Depressive symptoms (0-60)	8.4 (8.1)	8.7 (7.6)	9.2 (7.5)	8.6 (7.3)	P<.001
Cognitive functioning (0-30)	26.6 (3.3)	26.9 (3.1)	27.0 (3.2)	27.2 (2.7)	P<.001

[a]All descriptives are weighted to the age- and gender distribution in 2001-02; trends were age- and gender adjusted

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Table 4. Time trend in day admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]
Time in years[b]	1.105 (1.083-1.127)***	
+Demographics[c]	1.104 (1.082-1.126)***	-1%
+Psychosocial[d]	1.101 (1.079-1.123)***	-3%
+Lifestyle[e]	1.103 (1.081-1.126)***	+2%
+Health status[f]	1.097 (1.074-1.120)***	-5%

†N=4036 observations from a total of 2010 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] Adjusted for age and gender
[c] Institutionalized, Marital status, urbanization,
[d] Network size, income, instrumental and emotional support
[e] Sports physical activity and smoking
[f] Chronic diseases, functional limitations, self-rated health, physical performance, polypharmacy, systolic and diastolic blood pressure and cognitive functioning

Table 5. Time trend in overnight hospital admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.013 (0.996-1.030)			
+Demographics	1.016 (0.999-1.034)	+23%	Education	+15%
			Urbanization	+8%
+Psychosocial[d]	1.016 (0.999-1.034)	-0%		
+Lifestyle	1.019 (1.001-1.037)*	+19%	BMI	-6%
			Non-Sports PA	-6%
			Sports PA	+19%
			Smoking	+13%
+Health status	1.004 (0.985-1.022)	-21%	Chronic diseases	-37%
			Functional limitations	-37%
			Self-rated health	-21%
			Physical performance	-5%
			Polypharmacy (>=5 vs.<5)	-68%
			Systolic blood pressure	-5%
			Diastolic blood pressure	-5%
			Depressive symptoms	-5%

†N=3809 observations from a total of 1925 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Network size, income, mastery, instrumental support, emotional and social loneliness

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Table 6. Time trend in acute overnight admission and explanatory factors†

	OR (95% CI)	Change in regression coefficient[a]	*Explanatory factors*	Change in regression coefficient[b]
Time in years[c]	1.033 (1.014-1.052)**			
+Demographics[d]	1.036 (1.016-1.056)***	+9%		
+Psychosocial[e]	1.036 (1.017-1.056)***	+3%		
+Lifestyle	1.041 (1.020-1.061)***	+11%	Non-sports physical activity	-3%
			Sports physical activity	+6%
			Smoking	+8%
+Health status	1.031 (1.011-1.052)**	-22%	Chronic diseases	-15%
			Functional limitations	-15%
			Self-rated health	-10%
			Physical performance	-0%
			Polypharmacy (>=5 vs. <5)	-22.5%
			Depressive symptoms	-2.5%
			Cognitive functioning	-0%

†N=4103 observations from a total of 2103 respondents
*P<0.05 **P<0.01 ***P<0.001
[a] After adding this block, compared to a model with all previously entered blocks.
[b] After adding this covariate, compared to a model with all previously entered blocks.
[c] Adjusted for age and gender
[d] Education, urbanization,
[e] Network size, mastery, instrumental support , emotional and social loneliness

Figure 1. Study design and number of participants

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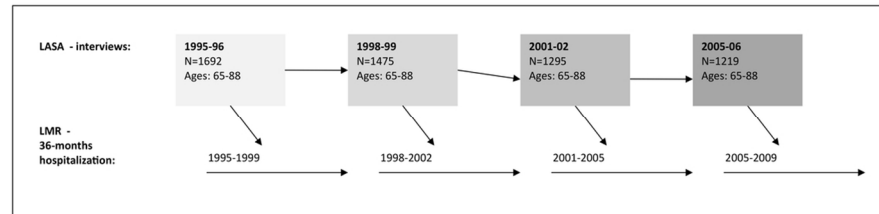
Figure 1. Study design and number of participants

110x40mm (300 x 300 DPI)

Appendix Table 1. Time trends in admission risk, adjusted for other admission types

	Day admission OR (95% CI)	Overnight admission OR (95% CI)	Acute overnight admission OR (95% CI)
Time in years[a]	1.097 (1.074-1.120)***		
+Overnight admission (yes/no)	1.098 (1.075-1.121)***		
Time in years[a]		1.004 (0.985-1.022)	
+Day admission (yes/no)		0.990 (0.972-1.009)	
Time in years[a]			1.031 (1.011-1.052)**
+Day admission (yes/no)			1.021 (1.000-1.042)*

*P<0.05 **P<0.01 ***P<0.001

[a] Adjusted for all covariates

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 2)
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 2)
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported (page 4-5)
Objectives	3	State specific objectives, including any prespecified hypotheses (page 5)
Methods		
Study design	4	Present key elements of study design early in the paper (page 5)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (pages 5-6)
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (page 5)
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed
		Case-control study—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (pages 6-7)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (pages 6-7)
Bias	9	Describe any efforts to address potential sources of bias (page 5-8, 11)
Study size	10	Explain how the study size was arrived at (page 5)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 6-7)
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (page 7-8)
		(*b*) Describe any methods used to examine subgroups and interactions (na)
		(*c*) Explain how missing data were addressed (imputation for one variable; page 7; complete cases at each wave were analysed: page 8)
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *(na, this was a trend study in which follow-up was not required. See page 11 for a discussion of the effects of frailty or selective survival)*
		(*e*) Describe any sensitivity analyses (See our results in Appendix Table 1)

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 5 and reference 19)
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (Tables 1 and 2)
		(b) Indicate number of participants with missing data for each variable of interest (we indicated the number of participants per analysis – tables 3-5)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) (page 5)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time (Table 1)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (Tables 1-5)
		(*b*) Report category boundaries when continuous variables were categorized (Tables 1-5)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (na)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (see results in Appendix Table 1)

Discussion

Key results	18	Summarise key results with reference to study objectives (page 9)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 11)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 12)
Generalisability	21	Discuss the generalisability (external validity) of the study results (page 11)

Other information

| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (page 12) |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.