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Regional differences in health further explained

The contribution of lifestyle, loneliness and mastery

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Abstract Like in most Western countries, regional health inequalities are also present in the Netherlands. Explaining these inequalities is necessary for policymakers to target interventions to reduce them. Regional health inequalities are usually attributed to demographic and socio-economic factors, while lifestyle and psychosocial factors are increasingly shown to impact individuals' health. Therefore, this study analyses the role of lifestyle, loneliness, and self-mastery in explaining regional inequalities, in addition to demographic factors and SES, for self-rated health, presence of chronic diseases, and psychological distress. Analyses are performed in the linked dataset from the Dutch Public Health Services, Statistics Netherlands, and the National Institute for Public Health and the Environment for the year 2016 ($n = 334{,}721$). The results show that lifestyle, loneliness and self-mastery contribute to the regional health inequalities in self-rated health and presence of chronic diseases. For psychological distress, both loneliness and self-mastery contribute to the regional health inequalities. Addressing lifestyle and psychosocial factors can offer policymakers additional pathways to bridge regional health inequalities. In this study, the region of Zuid-Limburg represents the reference region. Use compare regions for health and healthcare costs (Regiovergelijker gezondheid en zorgkosten [1]) in order to select all other Dutch regions as reference region.

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Introduction

Large socioeconomic health differences are prevalent in the Netherlands, and these differences have barely changed or have even increased in recent decades [2]. There are also regional differences. For example, 78.5% of all adults in the Dutch Public Health Services region of Central Holland (*Hollands Midden*) report a (very) good self-perceived health, compared with 69.5% of those living in South Limburg (*Zuid-Limburg*) [3]. The underlying determinants of health inequalities are very complex. They are often related to socioeconomic status (SES) [4], accumulate over different stages of life, and often lie outside the domain of the health sector [4]. Factors in the areas of housing, well-being, working and living environment, and education are related to health [5]. Moreover,

the prevalence of the determinants of health differs greatly per region.

When explaining health differences between regions, the population is usually adjusted for differences in age, gender, income, education level, and migration background. According to studies based on the Health Monitor 2016, 11% of the variation in perceived health can be explained by these factors [6]. The authors suggested that in follow-up research, factors based on well-being and lifestyle should also be included to explain differences in perceived health. There is a large body of evidence for the negative health effects of lifestyle habits, such as smoking, alcohol consumption, and (inadequate) physical activity [7]. Lifestyle determinants alone, however, are not sufficient to explain health differences [4, 8].

In recent years, well-being and psychosocial factors related to health have gained increasing attention. For example, loneliness (the physical experience of a lack of connection with other people [9]) has been directly associated with increased mortality [10], morbidity, poorer mental health [11], and unhealthy habits such as smoking [11, 12], higher body mass index (BMI) [12], and less physical activity [12]. Moreover, in our current participatory society, citizens need better mastery skills to direct their own lives, even when they rely on support or care from others [13]. Although this is important for good (self-rated) health, it is not realistic for everyone [14]. Degrees of loneliness and mastery skills can vary per region and can thus contribute to regional health inequalities. All these factors together complicate efforts to diminish health inequalities. These inequalities represent a complex social issue, which requires a broader view [4]. In addition to demographic factors and SES, more research is needed to determine the contribution of lifestyle, loneliness, and mastery to explaining regional health inequalities.

The aim of this study was to further explain regional health inequalities in self-rated health, chronic disease, and psychological distress by using a more extensive set of lifestyle factors, loneliness, and mastery, in addition to demographic factors and SES. With the results of this research, we aimed to provide more insight into the factors associated with regional health inequalities in order to provide policymakers with more leads to help diminish health inequalities.

Methods

Data and sampling

This was a cross-sectional study based on data from the Dutch Health Survey (2016) and registry data from Statistics Netherlands. In accordance with the Dutch Public Health Law, Dutch municipalities are obliged to assess local public health issues. For this purpose, the Health Survey is held once every four years. This survey is a collaboration between the Dutch Public Health Services, the Dutch National Institute for Public Health and the Environment (*RIVM*), and Statistics Netherlands. The survey covers various topics regarding the respondent's personal situation, such as lifestyle, mental and physical health, loneliness, household, and mastery. As a result of the sampling method used (complex sample method), weighting factors were calculated based on a number of individual and regional background characteristics to ensure the sample was representative of the entire Dutch population [15]. The sample ($N = 457{,}150$; response rate: ~40% [15]) included the non-institutionalized population aged 19 years and over.

The registry data provided by Statistics Netherlands were based on the Dutch Personal Records Database and data from the Dutch Tax and Customs Administration for the entire Dutch population. All data were linked in a secured environment, which is managed by Statistics Netherlands, and processed anonymously. After data linkage and exclusion of missing data, the sample included 334,721 respondents.

Dependent variables

For this study, three different dependent variables from the Health Survey were used. The variable "self-rated health" was assessed with the question "How would you rate your health in general?", which is answered on a five-point Likert scale. The response categories were dichotomized into good self-rated health ("good" or "very good") and poor self-rated health ("fair", "poor", or "very poor"). The variable "chronic disease" was derived from the question "Do you have one or more long-term diseases (expected duration six months or longer)?", with the answer options "yes" and "no". This question does not differentiate between physical and mental diseases.

Psychological distress was derived from the Kessler-10 questionnaire (K10) [16]. The ten questions in this questionnaire are answered on a five-point Likert scale, resulting in a total score ranging from 10 to 50. Scores of 30 and higher were considered as "high risk" (see Appendix Tables A1 and A2 for details).

Independent variables

The independent variables in this study included region, demographic factors, SES, lifestyle, loneliness, and mastery. The variable "region" was based on the 2016 division of the Dutch Public Health Services (resulting in 25 regions). The region of Zuid-Limburg was the reference group as this region scores worst on many health-related factors and outcome measures based on the information published by the RIVM [3]. Zuid-Limburg has the highest percentages of adults with a chronic disease (38.7% vs 33.9% nationwide), adults with (very) poor or fair self-rated health (30.5% vs 24.4%), lonely adults (47.8% vs 43.0%), and adults with insufficient mastery (12.5% vs 9.9%) [3].

Demographic factors included age, gender, migration background, and marital status. SES consisted of the highest attained level of education, the quartile of standardized household income, and income inadequacy. Household income was standardized for the number of persons in the household and then classified into quartiles based on income data of the entire Dutch population. The variable "income inadequacy" was examined with the question "In the past 12 months, have you had any concerns making ends meet with your household income?" Income inadequacy is considered to be a subjective measure of income as part of SES since it is also related to health, in addition to the objective income [17]. Lifestyle variables included BMI category [18] and sufficient physical activity (at least 2.5 hours of moderately intensive exercise or intense training twice a week, as defined by the Health Council [19]) as a proxy for eating and exercise behavior, smoking history, and alcohol con-

sumption ("never", "moderately", or "excessively" (i.e., >14 alcohol beverages a week for women and >21 alcohol beverages a week for men)).

The variable "loneliness" was based on the total score on the eleven statements of the De Jong–Gierveld scale [9]. These statements refer to feelings of severe loneliness, problematic situations, companionship, and sociability (e.g., "I experience a general sense of emptiness" or "There are many people I can trust completely"). The answer options are "yes", "more or less" and "no". An individual is considered to be somewhat lonely if their score is in the range of 3 to 8, severely lonely with a score of 9 or 10, and very severely lonely with a score of 11 [20].

The variable "mastery" was assessed with the seven statements of the Pearlin and Schooler Mastery Scale [21]. These statements (e.g., "I have little control over the things that happen to me") are answered on a five-point Likert scale (ranging from "strongly agree" to

Table 1 Sample characteristics (n = 334,721)

variable	category	n	%
gender[a]	Male	159,251	47.6%
migration background[a]	Dutch-born	294,573	88.0%
	Western migration background	28,204	8.4%
marital status[b]	Married/living together	224,234	67.0%
	Never married	35,899	10.7%
	Widowed	23,052	6.9%
highest attained level of education[b]	Primary school	19,061	5.7%
	Lower vocational education	102,886	30.7%
	Middle vocational/secondary	106,341	31.8%
standardized household income quartile[a]	0–25%	42,250	12.6%
	26–50%	84,243	25.2%
	51–75%	98,107	29.3%
self-perceived income inadequacy[b]	Inadequate, major concerns	9,490	2.8%
	Inadequate, some concerns	34,273	10.2%
	Adequate, minor concerns	115,299	34.4%
physical activity[b]	Insufficient	94,343	28.2%
body mass index, kg/m²[b]	Normal (18.5–25)	152,321	45.5%
	Overweight (25–30)	128,977	38.5%
	Obese (> 30)	49,223	14.7%
alcohol consumption[b]	Never	32,663	9.8%
	Moderate	275,392	82.3%
smoking history[b]	Never smoked	135,642	40.5%
	Former smoker	144,994	43.3%
chronic disease[b]	None	203,330	60.7%
self-rated health[b]	Very (good)	247,707	74.0%
psychological distress[b]	No, low or moderate risk	319,533	95.5%
		Average	sd
age, years[a]		59.2	16.9
loneliness score[b]		2.8	3.1
mastery score[b]		26.7	5.2
Based on unweighted, non-imputed data *SD* standard deviation [a]Registry data [b]Self-reported data			

"strongly disagree"), with a total score of 7–35. The higher the total score, the more control one experiences over their life.

Statistical analyses

The relative risks for the negative health outcomes were modeled using a series of logistic and Poisson regressions. The outcomes "poor self-rated health"

Table 2 Regional differences in uncorrected and fully corrected models

region	self-rated health (very) poor or fair PR (95% CI)		at least one chronic disease PR (95% CI)		high risk for psychological distress OR (95% CI)	
	Model 1: region	Model 4: total[a]	Model 1: region	Model 4: total[a]	Model 1: region	Model 4: total[a]
Zuid-Limburg	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Zuid-Holland-Zuid	*0.75 (0.70–0.80)*	*0.83 (0.79–0.88)*	*0.83 (0.78–0.87)*	*0.88 (0.84–0.92)*	*0.66 (0.54–0.79)*	*0.76 (0.60–0.96)*
Zeeland	*0.91 (0.85–0.96)*	1.00 (0.95–1.05)	*0.87 (0.83–0.91)*	*0.89 (0.85–0.93)*	*0.70 (0.58–0.84)*	*0.80 (0.64–0.99)*
Zaanstreek-Waterland	*0.82 (0.78–0.86)*	*0.94 (0.90–0.98)*	*0.93 (0.90–0.97)*	1.01 (0.97–1.05)	*0.82 (0.72–0.94)*	1.09 (0.92–1.30)
West-Brabant	*0.88 (0.84–0.93)*	1.00 (0.95–1.05)	*0.81 (0.77–0.84)*	*0.85 (0.82–0.89)*	*0.75 (0.65–0.88)*	0.96 (0.79–1.16)
Utrecht	*0.73 (0.69–0.76)*	*0.94 (0.90–0.98)*	*0.82 (0.79–0.85)*	*0.95 (0.93–0.98)*	*0.69 (0.61–0.77)*	0.94 (0.81–1.09)
Twente	*0.75 (0.71–0.80)*	*0.88 (0.83–0.93)*	*0.89 (0.85–0.94)*	0.98 (0.94–1.02)	0.96 (0.81–1.14)	*1.49 (1.20–1.84)*
Rotterdam	*0.93 (0.89–0.97)*	*0.93 (0.89–0.96)*	*0.94 (0.91–0.97)*	0.98 (0.95–1.01)	1.07 (0.96–1.19)	0.99 (0.86–1.15)
Noord- en Oost-Gelderland	*0.73 (0.69–0.77)*	*0.89 (0.85–0.93)*	*0.95 (0.92–0.99)*	1.03 (0.99–1.07)	*0.71 (0.62–0.81)*	1.05 (0.89–1.25)
Limburg-Noord	*0.86 (0.82–0.90)*	0.97 (0.93–1.01)	*0.93 (0.89–0.96)*	0.97 (0.94–1.01)	*0.67 (0.59–0.76)*	*0.84 (0.71–0.99)*
Kennemerland	*0.72 (0.68–0.76)*	*0.90 (0.85–0.94)*	*0.84 (0.80–0.88)*	*0.94 (0.90–0.97)*	*0.68 (0.58–0.79)*	1.01 (0.84–1.22)
IJsselland	*0.72 (0.67–0.77)*	*0.91 (0.85–0.97)*	*0.91 (0.87–0.96)*	1.03 (0.98–1.08)	*0.70 (0.58–0.84)*	0.99 (0.79–1.25)
Hollands Noorden	*0.78 (0.74–0.82)*	*0.95 (0.91–0.99)*	*0.87 (0.83–0.91)*	*0.96 (0.92–0.99)*	*0.71 (0.61–0.82)*	0.95 (0.79–1.14)
Hollands Midden	*0.72 (0.68–0.75)*	*0.86 (0.82–0.90)*	*0.93 (0.90–0.97)*	1.02 (0.98–1.05)	*0.82 (0.72–0.92)*	1.11 (0.94–1.30)
Hart voor Brabant	*0.84 (0.80–0.88)*	1.00 (0.96–1.05)	*0.84 (0.80–0.87)*	*0.91 (0.88–0.94)*	*0.76 (0.67–0.86)*	1.05 (0.89–1.24)
Haaglanden	*0.88 (0.84–0.93)*	*0.92 (0.88–0.96)*	0.97 (0.93–1.01)	*1.04 (1.00–1.08)*	*1.27 (1.12–1.44)*	*1.22 (1.03–1.44)*
Groningen	*0.79 (0.74–0.83)*	0.96 (0.92–1.01)	*0.95 (0.91–0.99)*	*1.06 (1.02–1.11)*	*0.66 (0.57–0.78)*	0.84 (0.69–1.03)
Gooi en Vechtstreek	*0.76 (0.70–0.81)*	*0.94 (0.88–0.99)*	*0.85 (0.81–0.90)*	*0.93 (0.89–0.98)*	*0.71 (0.58–0.87)*	1.01 (0.78–1.29)
Gelderland-Zuid	*0.75 (0.71–0.79)*	*0.90 (0.86–0.95)*	*0.86 (0.82–0.90)*	*0.95 (0.91–0.99)*	*0.86 (0.75–0.98)*	1.19 (0.99–1.42)
Gelderland-Midden	*0.76 (0.71–0.81)*	*0.89 (0.84–0.94)*	*0.93 (0.88–0.98)*	1.01 (0.96–1.06)	0.95 (0.78–1.14)	1.19 (0.97–1.46)
Friesland	*0.73 (0.69–0.77)*	*0.86 (0.82–0.91)*	*0.89 (0.86–0.93)*	*0.95 (0.92–0.99)*	*0.66 (0.57–0.77)*	0.95 (0.79–1.14)
Flevoland	*0.81 (0.71–0.92)*	0.96 (0.87–1.07)	0.93 (0.85–1.02)	1.05 (0.96–1.14)	1.01 (0.74–1.37)	1.27 (0.90–1.79)
Drenthe	*0.76 (0.70–0.82)*	*0.88 (0.82–0.94)*	*0.90 (0.84–0.95)*	0.95 (0.90–1.01)	*0.65 (0.52–0.80)*	0.84 (0.63–1.13)
Brabant-Zuidoost	*0.88 (0.84–0.92)*	1.04 (0.99–1.08)	*0.83 (0.80–0.87)*	*0.90 (0.86–0.93)*	*0.83 (0.73–0.94)*	1.04 (0.87–1.24)
Amsterdam	*0.79 (0.74–0.84)*	*0.88 (0.84–0.93)*	*0.83 (0.79–0.87)*	*0.93 (0.89–0.98)*	0.96 (0.84–1.11)	1.03 (0.86–1.23)

Results of robust Poisson and logistic regressions ($n = 334,721$) based on weighted data. PRs and ORs in italics are significant ($P < 0.05$)
PR prevalence ratio, *OR* odds ratio, *CI* confidence interval
[a]Model 4 was corrected for region, demographic factors, SES, lifestyle, loneliness, and mastery

and "at least one chronic disease" were modelled with robust Poisson regressions because of the frequency of these outcomes (prevalence >10%). Odds ratios (ORs) of logistic regressions can substantially overestimate the prevalence ratios (PRs) for this type of outcome variables [22]. For the outcome "psychological distress", logistic regressions were used. For each outcome variable, six regression models were compared. Model 1 was only adjusted for region. This is a categorical variable with 24 dummies and the region of Zuid-Limburg as reference group. In Model 2, region, demographic factors, and SES were accounted for. In Model 3, the outcomes were corrected for region, demographic factors, SES, and a) lifestyle, b) loneliness, or c) mastery, respectively. Finally, in Model 4, all independent variables of this study were accounted for.

Given the number of missing data, all analyses were also performed with multiple imputed data (multivariate imputation by chained equations, 5 imputations, $n = 452,664$) [23]. These results and the original findings were comparable, making the findings robust. All analyses were performed using Stata 16 [24] and applied to the sampling design of the data.

Results

The sample included 334,721 persons, of whom more than half were women (52.4%), with a mean age of 59.2 years (standard deviation (SD): 16.9) (Tab. 1). The majority of the respondents was Dutch-born (88.0%), 8.4% had a Western migration background, and 3.6% had a non-Western migration background. In addition, 67.0% of the respondents were married or living together, 10.7% had never been married, 6.9% was widowed, and 9.4% was divorced. Furthermore, 74.0% of the respondents experienced a (very) good health, 60.7% had no chronic diseases, and 95.5% had no, a low, or a moderate risk of psychological distress. The mean loneliness score was 2.8 (SD: 3.1) (scores 0–3 indicated "not lonely"). For mastery, the mean score was 26.7 (SD: 5.2) (scale 7–35). The outcomes and factors were also weighted and are described per region (see Appendix Tables A4 and A5). An overview of the missing data can be found in Appendix Table A3.

Compared with residents of Zuid-Limburg, all residents of other Dutch regions had a lower risk of poor self-rated health in the uncorrected model, with PRs ranging from 0.72 to 0.93 (Tab. 2). In other words, if differences between regions remained uncorrected for any population characteristic, residents of Zuid-Limburg had a higher chance of poor self-rated health (8–39%) than residents of other regions. After adding demographic and SES factors, 23 regions remained significantly different. After adding lifestyle factors, 19 regions remained significantly different, and after adding loneliness, 21 regions remained significantly

Fig. 1 Prevalence ratios of having less than good self-rated health in other Dutch regions compared with Zuid-Limburg. Accounted for **a** region; **b** region, demographic factors, and socioeconomic status (*SES*); **c** region, demographic factors, SES, and lifestyle; **d** region, demographic factors, SES, and loneliness; **e** region, demographic factors, SES, and mastery; and **f** region, demographic factors, SES, lifestyle, loneliness, and mastery
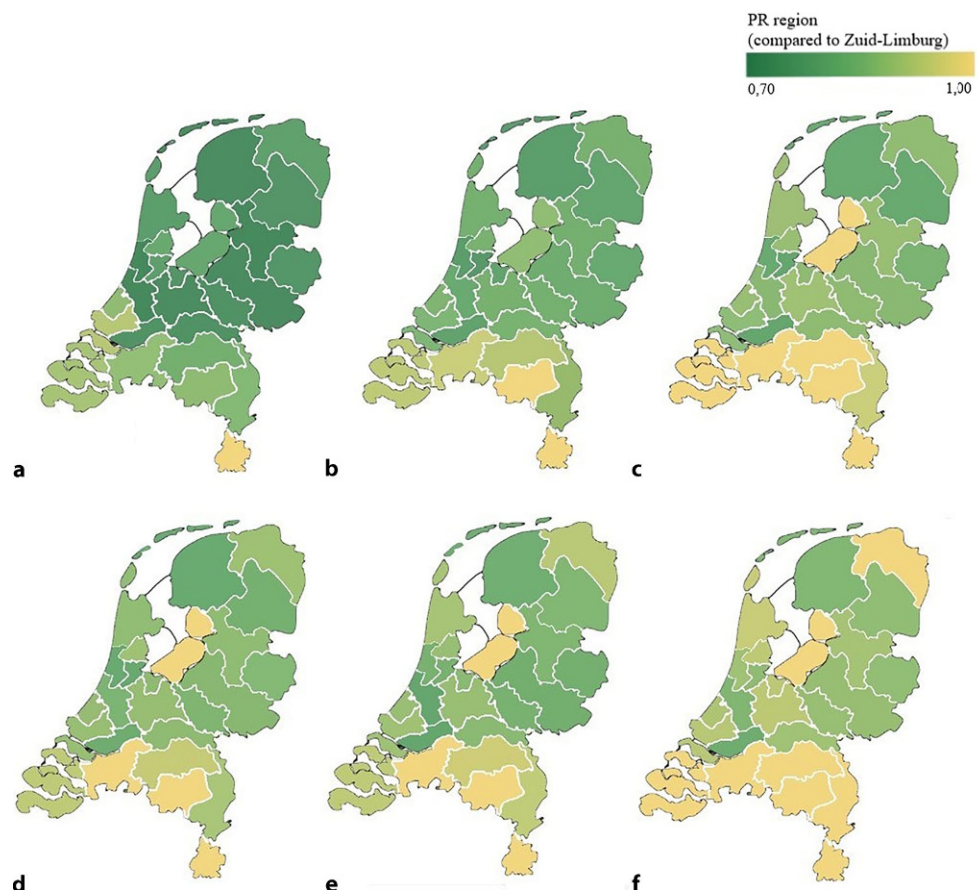
different. After addition of mastery, 20 regions remained significantly different from Zuid-Limburg (Fig. 1 and Appendix Table A6). When using the most extensive model, the regional differences in self-rated health remained significant in 17 of the 24 regions, with PRs ranging from 0.83 to 0.95 (Tab. 2).

The risk of having at least one chronic disease differed significantly between 22 regions and Zuid-Limburg in the uncorrected model; the PRs ranged from 0.81 to 0.95 (Tab. 2). The regional differences for chronic disease could be partly explained by demographic factors and SES (17 significantly different regions), lifestyle (15 significantly different regions), loneliness (15 significantly different regions), and mastery (14 significantly different regions) (Fig. 2 and Appendix Table A7). In the most extensive model, residents of Zuid-Limburg had a higher risk (4–18%) of having at least one chronic disease compared with the residents of 12 other regions (significant PRs ranged from 0.85 to 0.96). Residents of the region of Groningen had a higher risk of having at least one chronic disease compared with Zuid-Limburg residents in the most extensive model (PR: 1.06; 95% confidence interval (CI): 1.02–1.11).

The risk of psychological distress differed significantly between the 18 other regions and Zuid-Limburg in the uncorrected model; the ORs ranged from 0.65 to 0.86. The regional differences for the risk of psychological distress could be largely explained by demographic factors, SES, loneliness, and mastery (Fig. 3 and Appendix Table A8). Of the 19 significantly different regions in Model 1, 12 remained significantly different when demographic factors and SES were added, 10 remained significantly different with the addition of lifestyle, 6 remained significantly different with the addition of loneliness, and 5 remained significantly different with the addition of mastery. In the most comprehensive model, residents of three other regions had a lower risk of psychological distress compared with residents of Zuid-Limburg. These three regions were *South Holland–South* (Zuid-Holland-Zuid) (OR: 0.76; 95% CI: 0.60–0.96), Zeeland (OR: 0.80; 95% CI: 0.64–0.99), and Northern Limburg (*Limburg-Noord*) (OR: 0.84; 95% CI: 0.71–0.99). The residents of Twente (OR: 1.49; 95% CI: 1.20–1.84) and Haaglanden (OR: 1.22; 95% CI: 1.03–1.44) had a higher risk of psychological distress compared with those living in Zuid-Limburg. After adding demographic factors, SES, lifestyle, loneliness, and mastery, there were no significant differences between the other 19 regions and Zuid-Limburg. The results of the multiple imputed data set were comparable with the results based on the sample of 334,721 respondents.

Fig. 2 Prevalence ratios of having at least one chronic disease in other Dutch regions compared with Zuid-Limburg. Accounted for **a** region; **b** region, demographic factors, and socioeconomic status (*SES*); **c** region, demographic factors, SES, and lifestyle; **d** region, demographic factors, SES, and loneliness; **e** region, demographic factors, SES, and mastery; and **f** region, demographic factors, SES, lifestyle, loneliness, and mastery
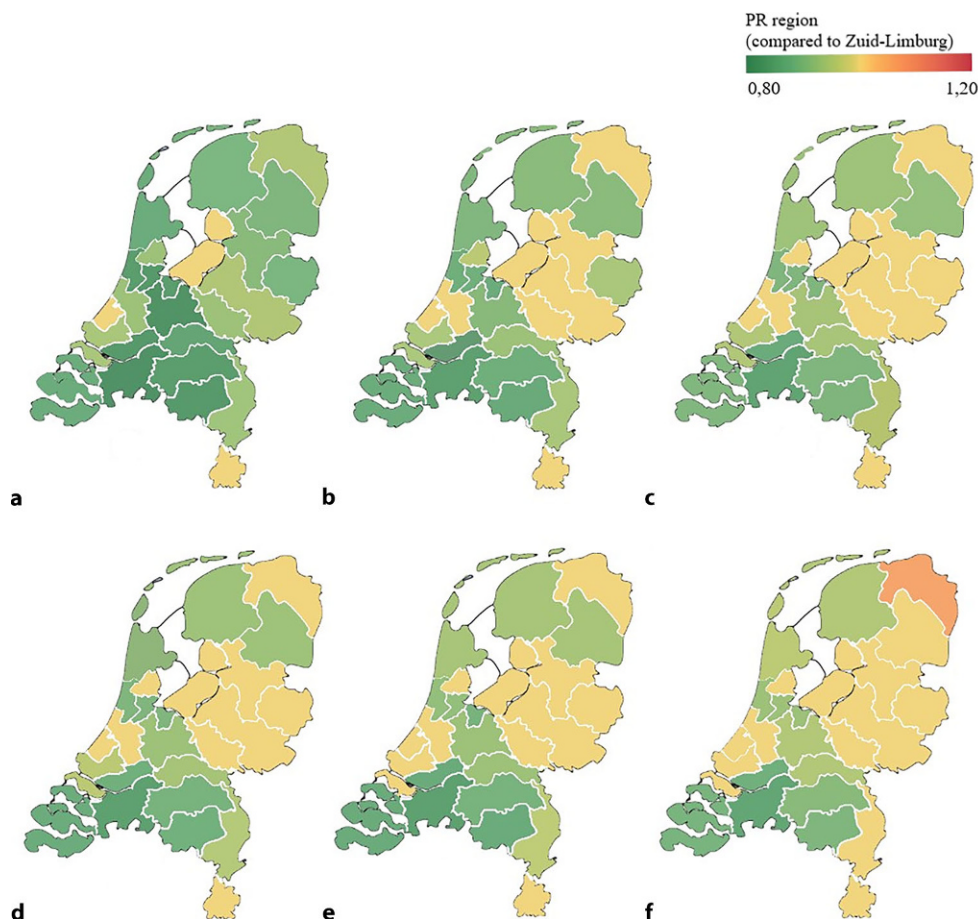
Fig. 3 Odds ratios of having high risk of psychological distress in other Dutch regions compared with Zuid-Limburg. Accounted for **a** region; **b** region, demographic factors, and socioeconomic status (*SES*); **c** region, demographic factors, SES, and lifestyle; **d** region, demographic factors, SES, and loneliness; **e** region, demographic factors, SES, and mastery; and **f** region, demographic factors, SES, lifestyle, loneliness, and mastery
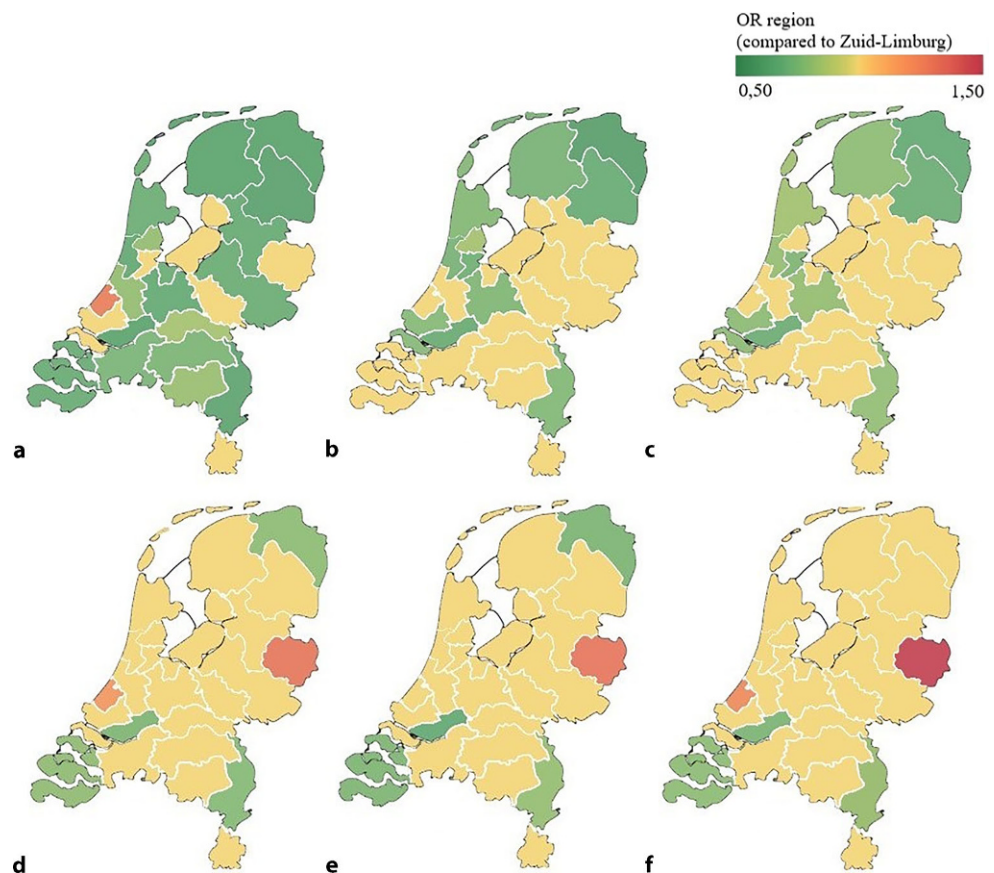
Discussion

The aim of this study was to explain the regional health differences in self-rated health, chronic disease, and psychological distress based on an extensive set of lifestyle factors, loneliness, and mastery, in addition to demographic factors and SES. When we corrected for all explanatory factors, the number of regions that differed from the region of Zuid-Limburg with respect to self-rated health decreased from 24 to 17. Lifestyle, loneliness, and mastery partly contributed to this difference, with 19, 21, and 20 significant regions, respectively (out of 23 after adjusting for demographic factors and SES). With regard to chronic disease, residents of 12 regions were less likely to have a chronic disease than residents of Zuid-Limburg after accounting for all explanatory factors. Lifestyle and loneliness (number of significantly different regions reduced from 17 to 15 for both) and mastery (from 17 to 14 significant regions) contributed to the differences between regions in self-perceived health and presence of chronic diseases. Of the 19 regions with significant differences in the risk of psychological distress, 14 were no longer significantly different when correcting for the explanatory factors. This could be largely explained by loneliness (from 12 to 6 significant regions) and mastery (from 12 to 5 significant regions), in addition to the corrections for demographic characteristics and SES (from 19 to 12 significant regions) and lifestyle (from 12 to 10 significant regions). This study presented regional differences compared with the reference region Zuid-Limburg. In the tool Compare Regions for Health and Healthcare Costs (Regiovergelijker gezondheid en zorgkosten [1]), users can select any reference region and display the results of the uncorrected model (Model 1) and the fully corrected model (Model 6) [1].

The correction for demographic factors and SES partly contributed to the explanation of regional differences in self-rated health. This finding is similar to the results of previous research in the Netherlands, in which municipal differences in self-rated health were partly explained by age, migration background, income, and education level [6]. Similarly, international studies have shown that regional health inequalities can be partially explained by personal characteristics. In the United States, 30% of mortality differences for women are explained by individual characteristics (demographic factors and SES), whereas 53% is attributed to contextual features per state (social cohesion, economic, and socio-political structure) [25]. In England, the north-south divide in cardiovascular diseases can also be partly explained by demographic factors and SES, in this case by smoking behavior, BMI, and blood pressure [26].

After adding all explanatory factors to the model, there were still some regional health inequalities. Which factors can further explain these differences? It is well known that neighborhood characteristics such as social cohesion, facilities, perceived safety, and less nuisance are associated with better health [27, 28]. Statistics Netherlands has published national and regional data on this topic in its Safety Monitor. These data showed that residents of the regions of Amsterdam, Rotterdam, parts of The Hague region, Utrecht city, and Zuid-Limburg feel less safe, experience more nuisance, and are less satisfied with the quality of life in neighborhoods [29]. In addition, the Dutch Opportunity Map (*KansenKaart*), which makes regional differences in upward mobility (i.e., the ability to improve one's social status relative to that of another social group) insightful, has shown that upward mobility in income is less common in people who grew up in the northern provinces of the Netherlands [30]. Upward mobility in education level (higher vocational training or university), on the other hand, is less common in people who grew up in the Dutch Bible Belt and the northern regions. These regional differences could be further investigated, in combination with lifestyle and psychosocial factors.

When explaining poorer health outcomes, cultural and historical aspects are often taken into consideration. For Zuid-Limburg, for example, its mining history is often considered [31]. When the mines closed, not only did many jobs disappear, but the social structures of mine, church, and state also collapsed. These structures provided education, healthcare, social cohesion, and housing in Zuid-Limburg. A possible consequence is that residents of Zuid-Limburg have a more dependent attitude and therefore experience a lower sense of mastery [31]. The disappearance of these structures, and the absence of adequate alternatives [32], has also led to a greater feeling of loneliness and less mastery. Nevertheless, even when we corrected for mastery and loneliness, regional differences remained (5–20% higher chance of poorer health and 4–18% higher chance of having a chronic disease). This may indicate the presence of other determinants we did not include or may imply that the used scales insufficiently measure loneliness and mastery. Although these are validated scales, feelings of loneliness and lower sense of mastery may not have been fully covered by the questions, as people feel politicians and government have abandoned them [32]. Perhaps future (qualitative and) longitudinal research can unravel the mechanisms behind these factors.

Our results offer leads for policymakers to reduce regional health inequalities by tackling unhealthier lifestyles and loneliness and strengthening mastery in the population. For some factors, interventions can be fairly simple by using straightforward programs, such as lifestyle campaigns. To combat loneliness, group interventions are recommended that focus on educational or social activities for specific target groups and not only on home visits or learning how to make friends [33]. In addition, as lifestyle habits, loneliness, and mastery are formed in the broad context of the individual's living environment, the causes of the causes need to be assessed as well [5]. This requires consideration of a broad range of domains beyond healthcare, such as labor, housing, education, and living environment [4, 34]. More qualitative and regional research is needed to determine exactly which problems are prevalent and which interventions are best suited for these problems.

Based on this study, no recommendations on specific interventions can be made, but we have shown that investments in these interventions can reduce regional health inequalities. Prioritization of vulnerable regions and populations is recommended [34], which is also in the interest of a regional approach of making healthcare more sustainable and looking at a broader perspective of prosperity [35, 36]. Regions are taking on a greater role in realizing local partnerships at the border of medical and social care and in bringing coherence in health, income, and well-being [35]. Aside from the possible leads this research offers based on the corrected differences, the uncorrected differences visualize the actual situation in vulnerable regions and indicate that extra attention and investments are needed.

A possible limitation of the study is related to the composition of the sample. It is known that certain groups are less inclined to participate in surveys, for example people with a lower SES and/or worse health, which can lead to selection bias [37]. In addition, people in the lowest income quartile were underrepresented in this dataset (12.6% of the respondents). This was taken into account when sampling and analyzing the data by adding weighting factors. Nevertheless, the weighted data showed that 18.7% of the respondents belonged to the lowest quartile. In addition, institutionalized residents are not included in the sample of the Health Survey. The underrepresentation of this group of citizens may have underestimated the actual regional health inequalities.

A second limitation is the use of cross-sectional data. This made it impossible to draw causal conclusions, and we could only analyze possible associations. For example, regions with more lonely residents can, as a result, become unhealthier. At the same time, citizens become lonelier as a result of their poorer health.

In conclusion, lifestyle factors, loneliness, and mastery are possible starting points for the explanation of regional health inequalities in the Netherlands. Lifestyle factors contribute to the explanation of regional differences in self-rated health and presence of chronic disease. In addition, loneliness and mastery contribute to explaining regional differences in self-perceived health, chronic disease, and psychological distress.

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