"All in the Family: Do Health Utility Patterns Cluster in Belgian Households?"

Authors: Regina Manansala[1], Zhuxin Mao[1], Joke Bilcke[1], Niel Hens[1,2], Philippe Beutels[1,3]

[1] Centre for Health Economics Research and Modelling Infectious Diseases, Vaccine and Infectious Disease Institute, University of Antwerp, Universiteitsplein 1, Wilrijk, 2610, Belgium
[2] Data Science Institute, I-BioStat, Hasselt University, Hasselt, Belgium, Agoralaan Gebouw D, Diepenbeek, 3590, Belgium
[3] School of Public Health and Community Medicine, The University of New South Wales, Sydney, Australia

Abstract

Evidence has shown that an individual's health and well-being can have quantifiable spillover effects on health-related quality of life (HRQoL) of caregivers and/or family members. Many studies have focused on individual-level data to explore factors influencing HRQoL, but few have evaluated within- and between household variations in HRQoL. Our work aims to explore clustering patterns of health utility among and within households in Belgium and identify individual and household-level determinants of HRQoL that can influence these clustering patterns. A Belgian national survey collected data on 1,336 individuals in 340 households in 2010-11 to study social contact behavior of households with at least one child under 13 years old. The survey collected participants' individual and household characteristics and EQ-5D-3L. A linear mixed-effects model was used to identify determinants influencing individual EQ-5D utility scores, while accounting for clustering within households. A total of 1,212 individuals over 307 households were included in this analysis.The median household size was 4, with a range of 2 to 7, and there were 153 households with at least one member with a health utility score less than 1. The average intraclass correlation coefficient (ICC) for the final model from 10 imputed datasets was 11.7% (range: 11.1%-2.0%), indicating modest heterogeneity in health utility scores across households. The individual-level predictors found to have a significant association with lower individual health utility scores include being sick with a severe illness ($b = -0.06$, $p < 0.001$), having dealt with a family member with a severe illness ($b = -0.03$, $p < 0.05$), and experiencing an abnormal day at time of response ($b = -0.02$, $p < 0.05$). Participants whose BMI was classified as 'obese' ($b = -0.07$, $p < 0.001$), 'overweight' ($b = -0.03$, $p < 0.05$), and 'underweight' ($b = -0.04$, $p < 0.05$) showed significant associations with lower health utility scores. Participants with 'other' occupational status (i.e., housewife, unemployed, or job-seeking; $b = -0.066$, $p < 0.001$) were found to have a significant negative association. Household clusters have a non-negligible influence on health utility scores that requires further investigation. Lower health utility scores among individuals are greatly associated with having or being in close proximity to severe diseases.

Introduction

Health is defined by a person's overall physical, mental, and social well-being and is influenced by a wide range of biological, societal, and environmental factors (1). An individual's health has been shown to have direct and indirect influences on the health and well-being of other people within close social relationships (in a community or household, etc) (2). These are apparent in most common infectious diseases with physical manifestations. Several studies have directly measured the rate of infectious disease transmission in households in Belgium (3,4); however, research has shown that subtle spillover effects, that is, the impact that an individual's health condition has on the health and well-being of others (such as family members and caregivers) (5,6) , also occur with non-communicable diseases (NCDs) and mental health conditions (7). Furthermore, lifestyle habits that have direct influence on health and overall quality of life are also shared among household members (8,9) and can have downstream implications on society and overall public health.

Health-related quality of life (HRQoL), including health utility scores, of individuals or patients suffering from a variety of diseases have been widely documented and its use to measure the commutation of health due to NCDs has been ubiquitous. There is a breadth of literature on the shared burden of disease within close contact relationships and inclusion of spillover effects in economic evaluations and healthcare policy-making is increasing (10). Chronic diseases, such as diabetes, have been shown to impact parents' stress and mental well-being due to worries about the child's health (11,12) and the involvement in disease maintenance (13). Radicke et al (14) found that parents' mental illness is associated with lower HRQoL for both parents and their children. Alternatively, Lawson et al (15) suggests that both positive and negative moods, due to mother's experience at work, can consequently affect the mood of their children.

Informal care is the care provided by family to patients with chronic or lifelong diseases. According to a report from the Belgian Health Care Knowledge Centre, 17% of the Belgian population older than 50 years old are informal caregivers in 2018 (16). A study examining the demographics of informal caregivers in Belgium (17) observed higher levels of psychological distress with higher care intensity. There is currently a greater focus on informal caregiving for the elderly population due to aging populations globally (17). Informal caregiving, however, also pertains to adolescents who are expected to care for younger siblings or grandparents (19).

Much of the current literature centers on parent-child, parent-elderly, and patient-caregiver relationships. Our work, which aims to explore clustering patterns of HRQoL among and within households with young children in the general Belgian population, is fundamental in filling research gaps on family spillover effects. We aim to identify individual and household-level determinants of HRQoL that can influence these clustering patterns, with consideration of household members' exposure to illness in the family or with someone being cared for.

Methods

Household Survey

A survey of Belgian households was conducted alongside a general population survey to study social contact behaviours in the Flemish population between November 2010 to April 2011 (3,4,20). Survey recruitment and dissemination are outlined in Goeyvaerts et al (3). In addition to contact diaries, this survey consisted of a general background questionnaire and a generic HRQoL questionnaire (EQ-5D-3L) with a Visual Analogue Scale (VAS) completed by all members of recruited households, which included at least one child aged 12 years or less. Two types of surveys were used - a normal adult survey and a similar survey adapted for children aged 0 to 12 years old with less formal language and completed by the parent or guardian in the household. Teenagers aged 13 to 18 years were asked to complete the survey on their own. A total of 1,336 individuals from 340 households participated in the survey.

Data

Table 1 lists the subset of 23 survey questions that were selected for inclusion in this analysis based on prior literature and relevance to the research topic. Variables that were recategorized or created based on the original data are indicated in the table.

Health Related Quality of Life

The survey responses to the five EQ-5D dimensions were used to calculate the primary outcome of interest, an individual health utility score using the EQ-5D-3L value set for Belgium (21)(‘eq5d’ R package version 0.15.3). Individuals in the survey were included based on

non-missing responses to each of the five EQ-5D dimensions. Participants' VAS health score was also ascertained in the survey.

Data Transformation and Imputation

The percentage of missing responses for the final included individuals based on EQ-5D are outlined in Table 1. A binary variable 'child aged under 13 - yes or no' was created due to the inherent age-specific recording of survey responses. Missing values for 'animal ownership' were manually re-coded with responses ascertained from responses by other household members, given that all other non-missing responses within the household are consistent. These values are assumed to be consistent among all members of the household as individuals are included in the survey if they live more than 50% of the time in a household.

Household-level variables for child care, severe disease, and smoking were also created. A household is determined to have child care if at least one child attends day care or school. Household-level exposure to severe disease was determined if any individual household member responded 'yes' to having dealt with severe illness themselves, with a family member, or with someone in their care. If any individual household member reported being a 'current smoker', the household is determined to have at least 1 smoker, while other households are identified as having no smokers. Household-level educational attainment and occupation were ascertained for the original data (prior to imputation) from adult members of the household. Household education was defined as having at least one parent with a university degree or both parents having less than a university-level education. The binary household occupation variable was defined as having both parents working full- or part-time or having at least one parent not working full- or part-time.

Missing values were handled with multiple imputation using the R package 'mice' (version 3.16.0) unless otherwise denoted. Given the wide range of proportions of missing values (1% to 33%), a total of 10 imputation iterations were implemented with 75 burn-in iterations. Variables with missing values were assessed for multicollinearity against remaining possible predictor variables for imputation. Height and weight were regressed against age, gender, height and weight to account for changes in growth rates for children and adults. The remaining variables with missing values were regressed against all other original variables except variables deemed multicollinear in initial imputation variable specification and identifier variables. Binary

variables were imputed using logistic regression and remaining variables were imputed using the predictive mean matching method due to the nature of the variable or sparseness (22).

There were 10 new variables created after imputation that were further considered in our final model. The variable Body Mass Index (BMI) was calculated as BMI = weight in kg/(length in m)^2 and categorized into standard categories: underweight, normal weight, overweight, and obese, based on World Health Organization (WHO) guidelines. BMI categorization for participants under 18 years were determined using standard deviation scores and growth percentiles calculated using the 'childsds' package in R (version 0.8.0) referencing WHO standards or Belgian parameters, if applicable. New maternal education, adult education, and combined education variables were created to ascertain individual education levels from 'child school' and 'participant education' responses. The education and occupation variables were further recategorized to facilitate interpretation of results and to ensure adequate sample sizes in each category.

Statistical Analysis

Descriptive statistics for all potential determinants, using the original (hereinafter referred to as the baseline) and imputed datasets, are outlined in Table 1. The association between baseline averages of household health utility scores and household educational attainment and occupation status were assessed using linear models. Correlations between potential determinants were assessed using contingency tables, Spearman rank correlations, and chi-square tests. The associations between health utility scores and all potential determinants were examined using linear mixed effects models accounting for household-level clustering. For variables in which survey responses vary by age group, models were adjusted to include an interaction with a binary age group identifier and compared using AIC. Models with original and newly created variables were further manually compared using AIC and the variable with the lowest average AIC for all 10 imputation iterations was retained.

A fully specified model was identified after selecting between duplicated or correlated variables. Backward model selection was performed on each individual imputed data set using the fully specified model. For each imputed data set, the variables in the selected model were tallied and included in the model based on how many times a variable appeared in the results. The selected model was further assessed for multicollinearity and fit using a linear mixed-effect

model with household clusters as a random effect (23). Pooled regression coefficients for the final model were obtained using Rubin's rules.

Results

Baseline Sample Characteristics

Individuals in the survey were subsequently "filtered" to ensure that remaining households consisted of 2 or more individuals, with at least one child under 13 years old. A total of 1,212 individuals in 307 households were included in this analysis. The average age of participants included in the analysis is 23.5 (17.5) [0, 60] with 43% categorized as 'children' based on survey guidelines and 51% identifying as female and 49% identifying as male. There were 101 individuals who reported experiencing severe disease, 482 reported having contact with a family member with severe disease, and 63 reported caregiving for someone with severe disease. The average health utility score for the study sample was 0.94 [0.24, 1] and the average VAS health score for the study sample at baseline was 87.93 [7, 100].

Associations between Health Utility Score and Household Characteristics

Household sizes in our sample range from 2 to 7 members, with 92% of total households identifying as two-parent households and 8% identifying as single-parent households. There were 237 participants among 153 households with a health utility score less than 1. Out of the 153 households, there were 62 households with more than 1 member with health utility score less than 1 and 6 households in which all members' health utility score was less than 1. For households with at least 1 member with health utility scores below 1, the average health utility score is 0.88 [0.24, 1] and the average VAS health score is 85.6 [7, 100]. Figure 1 shows a distinct split in the distribution of average household health utility scores based on household composition, with households where more than 50% of members have health utility scores below 1 exhibiting lower average health utility scores.

Table 1 - Descriptive Statistics of Original Survey Results After Accounting for Households with Non-Missing Responses to the Five EQ-5D Dimensions

Variable	Variable Description	Levels	N (Baseline)	Percent Missing (out of 1212)
Type	Who filled the diary in?	Adult, himself	606	0%
		Teenager or older child himself	81	
		Parent on behalf of child	525	
Age	Age of person whom the diary refers to	Mean	23.5	0%
		Median	17.5	
		Min	0	
		Max	60	
Age Group Category	Age group (adult or child)	Child (<= 12 years old)	517	0%
		Adult (> 12 years old)	695	
Gender	Gender of the person whom the diary refers to	Female	615	0%
		Male	597	
Height	The height of the participant (in m)	Mean	1.52	34%
		Median	1.62	
		Min	0.47	
		Max	2.01	
Weight	The weight of the participant (in kg)	Mean	52	35%
		Median	55	
		Min	6	
		Max	133	
Household Size	Household size including participant	Mean	4.1	0%
		Median	4	
		Min	2	

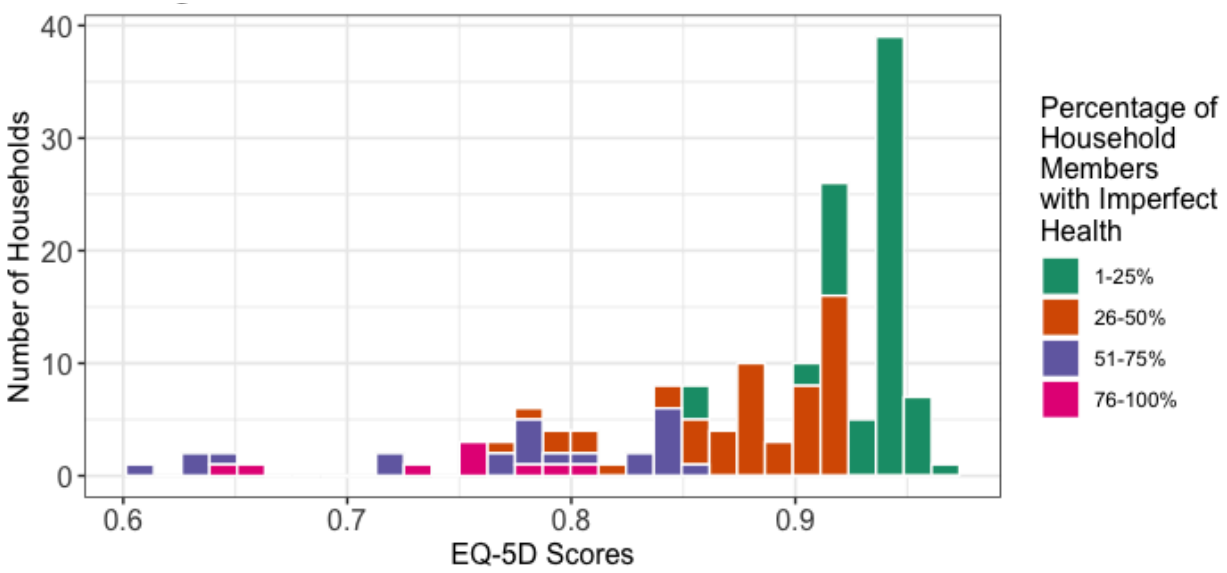
		Max	7	
Severe Disease - Self	Have you been in contact with a severe disease: yourself?	Yes	101	3%
		No	1078	
Severe Disease - Family	Have you been in contact with a severe disease: family member?	Yes	482	4%
		No	687	
Severe Disease - Caregiving	Have you been in contact with a severe disease: someone you were taking care of?	Not applicable/child respondent	525	7%
		Yes	63	
		No	538	
Household Parental Type	What kind of household are you living in?	Single-parent family	67	0%
		Two-parent family	1145	
Uncommon Day	Was this an uncommon day?	Yes	361	1%
		No	844	
Animal Ownership	Does your household own at least one living animal?	Yes	840	0%
		No	372	
Child Care	Does the child attend daycare or school?	Not applicable/adult respondent	687	0%
		Yes	515	
		No	9	
Child School	[<12y] Is the child going to school?	Not applicable/adult respondent	690	0%
		Yes, pre-school	129	
		Yes, primary school	282	
		Yes, not pre- or primary school	56	
		No	53	
Education	Educational level of the person filling in the diary (only if diary type == 1 or 3) For children < 13 years : maternal education	No formal schooling	5	1%
		Primary school	52	
		Secondary school (lower)	73	
		Upper secondary school (upper)	261	
		Secondary school (unspecified)	100	

		University degree (lower)	462	
		University degree (higher)	247	
		University degree (unspecified)	0	
		Vocational education (FI)	0	
Occupation	Occupational status of the person filling in the diary	Working full- or part-time	537	3%
		Retired	0	
		At home (housewife)	22	
		Currently unemployed/job seeking	13	
		In full time or further education	550	
		Other	50	
Smoking	Individual smoking status	Not applicable/child respondent	525	0%
		Smoker	110	
		Ex-smoker	107	
		Non-smoker	465	
		Unknown	5	
EQ-5D - Mobility	The health state of the participant: regarding mobility	I have no problems in walking about	1193	0%
		I have some problems in walking about	18	
		I am confined to bed	1	
EQ-5D - Self-Care	The health state of the participant: regarding self care	I have no problems with self-care[a]	1181	0%
		I have some problems washing or dressing myself	19	
		I am unable to wash or dress myself	12	
EQ-5D - Usual Activity	The health state of the participant: regarding activity	I have no problems with performing my usual activities	1161	0%
		I have some problems with performing my usual activities	49	
		I am unable to perform my usual activities	2	
EQ-5D - Pain	The health state of the participant: regarding pain	I have no pain or discomfort	1027	0%

		I have moderate pain or discomfort	181	
		I have extreme pain or discomfort	4	
EQ-5D - Anxiety or Depression	The health state of the participant: regarding fear and/or depression	I am not anxious or depressed	1156	0%
		I am moderately anxious or depressed	53	
		I am extremely anxious or depressed	3	
VAS	The health state of the participant on a scale from 0 (worst) to 100 (fittest) (VAS)	Mean	87.93	2%
		Median	90	
		Min	7	
		Max	100	

[a](or is too young for self care)

Figure 1. Distribution of Average Household Health Utility Scores among Households with at least 1 member with Health Utility Score < 1 (n = 153)



At baseline, there were 257 households in which all parents were working full- or part-time with an average household health utility score of 0.95 [0.61, 1.00]. The 30 households in which at least one parent was not working full- or part-time had an average health utility score of 0.89 [0.63, 1.00]. A total of 216 households had at least one parent with at least a university degree with an average household health utility score of 0.95 [0.61, 1.00]. The 85 households in which both parents had lower than a university level education had an average health utility score of 0.92 [0.63, 1.00]. In addition to frequency counts, Table 2 outlines the results of bivariate linear models evaluating average household health utility in relation to household-level determinants. Households with one or more parents not working full or part-time [$b = -0.05$, $p < 0.001$] and households with all parents with less than a university level education [$b = -0.03$, $p < 0.05$] were significantly associated with lower average household health utility scores. Households with at least one member who has dealt with severe illness with self, family, and/or while caring for others was also found to have a significant negative effect on average household health utility scores [$b = -0.04$, $p < 0.001$].

Table 2 . Results of Bivariate Linear Regression Models Evaluating the Relationship Between Average Household EQ-5D Scores and Household-Level Determinants

	Levels	N	Estimate (SE)
Household size	*4 (reference)*	150	0.952 (0.007) ***
	2	10	-0.037 (0.026)
	3	79	-0.039 (0.011) ***
	5	55	0.003 (0.013)
	6	11	-0.026 (0.025)
	7	2	-0.067 (0.057)
Household Parental Type	*Dual-parent household (reference)*	283	0.942 (0.005) ***
	Single-parent household	24	-0.024 (0.017)
Household Child Care	*At least one child in the household is in daycare or school (reference)*	301	0.875 (0.036) ***
	No children in household in daycare or school	5	0.066 (0.036) .
Household Severe Disease	*No members in the household has dealt with severe illness (reference)*	223	0.967 (0.009) ***
	At least one member of household has dealt	74	-0.037 (0.011) ***

	with severe illness (with self, family, or because of caring for others)		
Household Smoking	*There are no current smokers in the household (reference)*	225	0.941 (0.005) ***
	At least one member of household is a current smoker	82	-0.003 (0.01)
Household Animal Ownership	*There are no pets in the household (reference)*	208	0.938 (0.008) ***
	There is a pet in the household	99	0.003 (0.01)
Household Occupation	*Both parents working (reference)*	257	0.947 (0.005) ***
	At least one parent not working	30	-0.054 (0.015) ***
Household Education	Both parents with less than university education	85	-0.026 (0.01) *
	At least one parent with university education (reference)	216	0.948 (0.005) ***

*$p < 0.001$: '***'; $p < 0.01$: '**'; $p < 0.05$: '*'; $p < 0.1$: '.'*

The results of the mixed-effects models assessing the relationship between individual health utility score and the household-level determinants, while accounting for household as a clustering variable, are provided in the Supplement (Suppl. Table 2).

Regression Results

The final regression model is shown in Table 3. The pooled random effects variance for the 10 imputed datasets was 0.002 and the average ICC was 11.7% (range: 11.1%, 12.0%), indicating minimal heterogeneity in health utility scores between households and suggesting substantial homogeneity within households.

The model includes individual-level demographic determinants such as age group and occupation and the health determinant BMI. Although insignificant, children aged 12 and under appeared to have a weak negative association with health utility score ($b = -0.004$, $p > 0.1$). An unadjusted model with the binary age variable and health utility score, while accounting for household clusters, showed a weak, but positive association with health utility score for children aged 12 and under ($b = 0.02$, $p < 0.05$). The binary age classifier was selected over the

participants' numeric age due to the bimodal distribution of age in our study sample and after further comparison of unadjusted models and evaluations for multicollinearity.

Table 3 - Results of Mixed Effect Models Linking EQ-5D Scores to Individual and Household-Level Survey Responses

	EQ-5D Score with Household Cluster	
	Estimate (SE)	
Intercept	0.981 (0.008)	***
Adult	*reference*	
Child	-0.004 (0.033)	
Occupation : Full- or part-time employment	*reference*	
Occupation : In full time or further education	0.002 (0.013)	
Occupation : At home (housewife), unemployed/job seeking, other	-0.066 (0.018)	***
BMI : Normal	*reference*	
BMI : Not Calculated	0 (0.027)	
BMI : Obesity	-0.072 (0.021)	***
BMI : Overweight	-0.027 (0.011)	*
BMI : Underweight	-0.037 (0.017)	*
Exposure to Severe Disease - Caregiving : No	*reference*	
Exposure to Disease - Caregiving : Not applicable/Children	0.002 (0.034)	
Exposure to Disease - Caregiving : Yes	-0.026 (0.018)	
Exposure to Disease - Family : No	*reference*	
Exposure to Disease - Family : Yes	-0.027 (0.008)	**
Severe Disease - Self : No	*reference*	
Severe Disease - Self : Yes	-0.062 (0.013)	***
Uncommon Day : No	*reference*	
Uncommon Day : Yes	-0.023 (0.008)	**
Variance of Residuals	0.013	
Variance of Random Effect	0.002	
ICC	0.117	
Marginal R2	0.084	

Conditional R2	0.191
AIC	-1558.86

*p < 0.001: '***'; p < 0.01: '**'; p < 0.05: '*'; p < 0.1: '.'*

Participants' occupation status as 'in full-time or further education' did not show a significant effect on health utility scores (b = .002, p > 0.1); however, those with 'other' occupational status (i.e., housewife, unemployed, or job-seeking; b = -0.07, p < 0.001) were found to have a significant negative association. Participants experiencing an uncommon day at the time of survey completion (e.g. due to illness, no school or child care, or on holiday) were captured in our model and were also found to have a significant negative association with EQ-5D (b = -0.02, p < 0.01). The participants' BMI classification was the only physical health indicator captured in our model selection. Compared to being classified as having normal BMI, underweight (b = -0.04, p < 0.05), overweight (b = -0.03, p < 0.05), and obese (b = -0.07, p < 0.001) BMI classifications were significantly associated with lower health utility scores.

When evaluated against health utility scores individually, the three survey questions regarding the participants' proximity to severe disease were shown to have negative associations with HRQoL. Being sick with a severe disease had the strongest effect on lower health utility scores (b = -0.06, p < 0.001), while having a family member with severe disease had a weaker negative effect on health utility score (b = -0.03, p < 0.01). Being a caregiver for someone with or experienced severe disease had a small, but negative association with health utility score (b = -0.04, p < 0.05) compared to not having dealt with severe illness (Suppl. Table 1). In our adjusted model, being sick with a severe disease (b = -0.06, p < 0.001) and being in close contact with a family member with a severe disease (b = -0.03, p < 0.001) remained negatively associated with lower health utility scores, while adult caregivers, regardless of exposure to severe disease, were not significantly associated with health utility scores.

Additional models were run to include household size and household smoking status, a potential indicator for health of the household. Compared to 4-member households, the median in our study sample, households with 3 members were significantly associated with lower health utility scores [b = -0.03, p < 0.01]. Having at least one smoker in the household showed a weaker, non-significant negative association with health utility score [b = -0.002, p > 0.1].

Discussion

To our knowledge, this survey is the first of its kind to collect demographic, health, and HRQoL data on households with children and to subsequently model HRQoL within and between households. Households with a higher percentage of members having health utility scores below 1 had lower average household health utility scores. On an individual level, there is minimal homogeneity in health utility scores within households. Our results indicate a non-negligible contribution of household clusters on HRQoL and individuals' occupation, physical health, and proximity to severe disease can negatively affect their HRQoL.

The primary purpose of this survey was to study social contact behaviours of household members within and outside their household. (3). A 2018 article by Goeyvaerts et al that evaluated the accompanying contact survey found a high degree of within-household clustering of contacts but, especially on weekdays, decreasing connectedness with increasing household size. (24). Since this is of interest to contact behavior, a question about whether the participants experienced a normal week or weekend day was included and, in this analysis, this was found to have a significant negative effect on EQ-5D scores. Out of the 361 respondents who reported not experiencing a normal day at baseline, 6% reported being ill, 1% reported having to stay home for a household member who was ill, and 93% cited other reasons, such as vacation or school closures. Changes in a single day's activity are not routinely ascertained in HRQoL studies. While illness has been directly associated with lower HRQoL (25), our survey data is not sufficient to draw conclusions in line with the existing literature on parents' and children's perceptions of family holidays (26,27).

Our results showed a statistically significant lower health utility score for participants at home, unemployed or job-seeking compared to the employed. At the household-level, we also found that households with at least one parent not working were significantly associated with lower average household health utility scores. These results are consistent with several existing studies (28,29), including a 2019 study by Norström et al (30), which concluded that unemployment can have a substantial impact on HRQoL. Their evaluation of unemployment against the five EQ-5D dimensions showed a significant increase in difficulties with usual activities and anxiety/depression. In our study sample, 9 participants categorized as at home or unemployed reported some problems with usual activities and 4 participants reported being somewhat anxious or depressed.

We considered four survey questions pertaining to the participants' current health state: height, weight, smoking status, and having dealt with severe disease. The participants' BMI was calculated based on the recorded height and weight; however, for children under 2 years old, both the World Health Organization and Centre for Disease Control recommend the use of growth charts and therefore categorized as 'BMI Not Calculated'. Our model captured the participants' BMI status with all non-normal categories being significantly associated with lower health utility scores. Several studies have shown an association between obesity and HRQoL (31–33); however, Stephenson et al (34) emphasize the role of comorbidities along the causal pathway between obesity and low HRQoL.

The smoking status of adult survey participants was used to determine the household smoking status and intended to serve as a representation of the household's overall health. Smoking has been widely associated with lower HRQoL (35–37). Although not a significant factor in our model, parental smoking has been associated with childhood obesity (38), asthma and other respiratory illnesses (39) and can increase likelihood of nicotine adoption and dependence in adulthood (40).

A household member having dealt with severe illness had a significant, negative effect on average household health utility scores. When evaluated at the individual level, having a severe disease is among the factors with the strongest association with lower health utility score in our sample. However, the nature of our survey question does not delineate specific severe diseases. A 2019 systematic review by Van Wilder et al (41) compiled the EQ-5D scores related to several chronic diseases and showed that EQ-5D scores decreased in relation to increased severity of disease. The extent of severe illness can have spillover effects among family members, with effect magnitudes varying based on the closeness of familial relationships (42). The weak, but significant effect of having dealt with a family member with severe disease on lower health utility scores is suggestive of some health burden impacts in our study sample. Wu et al (43) found a positive association between the HRQoL of children with rare genetic disorders and their parents, with a calculated reduction in HRQoL of 0.06 in parents compared to parents with children without rare genetic disease. Sjolander et al. (44) evaluated the HRQoL of cancer patients' family members and showed that their HRQoL was lower than the population norm during a 1 year period after the family member's cancer diagnosis, with a pronounced effect on partners compared to children.

Exposure to severe disease as a caregiver did not have a significant effect on health utility scores. The survey question was limited to participants aged 13 and older and does not differentiate between caregiving within or beyond the household. Among the 63 respondents who reported exposure to severe disease because of caring for others, 67% worked in the public health sector. Literature on the general health related quality of life among healthcare workers is sparse (20). An Italian study on 324 healthcare workers found lower quality of life scores in vitality, social function, and emotional interference in usual activities, but higher quality of life scores in physical aspects of well-being compared to the general population (45). The authors suggest that professional caregivers are better equipped to manage the stresses of caregiving.

Similar to the question regarding participants' severe disease, the binary response to having dealt with severe illness in the family or while caring for someone else did not delineate the severity of diseases nor did it directly quantify the number of participants who are formal or informal caregivers. The heterogeneity in household-level responses to our survey question on having dealt with a family member with severe illness could also be attributed to varying interpretations of "family member" extending beyond the immediate family. Informal caregiver burden has been widely investigated (6). A 2018 survey on informal caregiving in Belgium found that 3.6% of participants provided care for patients within their own households, while 7.4% cared for family members living outside their households (17).

There are additional limitations inherent to our study. The elderly population is absent from our study sample as it was beyond the scope of the primary purpose of this survey. Buckinx et al (46) evaluated the quality of life of elderly informal caregivers and found significant mental burden and decreased physical activities compared to the general elderly population. Alternatively, Shin et al found considerable HRQoL burden for family caregivers living with elderly dementia patients compared with the quality of life of non-caregivers. Both studies highlight the significant role of elderly family members in familial health spillover effects.

In our household survey, the generic EQ-5D-3L questionnaire was given to all study participants, including children and teenagers. For children under 12 years, responses were recorded by parents, while most teenagers were asked to complete the survey on their own. In 2006, Ravens-Sieberer et al. (47) identified several challenges associated with assessing children and adolescents' HRQoL, one of which questioning the value of 'self-rated' versus 'externally rated' HRQoL measurements. A 2010 article by Wille (48) suggests that the generic EQ-5D-3L

measure was satisfactory in measuring children and adolescent HRQoL. This intrument's use, however, is limited to children at least 8 years of age. Out of our total number of study participants, 21% were younger than 8 years old and for whom Ravens-Sieberer's initial proposition is wholly relevant. Subsequent studies conducted in Germany evaluated parent-child agreement in HRQoL measurements and showed an increase in response disagreement with a decrease in child age (49). These studies also suggest external factors, such as socioeconomic status, can influence parents' estimation of their child's HRQoL (50), but are beyond the scope of our analysis.

Household-level variables were not directly ascertained in our survey; therefore, household-level determinants considered in our analysis were extrapolated from individual responses, limiting the strength of our assertions. Furthermore, the broad categorization of our occupation variable grouped participants working full- or part-time, overlooking the potential income-related nuances that may affect HRQoL at the individual and household-level. Education is often used alongside occupation as an indicator for socioeconomic status (51). Variations of individual education levels were considered for this analysis and notably excluded from the final model. At the household-level, we found that households in which both parents did not have a university degree were significantly associated with lower household average health utility scores. In Belgium, both salaries and health utility scores have been shown to increase with higher educational attainment (20,52,53). Additionally, Van Droogenbroek et al. (17) found significant associations between household income and emotional distress as a result of providing informal care.

Household-level demographic factors and exposure to severe disease are significantly related to average household health utility. The moderate impact of household clusters in our model's results additionally suggests a non-negligible effect on individual health utility that requires further investigation. It is important to note that individual level circumstances only partially captured by our survey, such as provision of care to external family members, may still lead to variability within households. Our survey captured participants' health utility scores in a single time point in their lifetime, but evidence suggests that prolonged positive or negative health effects can have downstream implications to an individual's close social relationships.

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Appendix

Regression Results

Supplementary Table 1 - Pooled Results from the Linear Mixed-Effects Models Evaluating the Relationship between Individual Health Utility Score and the Individual-Level Determinants, while Accounting for Household as a Clustering Variable

Variable		Estimate (SE)		Variance of Random Effect	ICC
Type	*Adult (reference)*	0.93 (0.01)	***	0.0024	0.1465
	Teenager or older child himself	0.03 (0.01)	*		
	Parent on behalf of child	0.02 (0.01)	**		
Age	*(Intercept)*	0.96 (0.01)	***	0.0023	0.1438
	Participant age	-0.001 (0)	**		
Binary Age Group Category	*Adult (reference)*	0.935 (0.01)	***	0.0023	0.1419
	Child	0.016 (0.01)	*		
Gender	*Male (reference)*	0.941 (0.01)	***	0.0023	0.1431
	Female	0.002 (0.01)			
Uncommon Day	*No (reference)*	0.95 (0.01)	***	0.0023	0.1383
	Yes	-0.02 (0.01)	*		
Child School	*Child in primary school (reference)*	0.969 (0.01)	***	0.0022	0.1390
	Adult or no response	-0.034 (0.01)	***		
	Child in preschool	-0.033 (0.01)	*		
	Child in school; not pre- or primary school	-0.037 (0.02)	*		
	Child not in school	-0.054 (0.02)	**		
Child School (Recategorized)	*Child in school (reference)*	0.96 (0.01)	***	0.0023	0.1413
	Adult or no response	-0.02 (0.01)	**		
	Child not in school	-0.04 (0.02)	*		
Child Care	*Child attending school or daycare (reference)*	0.95 (0.01)	***	0.0023	0.1389
	Adult or no response	-0.02 (0.01)	*		
	Child not attending school or daycare	-0.04 (0.04)			
Education	*University degree (lower) (reference)*	0.92 (0.01)	***	0.0023	0.1400
	No formal schooling	0.01 (0.06)			
	Primary school	0.02 (0.02)			
	Secondary school (lower)	0.02 (0.02)			

	Upper secondary school (upper)	0.02 (0.02)			
	Secondary school (unspecified)	0.03 (0.02)			
	University degree (higher)	0.03 (0.02)			
Occupation	*Working full- or part-time (reference)*	0.94 (0.01)	***	0.0023	0.1407
	At home (housewife)	-0.03 (0.03)			
	Currently unemployed / job seeking	-0.11 (0.03)	**		
	In full time or further education	0.02 (0.01)	**		
	Other	-0.03 (0.02)	.		
Severe Disease - Self	*Did not deal with a serious illness (reference)*	0.95 (0)	***	0.0021	0.1303
	Have dealt with a serious illness	-0.07 (0.01)	***		
Severe Disease - Family	*Did not deal with a serious illness in family (reference)*	0.96 (0.01)	***	0.0021	0.1290
	Have dealt with a serious illness in family	-0.04 (0.01)	***		
Severe Disease - Caregiving	*Did not deal with a serious illness because of caring for others (reference)*	0.94 (0.01)	***	0.0023	0.1414
	Child; not applicable	0.01 (0.01)			
	Have dealt with a serious illness because of caring for others	-0.04 (0.02)	*		
Smoking Status	*Current smoker (reference)*	0.91 (0.01)	***	0.0024	0.1451
	Child or no response	0.04 (0.01)	**		
	Ex-smoker	0.01 (0.02)			
	Non-smoker	0.03 (0.01)	*		
	Unknown	-0.06 (0.06)			
VAS	*(Intercept)*	0.56 (0.03)	***	0.0017	0.1216
	Constant	0.004 (0)	***		
Maternal Education	*University Degree (reference)*	0.95 (0.01)	***	0.0023	0.1389
	Adult or no response	-0.02 (0.01)	*		
	Less than university	-0.01 (0.01)			
Adult Education	*University Degree (reference)*	0.93 (0.01)	***	0.0023	0.1410
	Child or no response	0.02 (0.01)	.		
	Less than university	0 (0.01)			
Occupation - Recategorized	*Working full- or part-time (reference)*	0.94 (0.01)	***	0.0023	0.1443
	In full time or further education	0.02 (0.01)	**		
	Stay at-home parent, unemployed, job-seeking, or other	-0.04 (0.01)	**		

Education - Recategorized [a]	*University (reference)*	0.94 (0.01)	***	0.0024	0.1467
	Unknown	-0.04 (0.07)			
	Child, not in school/child in preschool or daycare	-0.01 (0.01)			
	Primary school	0.03 (0.01)	**		
	Secondary school	0 (0.01)			
	No formal schooling	0.03 (0.07)			
Height	*(Intercept)*	0.96 (0.02)	***	0.0024	0.1433
	Height	-0.01 (0.01)			
Weight	*(Intercept)*	0.96 (0.01)	***	0.0023	0.1427
	Weight	-0.0003 (0.0001)	*		
BMI - Continuous	*(Intercept)*	1 (0.02)	***	0.0023	0.1429
	BMI	-0.003 (0.001)	***		
BMI - Categorical	*Normal (reference)*	0.95 (0)	***	0.0023	0.1454
	Not Calculated/Infants	-0.05 (0.02)	*		
	Underweight	-0.03 (0.02)	.		
	Overweight	-0.04 (0.01)	***		
	Obesity	-0.08 (0.02)	***		

*$p < 0.001$: '***'; $p < 0.01$: '**'; $p < 0.05$: '*'; $p < 0.1$: '.'*

[a]Transformed education combines child and adult education responses based on 'child school', 'education (original)', 'response type', and 'age group'.

Supplementary Table 2 - Pooled Results from the Linear Mixed-Effects Models Evaluating the Relationship between Individual Health Utility Score and the Household-Level Determinants, while Accounting for Household as a Clustering Variable

	Levels	Estimate (SE)		Variance of Random Effect	ICC
Household size	*4 (reference)*	0.952 (0.006)	***	0.0021	0.1321
	2	-0.037 (0.031)			
	3	-0.039 (0.011)	***		
	5	0.003 (0.011)			
	6	-0.026 (0.021)			
	7	-0.067 (0.046)			
Household Parental Type	*Dual-parent household (reference)*	0.94 (0)	***	0.0023	0.1425

	Single-parent family	-0.03 (0.02)			
Household Child Care	*At least one child in the household is in daycare or school (reference)*	0.942 (0.004)	***	0.0024	0.1450
	No	-0.046 (0.037)			
Household Severe Disease	*No members in the household has dealt with severe illness (reference)*	0.968 (0.009)	***	0.0021	0.1323
	Yes	-0.035 (0.01)	***		
Household Smoking	*There are no current smokers in the household (reference)*	0.942 (0.005)	***	0.0024	0.1450
	Yes	-0.002 (0.01)			
Household Animal Ownership	*There are no pets in the household (reference)*	0.934 (0.017)	***	0.0024	0.1445
	Yes	0.004 (0.01)			

*$p < 0.001$: '***'; $p < 0.01$: '**'; $p < 0.05$: '*'; $p < 0.1$: '.'*

Compared to the average household size of 4, households with 3 members were significantly associated with lower health utility scores [$b = -0.05$, $p < 0.001$]. Households with at least one member having dealt with a serious illness (with self, family, and/or while caring for others) was significantly associated with lower health utility scores [$b = -0.04$, $p < 0.001$]. Single-parent households, households without access to child care and with at least one member currently smoking had lower, but not significant, health utility scores, while having an animal in the household was associated with a minimal, but not significant, increase in health utility scores.