Themed Section: Evolution of EuroQoL

Selecting Bolt-On Dimensions for the EQ-5D: Examining Their Contribution to Health-Related Quality of Life

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ABSTRACT

Background: Generic preference-based measures may miss dimensions important for the health-related quality of life (HRQOL) of patients. When this happens, a possible solution is to add bolt-ons. Finch et al. (Finch AP, Brazier JE, Mukuria C, Bjorner JB. An exploratory study on using principal component analysis and confirmatory factor analysis to identify bolt-on dimensions: the EQ-5D case study. Value Health 2017;10:1362–75) have recently shown that bolt-ons can be systematically identified using factor analysis. Nevertheless, because for each bolt-on option a complete re-evaluation may be required, methods to select between them are needed. **Objectives:** To investigate the possibility of selecting bolt-ons using their ability to predict differences in HRQOL. It tests six factors (energy/vitality, satisfaction, relationships, hearing, vision, and speech), and 37 items loading on them, using the EuroQol five-dimensional questionnaire as a case study. **Methods:** Data were obtained from the Multi-Instrument Comparison study, an online survey on health and well-being measures carried out in six countries. Two tests were performed. In the first test, linear regressions were fitted to determine whether different bolt-ons helped explain variations in HRQOL as measured by the Health visual analogue scale. The upper anchor (100) of this scale represents excellent physical, mental, and social health, and the lower anchor (0) represents death. Bolt-on relevance was judged comparing

the strength, direction, and statistical significance of unadjusted β coefficients. In the second test, linear regressions were fitted to further investigate whether different factors and items helped explain the negative effect of six chronic conditions on HRQOL. A reduction in the coefficients for the chronic condition dummies meant that the factor or item detected the effect. **Results:** Energy/vitality, relationships, and satisfaction reported substantially larger coefficients than did speech, vision, and hearing. Also, items loading on energy/vitality, relationships, and satisfaction generally presented larger coefficients than did those loading on speech, vision, and hearing. The second test did not detect consistent decrements in the coefficients for chronic conditions when testing factors, but it generally did detect consistent decrements when testing items. **Conclusions:** The first test appeared useful for bolt-on selection. Further research is needed before using the second test.

Keywords: bolt-ons, descriptive systems, EQ-5D

Introduction

The recent history of health-related quality of life (HRQOL) measures can be traced back to the early 1970s [1,2], when these measures started to be developed to operationalize the definition of health proposed by the World Health Organization [3]. Because this definition did not offer any guidance on the content required in a health measure, developers made their own judgments on which indicators (i.e., dimensions or items) [4] and which aspects of the definition (i.e., physical, mental, and social well-being) [5,6] to consider. This resulted in HRQOL measures differing in their dimensions and items [1].

Nevertheless, HRQOL measures generally tap on theoretically inter-related domains, and a number of models have been proposed to explain the relationship between them [7–9]. One of the most influential ones is the Wilson and Cleary model [10]. According to this model, HRQOL measures include domains related to one or more of five constructs, namely, physiological factors, symptom status, functioning status, general health, and overall quality of life. Some measures include dimensions and items from multiple levels of the model, whereas others fit only at one level [10].

Certain HRQOL measures use preference weights as a scoring system. These measures differ from others, because their scoring responds to the basic rational of economic calculus and can for

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this reason be used in the assessment of health care interventions [1]. They are sometimes referred to as generic preference-based measures (GPBMs), health state utility value measures, or multi-attribute utility measures.

Similar to other HRQOL measures, GPBMs differ in the health dimensions and items they cover [11]. In an effort to ensure consistency in decisions, health technology bodies tend to express a preference for using only one GPBM in all assessments, for example, the EuroQol five-dimensional questionnaire (EQ-5D) for the National Institute for Health and Care Excellence [12]. Yet, this is not always possible, because some GPBMs may lack validity and responsiveness in some conditions and disease areas [13]. In those cases, using a different generic or specific measure with preferences attached [1] represents the suggested practice. Nevertheless, the use of a different measure from the reference case undermines the cross-program comparability [14–17] because it implies that different interventions are compared using different dimensions of health.

An option that has gained popularity consists in adding bolt-on dimensions to the measure lacking validity and responsiveness [18]. The use of bolt-ons might restore some form of comparability, because it ensures that the same core set of dimensions is used for all interventions. A recent study has shown that factor analysis can be used for identifying bolt-ons [19]. This study used a set of measures that are commonly used in economic evaluations and have been shown to cover most of the domains of interest described in the Wilson and Cleary model [20]. Hence, these represent an important and broad pool of candidate bolt-ons. By using factor analysis, Finch et al. [19] identified 6 factors, and 37 items loading on them, that were not related to the five-level EQ-5D (EQ-5D-5L).

A complexity that makes GPBMs differ from other HRQOL measures is that the bolt-ons cannot be simply added to the descriptive system of the original measure, but need to be valued in terms of preferences. Current evidence suggests that bolt-ons have an impact on coefficients also for the pre-existing dimensions of GPBMs [21–25]. This implies that for each bolt-on option, the new descriptive system needs to undergo a complete re-evaluation, a process that can be costly and complex. Hence, even if the bolt-ons measure distinct constructs relevant to expand the descriptive system of the investigated measure, some form of selection is required. Nevertheless, methods for choosing between bolt-ons after factor analysis identification do not exist to date.

This study aimed at covering this gap by exploring the possibility of using the ability of bolt-ons to predict differences in HRQOL to inform on their selection. This is an important aspect because the dimensions added to an HRQOL measure should tap on constructs that are relevant for patients and the general population. It uses linear regressions, a technique that was chosen because it is extremely common and easy to conduct [26]. This maximizes the utility of this research for future applications. The EQ-5D-5L was chosen as a case study, because previous research has identified bolt-on factors and items for this measure [19].

Methods

Data

This study used a large cross-sectional, observational online survey—the Multi-Instrument Comparison study. Data were collected by Richardson et al. [20,27] and covered 12 HRQOL and well-being measures, among which are those used in the present study. This is to date the largest data set on health and well-being measures available worldwide [20]. A detailed description of collection methods is available elsewhere [27]. Broadly, data were

obtained using quotas to ensure a sample with similar socio-demographic characteristics across six countries (Australia, Canada, Germany, Norway, the United Kingdom, and the United States). Responders were members of the general public who had previously agreed to participate in online surveys. Responders were excluded if 1) they completed the survey in less than 20 minutes, 2) they stated not to have a health problem but reported a self-assessed health status lower than 65 on the Health visual analogue scale (VAS), 3) large differences were found between duplicated questions, and 4 a difference of more than two response levels was found in pain questions of the EQ-5D and the Assessment of Quality of Life (AQoL-8D). The final sample comprised 8022 individuals, 6262 of whom self-reported to be affected by one of the following nine chronic health conditions: asthma, cancer, chronic obstructive pulmonary disease (COPD), depression, diabetes, hearing problems, arthritis, heart diseases, and stroke. The remaining 1760 individuals did not report to be affected by any chronic health condition.

Questionnaires, Items, and Factors

This study used the Health VAS as a dependent variable. This was intended as a proxy of HRQOL. The Health VAS is a self-reported rating scale of health today in which 100 and 0 are anchors for excellent health and death, respectively. It differs from the Euro-Qol VAS because it describes perfect health from a broader perspective. More specifically, perfect health is defined as excellent physical, mental, and social health. Physical health is defined as no pain, discomfort, or itching; perfect hearing, vision, and speech; and excellent strength, flexibility, movement, and energy. Mental health is defined as very happy, enthusiastic, and contented; never sad or depressed; and confident and with high self-worth. Social health is defined as excellent social and family relationships. Because the Health VAS reported an approximately normal distribution, this was considered as a continuous variable.

The present study used the EQ-5D-5L. In addition, items from the six-dimensional health state short form (SF-6D), the Health Utility Index Mark 3 (HUI3), the AQoL-8D, the 15D, the Personal Wellbeing Index (PWI), the Satisfaction with Life Scale (SWLS), the Office of National Statistics (ONS), and the ICEpop CAPability (ICECAP) measure were used. These items are the 37 identified as potential bolt-ons related to factors not already covered by the EQ-5D presented by Finch et al. [19]. This choice was made to allow comparability of results between item and factor regressions. All items from the GPBMs (EQ-5D, SF-6D, HUI3, AQoL-8D, and 15D) and subjective well-being measures (PWI, SWLS, ONS, and ICE-CAP) were ordinal categorical, reporting levels varying between 4 and 11. Items for the PWI, SWLS, and ONS were recoded to report level 1 as perfect satisfaction. The EQ-5D and selected items from the SF-6D, HUI3, AQoL-8D, 15D, PWI, SWLS, ONS, and ICECAP were used as independent variables, where each item was assigned a dummy for each of its levels. Wording for the items tested is presented in Appendix Table 1 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2018.07.001.

Finally, the six latent factors identified by Finch et al. [19], namely, satisfaction, hearing, vision, energy/sleep, relationships, and speech cognition, were used. Latent factors are continuous variables and were used as independent variables.

Analyses

Two tests were performed. The first test was carried out to discriminate between bolt-ons in terms of their ability to detect variations in HRQOL not already accounted for by the EQ-5D-5L. The second test further examined whether detected variations helped explain differences in HRQOL between patients and the general population in nine chronic conditions. This information

may be used to select between factors and items because for bolt-ons to be relevant they should be able to detect aspects of HRQOL not already covered by the parent measure (i.e., the EQ-5D), and these aspects should help in explaining differences in HRQOL between patients and the general population for one or more conditions. The ability of factors and items to detect differences in HRQOL might suggest that their addition would improve the validity and responsiveness of the EQ-5D.

First test

To assess whether factors and items were able to detect differences in HRQOL as measured by the Health VAS, a base model was estimated, regressing the Health VAS over the EQ-5D-5L dummies and sociodemographic controls. The model was subsequently extended with the inclusion of factors and items, each of which was added individually. Unstandardized β coefficients for factors and items are reported. For factors, these indicated the amount of decrease in HRQOL as a result of a unit change in the latent factor tested. For items, these indicated the amount of decrease in HRQOL associated with the level of the dummy variable compared with the reference case (best possible health/satisfaction). The size, direction, and statistical significance of the β coefficients were used to compare factors and items. Comparatively larger β coefficients meant that the factor/item was better in predicting differences in HRQOL not already captured by the EQ-5D-5L. Nonstatistically significant β coefficients suggested no impact of the factor or item in predicting differences in HRQOL. If the addition of a factor or item made one or more of the EQ-5D-5L dimensions not statistically significant, this meant that it was able to take full account of variations in HRQOL for those dimensions. If the factor or item substantially reduced the coefficient of one or more of the EQ-5D-5L dimensions, this showed a possible interaction between that factor or item and the dimension for which the coefficient was reduced. These latter two pieces of information may be used for selecting factors or items; for example, if a choice between two items related to the same factor has to be made, the item having less impact on the remaining dimensions of the EQ-5D should be chosen because this shows that it has less overlap with the aspects of health already covered by the questionnaire.

Analyses of observable variables (item regressions) were conducted in STATA/MP 14 (StataCorp, College Station, TX), and analyses of latent variables (factor regressions) were performed in Mplus version 7 (Muthén & Muthén, Los Angeles, CA).

Second test

To assess whether different factors and items were able to explain differences in HRQOL between patients and the general population, the second test replicated the methods used by Bockerman et al. [28]. The Health VAS was first regressed upon EQ-5D-5L dimension dummies, sociodemographic controls, and dummy variables for asthma, cancer, COPD, depression, diabetes, hearing problems, arthritis, heart diseases, or stroke. β coefficients for the conditions indicated the difference in HRQOL between responders in a disease group and the general population, not accounted by the EQ-5D-5L. Subsequently, the model was extended including also factors and items, each of which was added individually. If the factor or item took full account of variations in HRQOL for one condition, then the dummy variable for that condition was expected to be insignificant. A reduction in the β coefficient for the condition represented the responsiveness of the bolt-on to differences in HRQOL for that condition, controlling for the EQ-5D-5L. Nonstatistically significant β coefficients suggested no impact of the factor or item in predicting differences in HRQOL between patients and the general population. If the addition of a factor or item made one or more of the EQ-5D-5L dimensions not

statistically significant, this meant that the factor or item was able to take full account of variations in HRQOL for those dimensions in the general population group. If the factor or item substantially reduced the coefficient of one or more EQ-5D-5L dimensions, this showed a possible interaction between that factor or item and the dimension for which the coefficient was reduced in the general population group.

Analyses of observable variables (item regressions) were conducted in STATA/MP 14, and analyses of latent variables (factor regressions) were performed in Mplus version 7.

Results

Table 1 presents the background characteristics and health status, as measured by the EQ-5D-5L, of the survey responders.

First Test

Table 2 presents the results for the base model using the first test. All the EQ-5D-5L dimensions except self-care were able to explain variations in HRQOL. Removal of usual activities from the regression model resulted in self-care level 3 and level 4 becoming statistically significant with coefficients of −3.227 and −5.567, respectively, showing a possible interaction between usual activities and self-care. β coefficients were larger at increasing levels of severity/problems for all statistically significant dimensions except for usual activities, where level 4 was associated with a worse decrement than level 5. Mobility reported the smallest β coefficients, whereas anxiety/depression reported the largest.

Table 3 presents the results for the regressions using factors and items (each added individually). As can be seen, all factors explained variations in HRQOL over and above the EQ-5D-5L. The size of the β coefficients varied, with coefficients for relationships and satisfaction being approximately double, and of energy/sleep almost triple, than those for the remaining factors. All statistically significant dummies for the EQ-5D-5L dimensions in the base model remained statistically significant with the addition of latent factors, with their coefficients registering small or no changes.

In the item regressions, the items' performance differed depending on the factor on which they loaded. Items loading on energy/sleep, relationships, and satisfaction registered statistically significant results for most of their levels, whereas items loading on speech/cognition, vision, and hearing were frequently nonsignificant. β coefficients were generally larger for the items loading on energy/sleep, relationships, and satisfaction.

Systematic differences in the items' ability to detect variations in HRQOL were seen also between items loading on the same factor. For example, the items measuring energy in the energy/sleep factor reported substantially larger coefficients compared with the two items measuring sleep on the same factor. Similarly, although the two items measuring cognition on the speech/cognition factor reported moderate and statistically significant coefficients, none of the speech items was statistically significant.

Finally, some items reported β coefficient decrements that were inconsistent with the increase in the level of severity/problems. For example, 15D mental function reported a larger coefficient for level 2 of the dummy variable than for level 3, and AQoL close relationships (family and friends) reported a larger coefficient for level 5 than for level 6.

All statistically significant dummies for the EQ-5D-5L in the base model remained statistically significant with the addition of the items. Generally, their coefficients registered small or no changes. Nevertheless, coefficients for the EQ-5D anxiety/depression dimension often registered large decrements when items related to satisfaction were added, large to moderate decrements when items related to energy were added, and moderate

Table 1 – Background characteristics and health status of survey participants			
Variable	**Category**	**Frequency**	**Percentage**
Sex	Male	3848	48
	Female	4174	52
Age (y)	18−24	513	6
	25−34	944	12
	35−44	1137	14
	45−54	1689	21
	55−64	2008	25
	>65	1731	22
Highest education achieved	High school	2522	31
	Diploma or certificate	3241	41
	University	2259	28
Self-reported chronic health condition	None	1760	22
	Asthma	856	11
	Cancer	772	10
	COPD	66	1
	Depression	917	11
	Diabetes	924	11
	Hearing problems	832	10
	Arthritis	929	11
	Heart diseases	943	12
	Stroke	23	1
EQ-5D mobility	No problems	5337	67
	Slight problems	1491	19
	Moderate problems	824	10
	Severe problems	340	3
	Extreme problems/unable to	30	1
EQ-5D self-care	No problems	7033	88
	Slight problems	646	8
	Moderate problems	273	3
	Severe problems	62	1
	Extreme problems/unable to	8	<1
EQ-5D usual activities	No problems	5182	65
	Slight problems	1739	22
	Moderate problems	794	9
	Severe problems	256	3
	Extreme problems/unable to	51	1
EQ-5D pain/discomfort	No problems	2340	29
	Slight problems	3251	41
	Moderate problems	1619	20
	Severe problems	697	9
	Extreme problems/unable to	115	1
EQ-5D anxiety/depression	No problems	4012	50
	Slight problems	2348	29
	Moderate problems	1107	14
	Severe problems	393	5
	Extreme problems/unable to	162	2

Note. Each variable has a total number of responders of 8022.
COPD, chronic obstructive pulmonary disease; EQ-5D, EuroQol five-dimensional questionnaire.

reductions when items related to relationships were added. The greatest reductions were noticed for items related to life satisfaction. Coefficients for the EQ-5D usual activities dimension registered moderate decrements when energy items were added.

Second Test

Appendix Table 2 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2018.07.001 presents the base model for the second test. Tables 4 and 5 report the change in coefficients associated with the inclusion of factors and selected items. In the base model, dummies were statistically significant for all

chronic conditions, showing that the EQ-5D-5L only partially captures differences in the Health VAS between disease groups and the general population. The smallest coefficients were seen for hearing problems, arthritis, and asthma, followed by depression, diabetes, and heart diseases. Cancer, COPD, and stroke reported the largest coefficients.

None of the factors was able to take full account of the differences in the Health VAS between patients and the general population, because chronic condition dummies remained statistically significant and negative for all of them. Nevertheless, five factors had an impact on one or more of the coefficients of the chronic conditions, reducing their magnitude. More specifically,

Table 2 – β coefficients, statistical significance, and standard errors of dummy variables for the base model assessing the impact on HRQOL (Health VAS as dependent variable)

Variable	β coefficient	Standard error
Constant	80.449[*]	0.830
Education		
High school	Omitted	Omitted
Diploma	−0.283	0.438
University	0.991[†]	0.482
Age (y)		
18–24	Omitted	Omitted
25–34	1.105	0.912
35–44	0.009	0.887
45–54	−0.580	0.852
55–64	−0.653	0.843
>65	1.250	0.865
Sex		
Male	Omitted	Omitted
Female	2.729[*]	0.378
EQ-5D-5L mobility		
Level 1	Omitted	Omitted
Level 2	−3.346[*]	0.573
Level 3	−5.788[*]	0.852
Level 4	−9.479[*]	1.302
Level 5	−10.543[*]	3.249
EQ-5D-5L self-care		
Level 1	Omitted	Omitted
Level 2	−2.202[*]	0.762
Level 3	0.296	1.213
Level 4	−0.941	2.313
Level 5	1.710	5.924
EQ-5D-5L usual activities		
Level 1	Omitted	Omitted
Level 2	−7.495[*]	0.560
Level 3	−12.164[*]	0.900
Level 4	−17.338[*]	1.428
Level 5	−16.764[*]	2.584
EQ-5D-5L pain/discomfort		
Level 1	Omitted	Omitted
Level 2	−4.043[*]	0.474
Level 3	−7.834[*]	0.646
Level 4	−10.341[*]	0.912
Level 5	−14.691[*]	1.776
EQ-5D-5L anxiety/depression		
Level 1	Omitted	Omitted
Level 2	−6.221[*]	0.448
Level 3	−12.851[*]	0.603
Level 4	−21.522[*]	0.921
Level 5	−26.102[*]	1.378
R^2	0.439	

EQ-5D-5L, five-level EuroQol five-dimensional questionnaire; HRQOL, health-related quality of life; VAS, visual analogue scale.

[*] $P \leq 0.01$.

[†] $P \leq 0.05$.

satisfaction decreased the COPD dummy by 0.617; vision decreased the depression, diabetes, COPD, and stroke dummies by 0.863, 0.503, 0.436, and 2.623, respectively; and hearing, speech/cognition, and energy/sleep decreased the stroke dummy by 0.589, 0.580, and 1.561, respectively. Decrements for the COPD and stroke dummies should be interpreted with care, because they are based on small samples (i.e., 23 observations for stroke and 66 for COPD).

All the EQ-5D-5L dimensions that were statistically significant in the base model remained statistically significant with the addition of the latent factors, with their coefficients generally reporting small or no changes.

Also, none of the items was able to take full account of the differences in HRQOL between patients and the general population, because chronic condition dummies remained statistically significant and negative. Nevertheless, numerous items decreased the β coefficients for chronic conditions, with some of them having a general impact and others a specific one. For example, AQoL energy produced decrements for all chronic condition dummies that varied between −0.907 for arthritis and −3.059 for COPD. In contrast, the 15D hearing and HUI3 hearing substantially reduced only hearing problems (decrements of 0.974 and 0.706, respectively), with the next largest reduction being 4 and 3 times smaller; that is, COPD decreased by 0.226 for 15D hearing and by 0.221 for HUI3 hearing.

As for the first test, all the EQ-5D-5L dimensions that were statistically significant in the base model remained statistically significant with the addition of the items. Once again, coefficients for the EQ-5D anxiety/depression dimension often decreased when items loading on satisfaction, relationships, and energy were added, with items related to life satisfaction causing the largest switches.

Items related to energy once again produced decrements in the coefficients for the EQ-5D usual activities. The largest reduction was registered with the addition of AQoL energy.

Discussion

This study investigated the potential of using linear regressions for selecting bolt-ons after factor analysis identification. It assessed the usefulness of two tests. The first test appeared appropriate for selecting between potential independent factors and items. Results for factors and items were concordant in pointing at relationships, energy/sleep, and satisfaction factors, and items loading on them, as the most relevant bolt-ons. The study also showed systematic differences in items' ability to detect differences in HRQOL when they loaded on the same factor. These results suggest that despite loading on the same factor and being inter-related, energy and sleep measure partially different concepts, as do cognition and speech. Because energy and cognition appeared to be better in explaining variations in HRQOL than sleep and speech, items related to these concepts should be preferred when adapting them into bolt-on dimensions. These findings agree with those of previous research [29,30] that found "happiness," "emotional health," "cognition," "relationships," and "sensory deprivation" (e.g., vision loss) to be the most important aspects of health not covered by the EQ-5D. They also provide additional evidence compared with these studies on the relative importance of these aspects as add-on dimensions.

The second test generated results that are sometimes difficult to interpret. Although none of the factors and items was able to fully account for differences in HRQOL between patients and the general population, they were frequently able to explain a part of these differences. Decrements for items generally occurred in chronic conditions that were theoretically related to the aspects of health measured by the item. Some reductions occurred in chronic conditions not related to the aspects of health measured by the factor. Despite the fact that the number of observations for those conditions was generally small and therefore these results should be interpreted with care, the discrepancies in the results of factor and item regressions raise some doubts as to the ability of the second test to discriminate between bolt-ons. Further investigation is needed before using this technique.

Table 3 – β coefficients, statistical significance, and standard errors of factors and items for the first test			
Factor to which the item is related	**Factor/item tested**	**VAS-dependent variable**	
		β **coefficient**	**Standard error**
	Satisfaction	−4.323*	0.112
	Relationships	−5.298*	0.235
	Hearing	−1.209*	0.353
	Speech/cognition	−2.269*	0.287
	Vision	−2.185*	0.257
	Energy/vitality	−7.648*	0.217
Satisfaction	PWI satisfaction standard of living 1	Omitted	Omitted
	PWI satisfaction standard of living 2	−1.010	0.811
	PWI satisfaction standard of living 3	−2.830*	0.751
	PWI satisfaction standard of living 4	−6.449*	0.776
	PWI satisfaction standard of living 5	−8.040*	0.844
	PWI satisfaction standard of living 6	−10.477*	0.870
	PWI satisfaction standard of living 7	−9.834*	0.937
	PWI satisfaction standard of living 8	−12.078*	0.993
	PWI satisfaction standard of living 9	−14.152*	1.108
	PWI satisfaction standard of living 10	−12.871*	1.402
	PWI satisfaction standard of living 11	−11.483*	1.438
Satisfaction	PWI satisfaction achievement 1	Omitted	Omitted
	PWI satisfaction achievement 2	−0.102	0.860
	PWI satisfaction achievement 3	−2.648*	0.815
	PWI satisfaction achievement 4	−5.257*	0.832
	PWI satisfaction achievement 5	−8.485*	0.890
	PWI satisfaction achievement 6	−11.226*	0.869
	PWI satisfaction achievement 7	−12.363*	0.998
	PWI satisfaction achievement 8	−14.630*	1.058
	PWI satisfaction achievement 9	−17.779*	1.123
	PWI satisfaction achievement 10	−18.501*	1.258
	PWI satisfaction achievement 11	−18.922*	1.330
Satisfaction	ONS satisfaction with life 1	Omitted	Omitted
	ONS satisfaction with life 2	−0.361	0.880
	ONS satisfaction with life 3	−4.489*	0.845
	ONS satisfaction with life 4	−7.720*	0.883
	ONS satisfaction with life 5	−10.704*	0.946
	ONS satisfaction with life 6	−11.733*	0.949
	ONS satisfaction with life 7	−14.496*	1.050
	ONS satisfaction with life 8	−17.586*	1.081
	ONS satisfaction with life 9	−20.457*	1.095
	ONS satisfaction with life 10	−22.250*	1.217
	ONS satisfaction with life 11	−24.863*	1.236
Satisfaction	PWI satisfaction with life as a whole 1	Omitted	Omitted
	PWI satisfaction with life as a whole 2	−1.018	0.875
	PWI satisfaction with life as a whole 3	−4.575*	0.80
	PWI satisfaction with life as a whole 4	−8.823*	0.829
	PWI satisfaction with life as a whole 5	−12.252*	0.911
	PWI satisfaction with life as a whole 6	−12.376*	0.916
	PWI satisfaction with life as a whole 7	−15.976*	1.043
	PWI satisfaction with life as a whole 8	−19.238*	1.060
	PWI satisfaction with life as a whole 9	−21.300*	1.149
	PWI satisfaction with life as a whole 10	−19.737*	1.558
	PWI satisfaction with life as a whole 11	−22.271*	1.604
Satisfaction	SWLS satisfaction with life 1	Omitted	Omitted
	SWLS satisfaction with life 2	−3.511*	0.680
	SWLS satisfaction with life 3	−7.887*	0.721
	SWLS satisfaction with life 4	−12.342*	0.819
	SWLS satisfaction with life 5	−14.587*	0.828
	SWLS satisfaction with life 6	−19.591*	0.891
	SWLS satisfaction with life 7	−24.868*	1.145
			continued on next page

Table 3 – *continued*			
Factor to which the item is related	**Factor/item tested**	**VAS-dependent variable**	
		β **coefficient**	**Standard error**
Satisfaction	SWLS conditions of life are excellent 1	Omitted	Omitted
	SWLS conditions of life are excellent 2	−3.293*	0.821
	SWLS conditions of life are excellent 3	−6.843*	0.828
	SWLS conditions of life are excellent 4	−11.123*	0.884
	SWLS conditions of life are excellent 5	−14.229*	0.902
	SWLS conditions of life are excellent 6	−19.105*	0.951
	SWLS conditions of life are excellent 7	−23.262*	1.130
Satisfaction	SWLS life close ideal 1	Omitted	Omitted
	SWLS life close ideal 2	−2.136	0.951
	SWLS life close ideal 3	−6.733*	0.952
	SWLS life close ideal 4	−9.657*	1.014
	SWLS life close ideal 5	−11.826*	1.031
	SWLS life close ideal 6	−17.383*	1.049
	SWLS life close ideal 7	−20.917*	1.192
Satisfaction	SWLS gotten important things in life 1	Omitted	Omitted
	SWLS gotten important things in life 2	−1.909†	0.623
	SWLS gotten important things in life 3	−6.409*	0.658
	SWLS gotten important things in life 4	−8.394*	0.75
	SWLS gotten important things in life 5	−10.542*	0.781
	SWLS gotten important things in life 6	−14.878*	0.859
	SWLS gotten important things in life 7	−17.962*	1.064
Satisfaction	ONS life is worthwhile 1	Omitted	Omitted
	ONS life is worthwhile 2	−0.991	0.752
	ONS life is worthwhile 3	−4.001*	0.729
	ONS life is worthwhile 4	−6.368*	0.760
	ONS life is worthwhile 5	−10.142*	0.810
	ONS life is worthwhile 6	−11.748*	0.808
	ONS life is worthwhile 7	−15.392*	1.057
	ONS life is worthwhile 8	−17.329*	1.129
	ONS life is worthwhile 9	−18.589*	1.127
	ONS life is worthwhile 10	−19.099*	1.234
	ONS life is worthwhile 11	−22.434*	1.403
Satisfaction	SWLS if I could live life over 1	Omitted	Omitted
	SWLS if I could live life over 2	−1.143	0.830
	SWLS if I could live life over 3	−3.139*	0.838
	SWLS if I could live life over 4	−4.461*	0.885
	SWLS if I could live life over 5	−6.846*	0.838
	SWLS if I could live life over 6	−8.685*	0.857
	SWLS if I could live life over 7	−12.862*	0.898
Satisfaction	ONS happiness yesterday 1	Omitted	Omitted
	ONS happiness yesterday 2	−1.693	0.719
	ONS happiness yesterday 3	−4.224*	0.712
	ONS happiness yesterday 4	−7.323*	0.749
	ONS happiness yesterday 5	−11.050*	0.816
	ONS happiness yesterday 6	−12.203*	0.793
	ONS happiness yesterday 7	−13.346*	1.002
	ONS happiness yesterday 8	−15.807*	1.095
	ONS happiness yesterday 9	−17.041*	1.061
	ONS happiness yesterday 10	−18.303*	1.203
	ONS happiness yesterday 11	−19.570*	1.139
Satisfaction	PWI satisfaction personal relationships 1	Omitted	Omitted
	PWI satisfaction personal relationships 2	−1.220	0.611
	PWI satisfaction personal relationships 3	−2.475*	0.627
	PWI satisfaction personal relationships 4	−4.891*	0.683
	PWI satisfaction personal relationships 5	−5.323*	0.793
	PWI satisfaction personal relationships 6	−7.147*	0.729
	PWI satisfaction personal relationships 7	−8.671*	0.963
	PWI satisfaction personal relationships 8	−10.254*	1.004
	PWI satisfaction personal relationships 9	−10.511*	1.059
	PWI satisfaction personal relationships 10	−11.847*	1.210
	PWI satisfaction personal relationships 11	−13.028*	1.248

Table 3 – continued

Factor to which the item is related	Factor/item tested	VAS-dependent variable	
		β coefficient	Standard error
Satisfaction	PWI satisfaction part of the community 1	Omitted	Omitted
	PWI satisfaction part of the community 2	−1.042*	0.801
	PWI satisfaction part of the community 3	−3.284*	0.753
	PWI satisfaction part of the community 4	−5.634*	0.783
	PWI satisfaction part of the community 5	−7.638*	0.845
	PWI satisfaction part of the community 6	−9.274*	0.757
	PWI satisfaction part of the community 7	−10.975*	1.029
	PWI satisfaction part of the community 8	−14.776*	1.112
	PWI satisfaction part of the community 9	−14.396*	1.149
	PWI satisfaction part of the community 10	−15.078*	1.298
	PWI satisfaction part of the community 11	−15.551*	1.380
Satisfaction	PWI satisfaction future security 1	Omitted	Omitted
	PWI satisfaction future security 2	−1.059	0.88
	PWI satisfaction future security 3	−2.746*	0.832
	PWI satisfaction future security 4	−4.238*	0.849
	PWI satisfaction future security 5	−6.783*	0.905
	PWI satisfaction future security 6	−8.868*	0.863
	PWI satisfaction future security 7	−9.674*	0.977
	PWI satisfaction future security 8	−10.433*	1.013
	PWI satisfaction future security 9	−13.005*	1.060
	PWI satisfaction future security 10	−13.540*	1.138
	PWI satisfaction future security 11	−14.227*	1.153
Satisfaction	PWI satisfaction spirituality 1	Omitted	Omitted
	PWI satisfaction spirituality 2	0.010	0.619
	PWI satisfaction spirituality 3	−0.236	0.628
	PWI satisfaction spirituality 4	−3.311*	0.729
	PWI satisfaction spirituality 5	−4.225*	0.875
	PWI satisfaction spirituality 6	−5.102*	0.517
	PWI satisfaction spirituality 7	−7.263*	1.160
	PWI satisfaction spirituality 8	−6.449*	1.345
	PWI satisfaction spirituality 9	−8.618*	1.593
	PWI satisfaction spirituality 10	−6.562*	1.738
	PWI satisfaction spirituality 11	−10.234*	1.348
Satisfaction	PWI satisfaction safety 1	Omitted	Omitted
	PWI satisfaction safety 2	−1.557	0.617
	PWI satisfaction safety 3	−3.609*	0.618
	PWI satisfaction safety 4	−6.792*	0.680
	PWI satisfaction safety 5	−7.524*	0.808
	PWI satisfaction safety 6	−9.551*	0.761
	PWI satisfaction safety 7	−10.360*	1.053
	PWI satisfaction safety 8	−13.351*	1.156
	PWI satisfaction safety 9	−13.584*	1.209
	PWI satisfaction safety 10	−16.936*	1.587
	PWI satisfaction safety 11	−15.295*	1.574
Relationships	AQoL enjoyment close relationships 1	Omitted	Omitted
	AQoL enjoyment close relationships 2	−2.410*	0.411
	AQoL enjoyment close relationships 3	−6.705*	0.633
	AQoL enjoyment close relationships 4	−9.235*	0.986
	AQoL enjoyment close relationships 5	−11.097*	3.265
Relationships	ICECAP love and support 1	Omitted	Omitted
	ICECAP love and support 2	−1.468*	0.420
	ICECAP love and support 3	−5.282*	0.604
	ICECAP love and support 4	−7.657*	1.561
Relationships	AQoL close relationships (family and friends) 1	−2.964*	0.425
	AQoL close relationships (family and friends) 2	−6.841*	0.619
	AQoL close relationships (family and friends) 3	−11.169*	0.885
	AQoL close relationships (family and friends) 4	−15.310*	1.815
	AQoL close relationships (family and friends) 5	−7.748*	2.095

Table 3 – *continued*

Factor to which the item is related	Factor/item tested	VAS-dependent variable	
		β coefficient	Standard error
Relationships	AQoL close relationships (including sexual) 1	Omitted	Omitted
	AQoL close relationships (including sexual) 2	−2.619*	0.449
	AQoL close relationships (including sexual) 3	−7.399*	0.570
	AQoL close relationships (including sexual) 4	−7.383*	0.920
	AQoL close relationships (including sexual) 5	−11.277*	1.365
Hearing	AQoL hearing 1	Omitted	Omitted
	AQoL hearing 2	−1.936*	0.443
	AQoL hearing 3	−2.576*	0.512
	AQoL hearing 4	−4.927*	1.126
	AQoL hearing 5	1.584	3.571
	AQoL hearing 6	8.191	5.420
Hearing	15D hearing 1	Omitted	Omitted
	15D hearing 2	−1.227†	0.490
	15D hearing 3	−1.360	0.754
	15D hearing 4	−0.047	2.090
	15D hearing 5	1.965	4.522
Hearing	HUI3 hearing 1	Omitted	Omitted
	HUI3 hearing 2	−0.216	0.654
	HUI3 hearing 3	−0.025	0.943
	HUI3 hearing 4	−1.665	1.086
	HUI3 hearing 5	−4.335†	1.478
	HUI3 hearing 6	9.290	5.761
Speech/cognition	AQoL communication 1	Omitted	Omitted
	AQoL communication 2	−0.842	0.606
	AQoL communication 3	−1.707	1.243
	AQoL communication 4	−1.457	2.042
Speech/cognition	HUI3 speech 1	Omitted	Omitted
	HUI3 speech 2	−1.445	0.749
	HUI3 speech 3	0.804	1.299
	HUI3 speech 4	−2.176	2.655
	HUI3 speech 5	−6.090	6.177
Speech/cognition	15D speech 1	Omitted	Omitted
	15D speech 2	−3.441	0.702
	15D speech 3	0.381	1.833
	15D speech 4	3.228	3.752
	15D speech 5	−9.872	8.141
Speech/cognition	15D mental function 1	Omitted	Omitted
	15D mental function 2	−3.557*	0.471
	15D mental function 3	−3.438†	1.215
	15D mental function 4	−5.656	2.338
	15D mental function 5	−1.006	6.211
Speech/cognition	HUI3 cognition 1	Omitted	Omitted
	HUI3 cognition 2	−3.022*	0.674
	HUI3 cognition 3	−3.674*	0.560
	HUI3 cognition 4	−4.940*	1.056
	HUI3 cognition 5	−7.719*	1.993
	HUI3 cognition 6	5.787	4.269
Vision	AQoL vision 1	Omitted	Omitted
	AQoL vision 2	−2.390*	0.494
	AQoL vision 3	−4.070*	0.548
	AQoL vision 4	−8.383*	1.513
	AQoL vision 5	−33.079†	11.450
	AQoL vision 6	14.274	8.131
Vision	HUI3 vision 1	Omitted	Omitted
	HUI3 vision 2	−1.489*	0.420
	HUI3 vision 3	−2.187	1.046
	HUI3 vision 4	−1.321	1.049
	HUI3 vision 5	−9.856*	2.178
	HUI3 vision 6	−2.377	6.165

Table 3 – continued

Factor to which the item is related	Factor/item tested	VAS-dependent variable	
		β coefficient	Standard error
Vision	15D vision 1	Omitted	Omitted
	15D vision 2	−2.286[*]	0.458
	15D vision 3	−3.653[*]	1.062
	15D vision 4	−1.448	1.595
	15D vision 5	−1.779	5.148
Energy/sleep	15D vitality 1	Omitted	Omitted
	15D vitality 2	−9.071[*]	0.456
	15D vitality 3	−17.609[*]	0.665
	15D vitality 4	−22.761[*]	0.862
	15D vitality 5	−29.180[*]	1.279
Energy/sleep	AQoL energy 1	Omitted	Omitted
	AQoL energy 2	−5.036[*]	0.844
	AQoL energy 3	−12.392[*]	0.885
	AQoL energy 4	−19.350[*]	0.947
	AQoL energy 5	−25.957[*]	1.194
Energy/sleep	SF-6D vitality 1	Omitted	Omitted
	SF-6D vitality 2	−3.228[*]	0.879
	SF-6D vitality 3	−8.685[*]	0.898
	SF-6D vitality 4	−14.132[*]	0.961
	SF-6D vitality 5	−19.493[*]	1.014
Energy/sleep	AQoL enthusiasm 1	Omitted	Omitted
	AQoL enthusiasm 2	−1.937[†]	0.627
	AQoL enthusiasm 3	−7.473[*]	0.662
	AQoL enthusiasm 4	−14.735[*]	0.826
	AQoL enthusiasm 5	−19.979[*]	1.358
Energy/sleep	AQoL sleeping 1	Omitted	Omitted
	AQoL sleeping 2	−2.119[*]	0.620
	AQoL sleeping 3	−4.776[*]	0.633
	AQoL sleeping 4	−7.722[*]	0.735
	AQoL sleeping 5	−9.646[*]	0.893
Energy/sleep	15D sleeping 1	Omitted	Omitted
	15D sleeping 2	−2.452[*]	0.461
	15D sleeping 3	−5.180[*]	0.580
	15D sleeping 4	−7.396[*]	0.781
	15D sleeping 5	−10.056[*]	1.673

AQoL, Assessment of Quality of Life; HUI3, Health Utility Index Mark 3; ICECAP, ICEpop CAPability; ONS, Office of National Statistics; PWI, Personal Wellbeing Index; SF-6D, six-dimensional health state short form; SWLS, Satisfaction with Life Scale; VAS, visual analogue scale.
[*] $P \leq 0.01$.
[†] $P \leq 0.05$.

Table 4 – Changes in chronic condition β coefficients after factors were included individually

Chronic condition	Base-model coefficient	Factors (change in coefficients)					
		Energy/sleep	Relationships	Satisfaction	Speech/cognition	Vision	Hearing
Cancer	−14.008	0.005	0.067	0.045	−0.070	−0.397	−0.069
Asthma	−9.587	−0.003	0.048	0.019	−0.042	−0.206	−0.040
COPD	−15.570	0.638	0.294	**−0.617**	−0.115	**−0.436**	−0.093
Depression	−11.123	−0.022	0.053	0.037	−0.055	**−0.863**	−0.055
Diabetes	−12.565	−0.050	0.053	0.062	−0.071	**−0.503**	−0.074
Hearing problems	−6.890	0.027	0.031	−0.014	−0.014	−0.274	−0.009
Arthritis	−7.731	0.010	0.039	0.003	−0.029	−0.060	0.026
Heart diseases	−13.323	−0.030	0.063	0.047	−0.069	−0.322	−0.069
Stroke	−20.651	**−1.561**	0.010	1.735	**−0.580**	**−2.623**	**−0.589**

Note. Boldface coefficients indicate reduction in β coefficients ≥ 0.5. All coefficients were statistically significant at $P \leq 0.05$.
COPD, chronic obstructive pulmonary disease.

Table 5 – Changes in chronic condition coefficients after items were included individually

		Factors on which items loaded									
		Energy/sleep						Relationships			
Chronic condition	Base-model coefficient	15D vitality	AQoL-8D enthusiasm	15D sleep	AQoL energy	SF-6D vitality	AQoL sleeping	ICECAP love and support	AQoL close relationships (family and friends)	AQoL close relationships (sexual)	AQoL enjoyment close relationships
Cancer	−14.008	**−1.733**	−0.383	−0.263	**−1.802**	**−1.048**	−0.434	0.107	0.174	−0.066	0.070
Asthma	−9.587	**−1.709**	−0.377	−0.455	**−1.618**	**−1.020**	−0.439	0.008	−0.089	0.073	−0.062
COPD	−15.570	**−2.162**	−0.36	−0.590	**−3.059**	**−2.187**	−0.451	0.179	0.213	0.062	0.605
Depression	−11.123	**−2.707**	**−1.763**	**−0.649**	**−2.836**	**−1.975**	**−0.807**	−0.138	**−0.677**	−0.537	−0.696
Diabetes	−12.565	**−1.835**	**−0.544**	−0.279	**−1.914**	**−1.160**	−0.459	0.070	−0.118	−0.139	−0.111
Hearing problems	−6.890	**−1.130**	−0.448	−0.111	**−1.194**	**−0.561**	−0.296	−0.074	−0.231	−0.106	−0.275
Arthritis	−7.731	**−0.786**	−0.403	−0.340	**−0.907**	−0.427	−0.477	0.097	−0.020	0.248	−0.013
Heart diseases	−13.323	**−2.031**	**−0.635**	−0.355	**−2.284**	**−1.363**	−0.444	0.020	0.027	0.111	0.143
Stroke	−20.651	**−2.959**	**−1.136**	**−0.561**	**−2.401**	−0.265	−0.484	**−1.010**	0.009	−0.473	−0.28

		Factors on which items loaded															
		Satisfaction															
Chronic condition	Base-model coefficient	ONS life	SWLS condition life	SWLS live life over	PWI standard living	PWI achievement	PWI life as whole	SWLS life as whole	SWLS life close ideal	SWLS got important things	ONS things worthwhile	ONS happiness	PWI personal relationships	PWI part of the community	PWI future security	PWI spirituality	PWI safety
Cancer	−14.008	**−0.841**	**−0.943**	0.138	0.023	**−0.446**	−0.397	**−0.782**	**−0.573**	−0.062	−0.408	**−0.627**	0.019	−0.282	−0.102	−0.252	−0.042
Asthma	−9.587	−0.259	**−0.513**	0.065	−0.212	−0.254	−0.206	−0.252	−0.339	−0.195	−0.169	−0.381	−0.064	−0.059	−0.094	0.084	−0.021
COPD	−15.570	**−0.537**	0.036	0.176	0.155	−0.168	−0.436	0.155	0.472	**−0.725**	−0.103	−0.276	0.200	−0.132	−0.138	−0.174	0.326
Depression	−11.123	**−0.598**	**−0.883**	**−0.591**	−0.232	**−0.911**	**−0.863**	**−0.981**	**−0.65**	**−0.556**	**−0.802**	**−0.517**	−0.314	**−0.592**	−0.256	−0.127	−0.265
Diabetes	−12.565	**−0.888**	**−0.832**	−0.170	−0.453	**−0.810**	**−0.503**	**−0.900**	**−0.674**	**−0.616**	**−0.832**	−0.393	−0.166	−0.376	−0.280	−0.078	0.031
Hearing problems	−6.890	−0.284	0.045	0.155	0.149	−0.167	−0.274	−0.228	0.040	0.119	−0.204	−0.193	−0.087	−0.199	0.003	0.034	−0.184
Arthritis	−7.731	−0.223	−0.177	−0.165	0.156	−0.111	−0.060	−0.329	−0.238	−0.251	−0.097	0.114	−0.087	−0.008	0.048	0.051	0.234
Heart diseases	−13.323	**−0.537**	**−0.512**	0.085	−0.153	**−0.593**	−0.322	−0.342	−0.316	0.074	−0.372	−0.250	0.028	−0.180	−0.169	0.022	0.032
Stroke	−20.651	**−2.582**	**−3.519**	**−1.648**	**−1.293**	**−0.904**	**−2.623**	**−2.290**	**−1.263**	**−2.258**	**−0.828**	**−0.734**	**−0.532**	**−1.596**	**−1.732**	**−0.746**	**−1.201**

		Factors on which items loaded										
		Vision			Hearing			Speech/cognition				
Chronic condition	Base-model coefficient	AQoL vision	HUI3 vision	15D vision	AQoL hearing	15D hearing	HUI3 hearing	HUI3 speech	15D mental function	AQoL communication	15D speech	HUI3 cognition
Cancer	−14.008	−0.194	−0.023	−0.052	−0.322	−0.112	−0.062	0.001	−0.296	−0.027	−0.019	−0.273
Asthma	−9.587	−0.218	−0.043	−0.038	−0.165	−0.073	−0.007	0.017	−0.070	0.002	−0.059	−0.101
COPD	−15.570	−0.284	−0.043	0.058	−0.441	−0.226	−0.221	−0.017	0.080	0.019	0.148	0.281
Depression	−11.123	−0.098	−0.101	0.052	−0.153	−0.055	−0.037	0.005	−0.456	−0.048	−0.100	−0.440
Diabetes	−12.565	−0.323	−0.139	−0.149	−0.181	−0.089	−0.067	0.016	−0.136	0.008	−0.008	−0.087
Hearing problems	−6.890	−0.364	−0.184	−0.208	**−1.663**	**−0.974**	**−0.706**	−0.022	−0.327	−0.224	−0.171	−0.376
Arthritis	−7.731	−0.187	−0.055	−0.004	−0.182	−0.059	−0.023	0.032	−0.010	0.020	−0.017	0.013
Heart diseases	−13.323	−0.208	−0.063	−0.057	−0.305	−0.108	−0.083	0.010	−0.080	−0.003	−0.057	−0.154
Stroke	−20.651	**−0.832**	**−0.751**	−0.477	−0.650	−0.153	−0.147	−0.139	**−1.137**	−0.202	**−0.916**	**−1.293**

Note. Boldface coefficients indicate reduction in β coefficients ≥0.5. All coefficients remained statistically significant at P ≤ 0.05.
AQoL, Assessment of Quality of Life; COPD, chronic obstructive pulmonary disease; HUI3, Health Utility Index Mark 3; ICECAP, ICEpop CAPability; ONS, Office of National Statistics; PWI, Personal Wellbeing Index; SF-6D, six-dimensional health state short form; SWLS, Satisfaction with Life Scale.

This study used a set of strategies that were broadly based on the statistical significance of the factors and items tested, the size and direction of their coefficients, and the consistency in HRQOL decrements at increasing levels of severity to discriminate between candidate bolt-ons. The same set of strategies could also be used to identify dimensions that need bolting off the investigated GPBM. This could be done in isolation, by selecting those dimensions that perform poorly, or comparatively, by comparing the size, direction, and interaction of coefficients for the EQ-5D-5L and other measures' dimensions. Using the first approach would suggest, in the case of the present study, to bolt-off the EQ-5D-5L self-care dimension, because most of its levels were not statistically significant because of an interaction with usual activities. Using the second approach would suggest, again in the context of the present research, to substitute the EQ-5D-5L self-care or the EQ-5D-5L mobility dimension with a dimension adapted from the items loading on the relationship or the satisfaction factors. Choice between these items could be informed by their impact on the remaining dimensions of the EQ-5D, where items causing smaller interactions should be preferred because they tap into aspects less related to those already covered in the EQ-5D. In addition, because some items reported decrements that were inconsistent with the increase in the levels of severity, it would be preferable to choose an item for a bolt-on dimension that had consistent decrements in HRQOL across severity levels.

Similarly, the size of β coefficients could also be used to set an empirical threshold of bolt-on relevance. For example, coefficients for the "worst-performing item" could be set as a threshold to compare coefficients from bolt-on items. If coefficients for the items are at least as large as those of the worst performing pre-existing dimension, then those items would be considered relevant bolt-on additions. This would result in retaining only those items that are at least "as good" as the worst-performing GPBM dimension. The usefulness of this approach, however, depends on a number of aspects, among which are the method used for the present analysis (e.g., linear regression), the HRQOL proxy used, and the inclusion of possible interaction terms.

This study has some limitations that need mentioning. First, it used linear regressions to model the impact of factors and items on HRQOL. Although this technique has been seen on numerous occasions to produce reliable estimates in models with self-reported rating scales as the dependent variable [31,32], other models (e.g., two-limit tobit models) could have been used to account for the bounding of the Health VAS variable. Second, possible interactions were noticed among some of the items and the EQ-5D dimensions. Interactions were initially calculated but were not reported because the large number of coefficients generated was difficult to interpret. Inclusion of interaction would have improved the precision of the estimates for those items. Third, factors and items tested in this study were identified through previous research that did not use disease-specific measures. Hence, other factors and items not tested might be equally relevant additions to the EQ-5D-5L. Fourth, the second test covered only nine chronic conditions, but other conditions might have also been relevant. Finally, sample sizes for the lowest levels of the scale were small in most of the variables tested. It is important to treat estimates generated from these dummies with care.

Conclusions

This study presents a useful method to select between alternative factors and items that can be developed/adapted into bolt-on dimensions. It is generalizable to other HRQOL measures, whether preference-based, generic, or disease-specific, and for this reason it has a wide application in the field of measuring health. In addition, it provides evidence on the comparative relevance of a set of bolt-ons for the EQ-5D-5L.

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Supplementary Materials

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jval.2018.07.001.

REFERENCES

[1] Brazier J, Ratcliffe J, Salomon JA. Tsuchiya A. Measuring and Valuing Health for Economic Evaluations. Oxford, UK: Oxford University Press; 2012.

[2] Karimi M, Brazier J. Health, health related quality of life and quality of life: What is the difference? Pharmacoeconomics 2016;34:645–9.

[3] World Health Organization. Constitution of the World Health Organization. Geneva, Switzerland: World Health Organization; 1948.

[4] Lerner M. Conceptualization of health and social well-being. Health Serv Res 1973;8:6–12.

[5] Newhouse J. Free for All?. Lessons from the RAND Health Insurance Experiment. Cambridge, MA: Harvard University Press; 1993.

[6] Ware J. Conceptualization and Measurement of Health for Adults in the Health Insurance Study. Model of Health and Methodology, Vol. 1. Santa Monica, CA: RAND; 1980.

[7] Bergner M. Measurement of health status. Med Care 1985;23:696–704.

[8] Nagi S. Some conceptual issues in disability and rehabilitation. In: Sussman MB, editor. Sociology and Rehabilitation. Washington, DC: American Sociological Association; 1965.

[9] Read JL, Quinn RJ, Hoefer MA. Measuring overall health: an evaluation of three important approaches. J Chronic Dis 1987;40:7S–21S.

[10] Wilson IB, Cleary PD. Linking clinical variables with health related quality of life: a conceptual model of patient outcomes. JAMA 1995;273:1.

[11] Brazier J, Rowen D. NICE DSU Technical Support Document 11: Alternatives to EQ5D for generating health state utility values. 2011. Available from: http://www.nicedsu.org.uk/TSD11%20Alternatives%20to%20EQ-5D_final.pdf.

[12] National Institute for Health and Care Excellence. NICE Guide to the Methods of Technology Appraisal. London: National Institute for Health and Care Excellence; 2008.

[13] Finch AP, Brazier JE, Mukuria C. What is the evidence for the performance of generic preference-based measures? A systematic overview of reviews. Eur J Health Econ 2018;4:557–70.

[14] Dowie J. Decision validity should determine whether generic or condition specific HRQOL measures is used in health care decisions. Health Econ 2002;11:1–8.

[15] Moock J, Kohlmann T. Comparing preference-based quality-of-life measures: results from rehabilitation patients with musculoskeletal, cardiovascular, or psychosomatic disorders. Qual Life Res 2008;17:485–95.

[16] Brazier J, Tsuchiya A. Preference-based condition specific measures of health: what happens to cross programme comparability. Health Econ 2010;192:125–9.

[17] Brazier JE, Rowen D, Mavranezouli I, et al. Developing and testing methods for deriving preference-based measures of health from condition-specific measures (and other patient-based measures of outcome). Health Technol Assess 2012;16:1–114.

[18] EuroQol Group Symposium. New Research for Future Approaches to Measuring and Valuing Health. Berlin, Germany: International Society for Pharmacoeconomics and Outcomes Research; 2012.

[19] Finch AP, Brazier JE, Mukuria C, Bjorner JB. An exploratory study on using principal component analysis and confirmatory factor analysis to identify bolt-on dimensions: the EQ-5D case study. Value Health 2017;10:1362–75.

[20] Richardson J, Iezzi A, Maxwell A. Cross-national comparison of twelve quality of life instruments: MIC paper 1, background, questions, instruments. Research Paper 76, Centre for Health Economics. Melbourne, Australia: Monash University; 2012.

[21] Longworth L, Yang Y, Young T, et al. Use of generic and condition-specific measures of health-related quality of life in NICE decision-making: a systematic review, statistical modelling and survey. Health Technol Assess 2014;9:1–224.

[22] Krabbe PFM, Stouthard MEA, Essink-Bot ML, Bonsel GJ. The effect of adding a cognitive dimension to the EuroQol multi-attribute health status classification system. J Clin Epidemiol 1999;4:293–301.

[23] Yang Y, Brazier JE, Tsuchiya A. Effect of adding a sleep dimension to the EQ5D descriptive system: a "bolt-on" experiment. Med Decis Making 2014;34:42–53.

[24] Yang Y, Rowen D, Brazier J, et al. An exploratory study to test the impact on three "bolt-on" items to the EQ-5D. Value Health 2015;18:52–60.

[25] Brazier J, Rowen D, Tsuchiya A, et al. The impact of adding an extra dimension to a preference-based measure. Soc Sci Med 2011;73:245–53.

[26] Pedhazur EJ, Schmelkin LP. Measurement, Design and Analysis: An Integrated Approach. Hillsdale, NJ: Lawrence Erlbaum Associates; 1991.

[27] Richardson J, Khan MA, Iezzi A, Maxwell A. Cross national comparison of twelve quality of life instruments. MIC Report 2. Research Papers 78, 80–83, and 85, Centre for Health Economics. Melbourne, Australia: Monash University; 2012.

[28] Bockerman P, Johansson E, Saarni SI. Do established health-related quality-of-life measures adequately capture the impact of chronic conditions on subjective well-being? Health Policy 2011;100:91–5.

[29] Devlin NJ, Hansen P, Selai C. Understanding health state valuations: a qualitative analysis of respondents' comments. Qual Life Res 2004;7:1265–77.

[30] Saha K, Mulhern B, Longworth L, Janssen B. Important aspects of health not captured by the EQ-5D: views of the UK general public. Rotterdam, The Netherlands: EuroQol Working Paper Series, EuroQol Research Foundation; 2016.

[31] Barton GR, Sach TH, Avery AJ, et al. Comparing the performance of the EQ-5D-3L and SF-6D when measuring the benefits of alleviating knee pain. Cost Eff Resour Alloc 2009;7:12.

[32] Whynes DK. Does the correspondence between EQ-5D-3L health state description and VAS score vary by medical condition? Health Qual Life Outcomes 2013;11:155.