



Measurement Invariance of a Quality-of-life Measure, CASP-12, within the English Longitudinal Study of Ageing (ELSA)

Ali Alattas^{1,2} · Farag Shuweihdi¹ · Kate Best¹ · Silviya Nikolova³ · Robert West¹

Received: 24 November 2023 / Accepted: 13 February 2024 / Published online: 22 February 2024
© The Author(s) 2024

Abstract

CASP-12 is a frequently used quality of life scale for older people, but limited efforts have been made to test the factor structure or to explore the measurement consistency of the scale across key characteristics. The aim of this study is to examine if the CASP-12 questionnaire has a well-defined factor structure with a second-order structure factor nested within four first-order domains: control, autonomy, pleasure, and self-realization. The study also aims to investigate if this factor structure is interpreted similarly by respondents of different genders, ages, educational levels, net wealth, and at two time periods, using a multi-group confirmatory factor analysis (MG-CFA). The results show that CASP-12 with lower four first-order domains (CASP-12-4D) is consistent across genders and two time periods and satisfies the second-order strong-invariance criteria. Furthermore, the instrument demonstrates consistency in weak levels across three age groups (50–59, 60–69, and 70–90), educational levels and net wealth, but not strong invariance. The sample was divided into three subsamples based on age groups to address this issue. The consistency of CASP-12-4D has met the second-order strong invariance level requirement across gender, age, education level and two-time periods. Net wealth however still fails to meet the strong invariance levels. The CASP-12-4D version will suit social and public health research which controls for age and wealth status.

Keywords Measurement invariance · Quality of life · Multi-group CFA · CASP-12

✉ Ali Alattas
mmaalat@leeds.ac.uk

¹ Leeds Institute of Health Sciences, Faculty of Medicine and Health, University of Leeds, Leeds, UK

² Basic Science Department, College of Science and Health Professions, King Saud bin Abdulaziz for Health Sciences, Riyadh, Saudi Arabia

³ EMEA Real World Methods & Evidence Generation, IQVIA, Reading, UK

Introduction

Assessing Quality of Life (QoL) has become crucial for delivering effective health and social care services to the elderly population (Van Leeuwen et al., 2019). Numerous studies have examined the intricate relationship between QoL and potential influencing factors using a variety of cohort datasets. For instance, these investigations have effectively measured the impact of familial support (Andrade et al., 2020), or medical occurrences like the diagnosis of cancer (Geessink et al., 2017) on QoL. The concept of QoL however is multifaceted, posing challenges in its measurement (Barofsky, 2012; Netuveli & Blane, 2008). Thus, focusing on a population sharing similar physical, mental, and social characteristics, such as the elderly, can enhance the consistency of QoL measurements (Netuveli & Blane, 2008; Williams, 1977). This approach ensures that any detected changes in QoL accurately mirror shifts in the underlying concept, rather than being influenced by variations in measurement techniques (Vandenberg & Lance, 2000), a critical aspect of clinical and public health research (González-Blanch et al., 2018).

One of the QoL scales, CASP-19, consists of 19 items organized into four domains - Control, Autonomy, Self-realization, and Pleasure. Developed from Maslow's psychological theory (Maslow, 2013), CASP-19 aims to assess the QoL of individuals aged 65 to 75 (Hyde et al., 2003). Despite numerous large datasets being utilized to investigate CASP-19 through the application of its second-order common factors, inconsistencies have arisen in the results (Sexton et al., 2013). In response, Wiggins et al. (2008) proposed a more concise version of CASP-19, comprising 12 items, which more dependably captures QoL than the original scale. Oliver et al. (2021a, b) reported several versions of the CASP-12 structure factors. Limited efforts however have been made to report the measurement consistency of CASP-12. Measurement invariance refers to the consistency in how an instrument is interpreted among various groups of individuals (Vandenberg & Lance, 2000).

In many studies, researchers often forget to consider measurement errors when looking at Quality of Life (QoL) among different groups. This oversight can lead to biased results (Lin et al., 2016). Health research commonly compares subgroups to help with clinical decisions (Lin et al., 2016). It is therefore crucial to consider how personal factors might affect how people respond to different situations, including when using CASP-12.

It's important to remember that older adults are not all the same. Factors like retirement, losing a spouse, dealing with chronic illnesses, and financial struggles can affect them differently. Also, as people get older, changes in their lives may lead to different priorities and motivations. That's why age is a key factor in understanding the quality of life for older adults (Scott et al., 2022). Gender, age, and education level also play a role in how older individuals perform on language tests (Lin et al., 2016; Snitz et al., 2009). Life circumstances, such as women being more likely to be widowed, can influence how they respond to assessments of their quality of life (Ko et al., 2019; Scott et al., 2022). Often, studies group together personal details like gender and education when studying older people (Johnson et al., 2013; Lin et al., 2016).

Additionally, a person's wealth affects various aspects of life, like getting good healthcare, staying active, and eating well. Having less money may sometimes mean sacrificing important things, like spending time with family. This trade-off means that people with different levels of wealth may see what makes a good quality of life in different ways (Kagan, 2022).

The authors have found no previous studies which explored the uniformity of the common second-order factor structure of CASP-12, encompassing four factors, across diverse groups in England. As a result, the current study has two aims: (1) to test three second-order structure factors of the CASP-12 using data from the English Longitudinal Study of Ageing (ELSA), and (2) to investigate whether the selected CASP-12 structure remains consistent across five variable groups: gender, age, educational levels, wealth, and two time periods.

Methods

Dataset

ELSA is a longitudinal research project which collects information from private households of individuals aged over 50 years residing in England (Steptoe et al., 2013). ELSA currently features nine waves of data collected over an 18-year period (Banks et al., 2021).

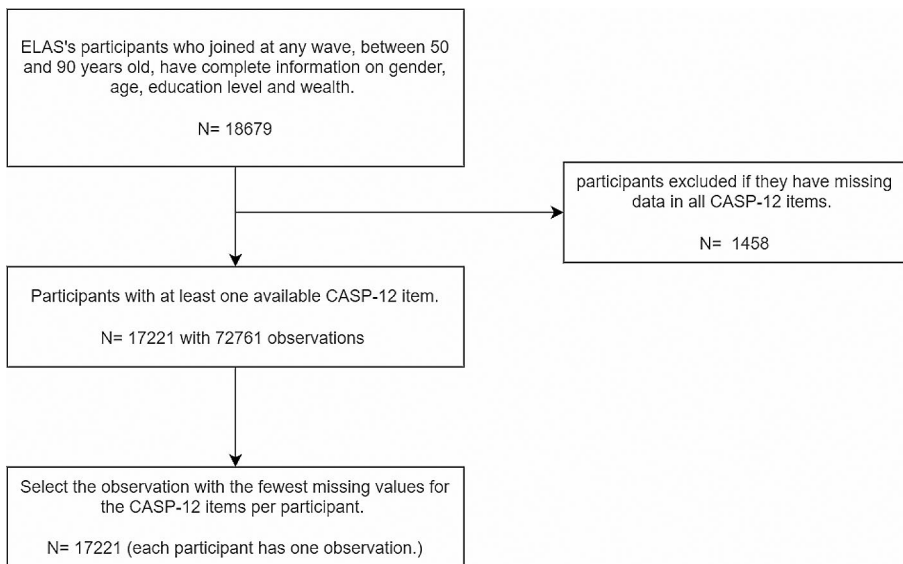
Measurements

Five categorical variables were selected for investigation, namely gender, age, education, net wealth, two time periods. Three age groups were compared: 50–59, 60–69, and 70–90 years. The reason for selecting these age groups was to assume participants within these ages share common perspectives for QoL. The participants were categorized into three education levels (high, average or foreign and low), following the approach of Alattas et al. (2023). The participants were categorized into three wealth levels (rich, average and poor), following the approach used in a previous study (Alattas et al., 2023). To increase the analysis power, new participants were included from wave one to wave nine and then classify them into two period groups: wave one participants and wave two through wave nine participants. We compared two time periods, W1 vs. w2 to W9, to see whether the perspective of the scale, CASP-12, between participants who joined at the first wave and those who joined at wave 2 onwards is invariant or not. Note that with this split, sample size for each group is comparable.

The CASP-12 instrument comprises 12 items that aim to evaluate an individual's QoL through four domains: control, autonomy, pleasure and self-realisation (Wiggins et al., 2008). The participants were asked a series of questions and rated their responses using a four-point scale from 0 to 3 where 0 indicated 'never,' 1 'not often,' 2 'sometimes' and 3 'often.' Any questions that had negative wording were given a reverse score. Reverse scoring flips the direction of the numerical scoring scale. This means that a score of 0 would be assigned to "often", while "sometimes" would get

Table 1 CASP-12 items with their domains

Item (number)	Domain
My age prevents me from doing the things I would like to do (C1)	Control
I feel that what happens to me is beyond my control (C2)	
I feel left out of things (C3)	
I can do the things I want to do (A1)	Autonomy
I feel that I can please myself what I do (A2)	
A lack of money stops me from doing things I want to do (A3)	
I look forward to each day (P1)	Pleasure
I feel that my life has meaning (P2)	
I enjoy the things that I do (P3)	
I feel full of energy these days (S1)	Self-realisation
I feel that life is full of opportunities (S2)	
I feel that the future looks good for me (S3)	

**Fig. 1** Procedure for selecting the analytical sample

a score of 1, “not often” would receive a score of 2, and “never” would be assigned a score of 3. The total score was obtained by adding up the responses to each question. A higher score indicated a better QoL. Table 1 presents all 12 items of the CASP-12.

Analytical Sample

Figure 1 shows the steps taken to select the analytical sample. A total of 18,679 participants were included from the ELSA study across nine waves. They were selected based on complete information available for four variables, including gender, age (between 50 and 90), education level and net wealth. Participants were excluded if no

information was available for any 12 items of the CASP-12. Additionally, repeated measures for included participants were removed as the measure with the least missing values of CASP-12 was kept. The final sample size after exclusions was 17,221 participants.

Statistical Approach

First, the summary statistics for the sample and five determinants were examined. Then a graphical analysis was conducted to explore the relationship between the participants age and the total scores of the CASP-12 as well as its four domains using regression splines. To achieve this, the *bs* function in R was utilized which employs B-splines for the analysis (Hastie, 1992).

Since we are interested in QoL as one component, Multiple Group Confirmatory Factor Analysis (MG-CFA) was conducted for several second-order structure factors for CASP-12. The requirements applicable to establish the second-order factor of the selected CASP-12 model are: (a) lower (first) order factors are highly correlated, and (b) there is a higher order factor that accounts for their relations (Chen et al., 2005). Thus, three second-order structured factors and a first-order structure factor (CASP-12-FO) were conducted. The three second-order structure factors are as follows: the first is a common second-order factor with four first-order factors (control, autonomy, pleasure, and self-realization), denoted here CASP-12-4D. The second is a common second-order factor with three first-order factors (CASP-12-3D), so the Control and Autonomy domains had combined. The third is like CASP-12-3D but with 11 items (CASP-11-3D), which item (A3) has been removed. The reason for deleting this item is that its loading factor value was less than 0.40, as shown in the results section.

Since the response values of the CASP-12 items are greater than two and all of the items have a moderate or high skewness, they were treated as continuous variables and the robust maximum likelihood was used to estimate the parameters of confirmatory factor analysis (CFA) (Robitzsch, 2020). In our analysis, we opted for the Robust Maximum Likelihood (RML) method over the Satorra-Bentler scaled chi-squared statistic. This decision was influenced by the limitation of the latter in handling incomplete data, as noted by Savalei and Rosseel (2022). Furthermore, RML is deemed more appropriate for datasets exhibiting moderate deviations from normality, as indicated by Li (2016).

The question of whether to treat response values on a scale as continuous or ordinal is a subject of ongoing discussion. According to (Robitzsch, 2020) treating response values ordinally may impose a normal distribution on latent factors, potentially introducing inaccuracies in empirical applications. Given our substantial sample size, any distinctions between different methods may be practically negligible and thus considered inconsequential.

A MG-CFA was undertaken to ensure that measurements are consistent of the CASP-12 across five variable groups: gender, age groups, educational levels, net wealth and two time periods. Sequentially, five levels of measurement invariance (MI) were tested following Chen et al. (2005), and each level introduced more equality constraints across groups with the consideration for second- and first-order factors. Configural invariance tests the equivalence of the fixed and free factor loadings

pattern. Weak invariance tests the equivalence of factor loadings across groups for first-order loadings and second-order factor loadings in two separate steps. Meanwhile, strong invariance, additionally to weak invariance, examines the equality of intercepts of indicators and means for first-order latent factors in two separate steps.

Three fit indices were considered: robust chi-square distribution with a degree of freedom (*df*), robust comparative fit index (RCFI) and robust root mean square error of approximation (RRMSEA). The Chi-square test is impacted by sample size, meaning that as the sample size grows, the test becomes more responsive to even minor variations between the correlation matrix of observed values and the correlation matrix of expected values. Alternatively, RCFI or RRMSEA were used to assess the goodness of fit. The CFI and RMSEA range from 0 to 1, and the values of 0.90 (acceptable fit) or 0.95 (good fit) are used as cut-points for the CFI while 0.06 (good fit) or 0.08 (acceptable fit) for RMSEA (Schumacker & Lomax, 2012). To compare five constrained models, the Δ RCFI criterion was used due to its lower sensitivity to sample size. Consequently, if there is a change in RCFI of less than 0.01 along with a change in RRMSEA of less than 0.015, the models can be considered to be comparable (Chen, 2007).

If the selected factor structure of CASP-12 did not meet the criteria for strong invariance among the five variable groups, the participants would be divided into subgroups based on the variable group with the poorest MG-CFA fit indices. Each subgroup would then be tested separately for MI. Due to missing observations in the sample, we selected an observation with the least missing values from the CASP-12 items for each participant. Also, we used all available information for participants with some missing values in the CASP-12 items by applying the FIML method. Full information maximum likelihood (FIML) was used to deal with missing data with parameter estimates being calculated using all of the available information (Cham et al., 2017). The analysis was performed in R and all of the CFA models were estimated using the *lavaan* version 0.6–12 package (Rosseel, 2012).

Results

Table 2 presents the distributions of gender, age, educational level, net wealth and two-time periods.

Out of the total sample, 54% were women. Half of the sample (51%) were aged between 50 and 59. Two-thirds of the sample consists of participants who are educated at a high or average level. Both wealthy and poor participants each represented 40%, with those classified as ‘average’ wealth accounting for 20%. More than half of the sample (57%) were from wave 1, while 43% participants were from waves 2 to 9.

Figure 2 illustrates the association between the total scores of CASP-12 and its four domains with age. The number of participants who have complete data on CASP-12 items is 16,816. Figure 2(a) indicates a negative relationship between the total scores of CASP-12 and age for individuals aged 70 and above. As shown in Fig. 2b and e, participants began to lose control and self-realization when they reached this age. However, their autonomy gradually increased (Fig. 2c). Among the CASP-12

Table 2 Summary characteristics of the sample

	N	%
<i>N</i> = 17,221		
<i>Gender</i>		
Men	7850	46%
Women	9371	54%
<i>Age</i>		
50–59	8726	51%
60–69	4084	24%
70–90	4411	25%
<i>Education level</i>		
High	4841	28%
Average or foreign	6765	39%
low	5615	33%
<i>Wealth</i>		
Rich	6897	40%
Average	3373	20%
Poor	6951	40%
<i>Two-time periods</i>		
Wave 1	9749	57%
Wave 2 to wave 9	7472	43%

domains, the pleasure domain had the highest scores, with an average score close to 9 (upper score) for most ages.

A CFA was conducted on three common second-order structure factors of CASP-12 as well as four first-order factor as shown in Table 3. The results showed that CASP-12-4D and CASP-12-FO achieved an excellent fit (RCFI=0.95 and RRMSEA=0.067) for CASP-12 and (RCFI=0.95 and RRMSEA=0.066). The standardized parameter estimates for both factor structures were displayed in Fig. 3.

Figure 3 shows that there is a higher (second) order factor that accounts for four lower (first-order) factor relations and four lower (first-order) were of the CASP-12 highly correlated. Thus, CASP-12 is applicable.

A second-order MG-CFA test of the CASP-12-4D was conducted separately for five variable groups: gender, age groups, educational levels, net wealth and time periods. Following this, a series of rigorous model tests was undertaken for five levels of invariance (configural, two weak invariance levels, and two strong invariance levels). As demonstrated in Table 4, RCFI value of the CASP-12-4D is around the benchmarks for a good fit as well as RRMSEA values for all five variable groups. Next, although RCFI value of CASP-12-4D met the invariance up to a second-order strong level for gender and two-time periods (Δ RCFI<0.01 and RRMSEA<0.015), the instrument failed to achieve that across age groups, educational level and net wealth. Note that the value of Δ RCFI exceeded the cutoff (0.01) between the weak and strong levels for these three variable groups. The value of Δ RRMSEA did not exceed the cut-off (0.015) except for age groups.

Next, we tested the second-order MG-CFA for three subsamples separately based on their age: 50–59, 60–69 and 70–90 years old because the MG-CFA fit indices were the poorest for age compared to the other variable groups that did not meet the requirement of the strong level (education and net wealth). Two age categories were defined within each age group. Table 5 shows CASP-12-4D's fit indices for all the

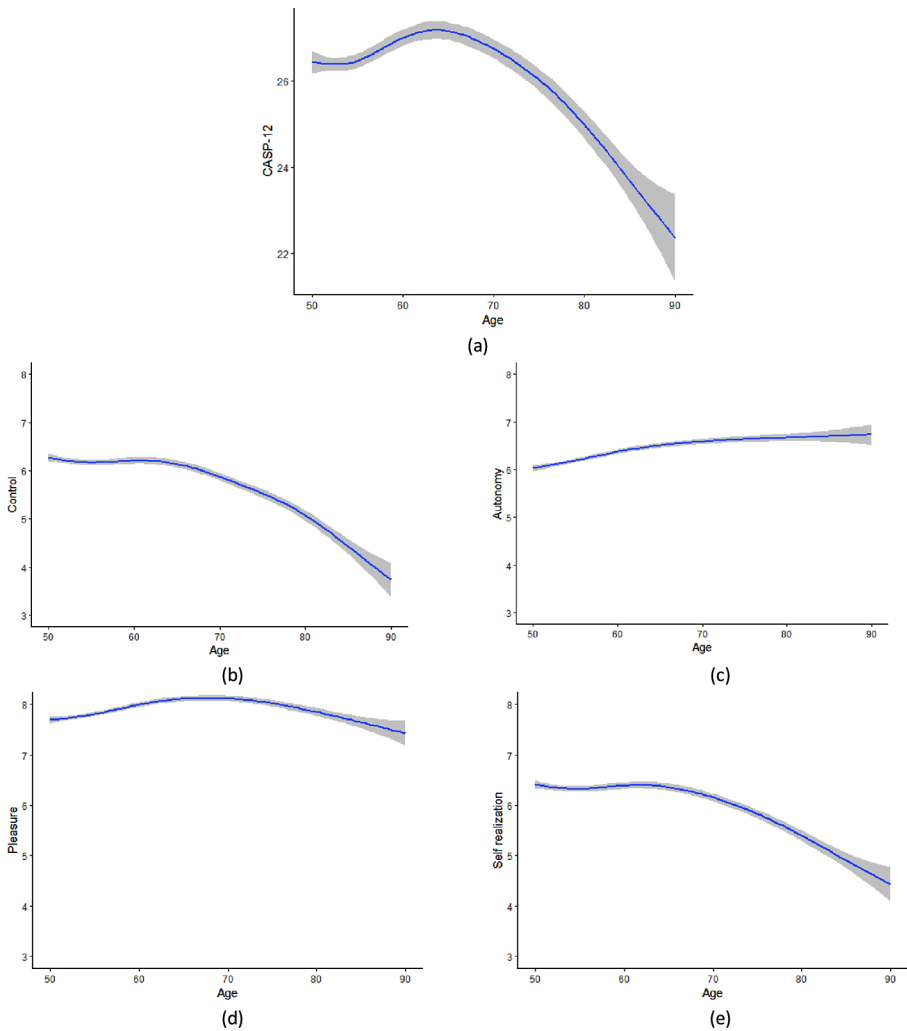


Fig. 2 The relationship between the CASP-12 score and several group variables using regression splines; only the participants with no missing values in the CASP-12 ($N=16,816$)

Table 3 Model fit statistics of Models CASP-12, CASP-12-3D, CASP-11-3D and CASP-12-FO

Structure factor	R^2	df	RCFI	RRMSEA
CASP-12-4D	3135.55*	50	0.945	0.067
CASP-12-3D	4664.58*	51	0.917	0.081
CASP-11-3D	4392.02*	41	0.918	0.089
CASP-12-FO	2955.35*	48	0.949	0.066

CASP-12-4D: is a common second-order with four domains (control, autonomy, pleasure and self-realization); CASP-12 -3D is a common second-order with only three demotions (control/autonomy, pleasure and self-realization). CASP-11-3D: the item A3 was deleted from CASP-12-3D; CASP-12-FO: only four first-order factors; * $p < 0.01$

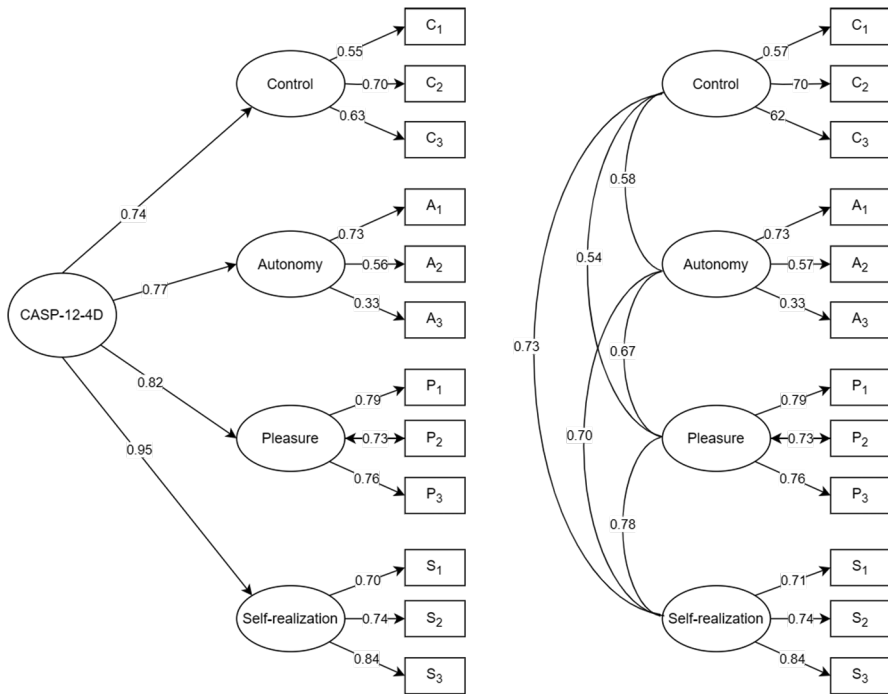


Fig. 3 Standardized factor loadings for the CASP-12-4D (left side) and for the CASP-12-FO (right side). All estimates $p < 0.01$. C, A, P and S refer to the items for each domain of the CASP-12 that are shown in Table 1

three samples. For younger participants, CASP-12 exceeded the benchmarks for a good fit for all five variable groups ($RCFI > 0.95$ and $RRMSEA < 0.060$) while the fit indices for the older and oldest participants achieved the acceptable fit. ($RCFI > 0.90$ and $RRMSEA < 0.080$). Except for the net wealth variable group ($\Delta RCFI > 0.01$), CASP-12 is consistent across all variable groups up to strong level for second-order factors. In the oldest participants, the $\Delta RCFI$ for the first-order strong level of the two age categories (70–79 vs. 80–90) is equal to the cut-off value (0.01). In addition, the net wealth groups were reduced to two (rich/average vs. poor) since the estimated variance of the self-realization domain was negative for participants with average net wealth. The value of $\Delta RRMSEA$ of the net wealth variable group did not exceed the cut-off (0.015) in all five test levels for all subsamples.

Discussion

This study evaluated the short version of the CASP-12 through three second-order structure factors and reported that the common second-factor with four first-order structure factor (CASP-12-4D) and the common first-order structure factor had the highest fit indices compared to the other structure factors. Additionally, CASP-12 was consistent across genders and time periods meeting the strong second and first-

Table 4 Five levels of multi-group confirmatory factor analysis (MG-CFA) for the second-order of the CASP-12-4D grouped by gender, age, educational level, net wealth and two-time periods

	Robust χ^2	Δ Robust χ^2	df	RRMSEA	Δ RRMSEA	RCFI	Δ RCFI
<i>Gender</i>							
Configural invariance	3258.86*	--	100	0.067	--	0.944	--
Weak invariance (FOFL)	3258.79*	-0.07	108	0.065	-0.002	0.944	0
Weak invariance (SFOFL)	3250.56*	-8.23	111	0.064	-0.001	0.944	0
Strong invariance (FOFLI)	3481.26*	230.7	118	0.064	0	0.94	-0.004
Strong invariance (SFOFLI)	3503.82*	22.56	121	0.064	0	0.94	0
<i>Age</i>							
Configural invariance	3006.86*	--	150	0.064	--	0.95	--
Weak invariance (FOFL)	3249*	242.14	166	0.064	0	0.946	-0.004
Weak invariance (SFOFL)	3312.89*	63.89	172	0.063	-0.001	0.944	-0.002
Strong invariance (FOFLI)	5796.73*	2483.84	186	0.081	0.018	0.901	-0.043
Strong invariance (SFOFLI)	6587.64*	790.91	193	0.085	0.004	0.888	-0.013
<i>Education level</i>							
Configural invariance	3181.57*	--	150	0.066	--	0.946	--
Weak invariance (FOFL)	3250.14*	68.57	166	0.063	-0.003	0.945	-0.001
Weak invariance (SFOFL)	3238.15*	-11.99	172	0.062	-0.001	0.945	0
Strong invariance (FOFLI)	4117.78*	879.63	186	0.067	0.005	0.929	-0.016
Strong invariance (SFOFLI)	4272.81*	155.03	193	0.067	0	0.927	-0.002
<i>Net wealth</i>							
Configural invariance	3233.9*	--	150	0.066	--	0.942	--
Weak invariance (FOFL)	3251.86*	17.96	166	0.063	-0.003	0.941	-0.001
Weak invariance (SFOFL)	3236.69*	-15.17	172	0.062	-0.001	0.941	0
Strong invariance (FOFLI)	4166.66*	929.97	186	0.068	0.006	0.923	-0.018
Strong invariance (SFOFLI)	4309.89*	143.23	193	0.068	0	0.921	-0.002
<i>Two-time periods</i>							
Configural invariance	3173.84*	--	100	0.06	--	0.945	--
Weak invariance (FOFL)	3206.4*	32.56	108	0.065	0.005	0.944	-0.001
Weak invariance (SFOFL)	3255.68*	49.28	111	0.064	-0.001	0.942	-0.002
Strong invariance (FOFLI)	3781.58*	525.9	118	0.067	0.003	0.934	-0.008
Strong invariance (SFOFLI)	4013.5*	231.92	121	0.068	0.001	0.93	-0.004

FOFL: first-order factors loadings; SFOFL: second- and first-order factors loadings; FOFLI: second- and first-order factors loadings and intercepts of measured indicators; SFOFLI: second- and first-order factors loadings and intercepts of measured indicators and means for first-order factors * $P < 0.01$

order invariance criterion. However, it displayed (second and first-order factors) weak invariance in terms of age, educational levels, net wealth, and two-time points, but not strong invariance. The consistency of CASP-12-4D across gender, two age categories, education levels, and time periods was improved and met (second and first-order factors) strong invariance by considering three separate age groups (50–59, 60–69 and 70–90). Net wealth still fails to meet the strong invariance levels, which might reflect the different perspectives of QoL between wealthy and poor people. Studies have reported inequality among them in several aspects, such as healthcare,

Table 5 Five levels of multi-group confirmatory factor analysis (MG-CFA) for the second-order factor of the CASP-12-4D in three separate samples based on age, grouped by gender, two age groups, educational level, net wealth and two-time periods

	50-59; N=8726						60-69; N=4490						70-90; N=4005					
	Robust χ^2	Δ	df	RCFI	Δ RCFI	RMSEA Δ	Robust χ^2	Δ	df	RCFI	Δ RCFI	RMSEA Δ	Robust χ^2	Δ	df	RCFI	Δ RCFI	RMSEA Δ
<i>Gender</i>																		
Configural invariance	1394.67*	--	100	0.959	--	0.06	857.82*	--	100	0.945	--	0.065	979.14*	--	100	0.931	--	0.073
Weak invariance (FOFL)	1396.38*	1.71	108	0.959	0	0.058	875.15*	17.33	108	0.943	-0.002	0.063	979.95*	0.81	108	0.931	0	0.07
Weak invariance (SFOFL)	1403.89*	7.51	111	0.959	0	0.057	878.16*	3.01	111	0.943	0	0.063	978.29*	-1.66	111	0.931	0	0.069
Strong invariance (FOFL)	1539.71*	135.82	118	0.955	-0.004	0.058	940.27*	62.11	118	0.939	-0.004	0.063	1063.43*	85.14	118	0.925	-0.006	0.07
Strong invariance (SFOFL)	1549.64*	9.93	121	0.955	0	0.058	952.82*	12.55	121	0.939	0	0.063	1068.2*	4.77	121	0.925	0	0.069
<i>Age (two groups)</i>																		
Configural invariance	1326.25*	--	100	0.961	--	0.059	852.86*	--	100	0.945	--	0.065	978.71*	--	100	0.93	--	0.072
Weak invariance (FOFL)	1321.74*	-4.51	108	0.961	0	0.056	843.24*	-9.62	108	0.945	0	0.062	988.52*	9.81	108	0.93	0	0.07
Weak invariance (SFOFL)	1333.19*	11.45	111	0.961	0	0.056	840.11*	-3.13	111	0.945	0	0.061	987.75*	-0.77	111	0.93	0	0.069
Strong invariance (FOFL)	1431.93*	98.74	118	0.958	-0.003	0.056	884.32*	44.21	118	0.943	-0.002	0.061	1117.14*	129.39	118	0.92	-0.01	0.071
Strong invariance (SFOFL)	1486.04*	54.11	121	0.956	-0.002	0.056	902.69*	18.37	121	0.942	-0.001	0.06	1175.95*	58.81	121	0.915	-0.005	0.072
<i>Education</i>																		
Configural invariance	1438*	--	150	0.959	--	0.059	914.01*	--	150	0.943	--	0.065	1038.48*	--	150	0.93	--	0.073
Weak invariance (FOFL)	1454.62*	16.62	166	0.959	0	0.057	918.72*	4.71	166	0.943	0	0.062	1047.905* ^b	9.425	166	0.929	-0.001	0.069
Weak invariance (SFOFL)	1457.4*	2.78	172	0.959	0	0.056	913.12*	-5.6	172	0.943	0	0.061	1058.64*	10.735	172	0.928	-0.001	0.068
Strong invariance (FOFL)	1718.85*	261.45	186	0.951	-0.008	0.058	1046.67*	133.55	186	0.934	-0.009	0.063	1148.22*	89.58	186	0.923	-0.005	0.068
Strong invariance (SFOFL)	1788.71*	69.86	193	0.949	-0.002	0.058	1067.43*	20.76	193	0.934	0	0.062	1164.39*	16.17	193	0.923	0	0.067
<i>Net wealth^c</i>																		
Configural invariance	1396.61*	--	150	0.957	--	0.058	869.1*	--	150	0.944	--	0.062	957.16*	--	100	0.931	--	0.072
Weak invariance (FOFL)	1446.15*	49.54	166	0.956	-0.001	0.057	870*	0.9	166	0.943	-0.001	0.059	974.21*	17.05	108	0.93	-0.001	0.07
Weak invariance (SFOFL)	1442.84*	-3.31	172	0.956	0	0.056	866.54*	-3.46	172	0.943	0	0.058	972*	-2.21	111	0.93	0	0.069

Table 5 (continued)

	50–59; N=8726				60–69; N=4490				70–90; N=4005												
	Robust χ^2	Δ	df	RCFI Δ RCFI	RMSEA Δ	Robust χ^2	Δ	df	RCFI Δ RCFI	RMSEA Δ	Robust χ^2	Δ	df	RCFI Δ RCFI	RMSEA Δ						
Strong invariance (FOFLI)	1960.91*	518.07	186	0.939	-0.017	0.063	0.007	1167.3*	300.76	186	0.927	-0.022	0.066	0.008	1113.59*	141.59	118	0.919	-0.011	0.071	0.002
Strong invariance (SFOFLI)	2060.26*	99.35	193	0.936	-0.003	0.063	0	1223.76*	56.46	193	0.917	-0.004	0.066	0	1133.36*	19.77	121	0.918	-0.001	0.071	0
<i>Two-time periods</i>																					
Configural invariance	1387.7*	--	100	0.958	--	0.06	--	852.59*	--	100	0.944	--	0.065	--	990*	--	100	0.931	--	0.073	--
Weak invariance (FOFL)	1384.18*	-3.52	108	0.958	0	0.058	-0.002	841.47*	-11.12	108	0.944	0	0.062	-0.003	989.5*	-0.5	108	0.931	0	0.07	-0.003
Weak invariance (SFOFL)	1403.99*	19.81	111	0.958	0	0.058	0	842.48*	1.01	111	0.944	0	0.062	0	988.96*	-0.54	111	0.931	0	0.069	-0.001
Strong invariance (FOFLI)	1512.12*	108.13	118	0.955	-0.003	0.058	0	906.36*	63.88	118	0.94	-0.004	0.062	0	1027.18*	38.22	118	0.929	-0.002	0.068	-0.001
Strong invariance (SFOFLI)	1576.48*	64.36	121	0.953	-0.002	0.058	0	954.74*	48.38	121	0.937	-0.003	0.062	0	1062.86*	35.68	121	0.926	-0.003	0.068	0

FOFL: first-order factors loadings; SFOFL: second- and first-order factors loadings; FOFLI: second- and first-order factors loadings and intercepts of measured indicators; SFOFLI: second- and first-order factors loadings and intercepts of measured indicators and first-order factors. * $P < 0.01$

^aIn the third sample (70–90), Only two wealth groups (rich/average and poor) since the estimated variance was negative of the self-realization domain for participants with average wealth

^bIn the third sample (70–90), estimated variance was negative of the self-realization domain for participants with low education

living conditions, and engaging in leisure activities that often enable wealthier individuals in aged communities to experience a better quality of life compared to poor people who attempt to have basic needs most of the time (Steptoe & Zaninotto, 2020).

CASP-12-4D could serve as a valuable tool for healthcare providers as well as social research by considering two domains of QoL (Control and self-realization) especially for those aged 70 and over. Also, by considering peoples' age and net wealth, the accuracy of interpreting CASP-12 score differences enhances. While there is no considerable difference in between rich and average participants (not detailed here), poor participants experience a more pronounced impact. Consequently, it is essential to conduct a sensitivity analysis if the participants' wealth status varies.

While the short version of the CASP (CASP-12) is generally favoured over its longer counterpart (CASP-19), the literature reveals various factor structures for the short version (Oliver et al., 2021). These structures underwent international modifications to enhance their psychometric robustness (Oliver et al., 2021a, b). In our study, the CASP-12-4D and CASP-12-FO models exhibited superior performance, aligning with similar findings in European populations that shared limitations in the autonomy domain (Oliver et al., 2021a, b). Note that different factor structures were deemed optimal in other European studies. For example, CASP-12 with three domains (control/autonomy, self-realization, and pleasure) was found to fit better in some instances (Sim et al., 2011; Wiggins et al., 2008). In a separate study, CASP-11 emerged after removing one item from the autonomy domain, as it demonstrated the lowest correlation coefficient (Hamren et al., 2015). A majority of these studies were conducted across various waves in the Survey of Health, Ageing, and Retirement in Europe (SHARE) datasets (Oliver et al., 2021a, b), with only a limited number focusing on the English population (Sim et al., 2011; Wiggins et al., 2008), often presenting CASP-12-3D. Notably, information on CASP-12-4D is relatively scarce in these studies, and the sample sizes tended to be small. Considering these factors, CASP-12-4D and CASP-12-FO may be preferable for use among older individuals in England, aligning well with the theoretical background of the four domains in the scale (CASP-12-4D). Their superior goodness-of-fit indices in a larger English population suggest their suitability for comprehensive assessments of QoL in England.

Although previous studies that tested the measurement invariance for CASP-12 is limited, and they only reported the partial measurement invariance, for example, study by Oliver et al. (2021) reported partial invariance of the CASP-12 across different age groups. In relation to wealth and its influence on Quality of Life (QoL), our findings align with those of other studies (Kim & Park, 2015; Wingen et al., 2021). It is consistently observed that individuals from higher socioeconomic backgrounds tend to experience elevated status and enhanced Quality of Life.

It is essential to report several difficulties while conducting longitudinal measurement invariance for CASP-12-4D. The ELSA dataset contains nine waves, but participants' on average respond to four waves. Moreover, the time between the two points is quite long, two years. In addition, an initial result indicated that the model identification ($RCFI > 0.90$) decreases with increased time points (waves). Therefore, there is a need to carry out further work to address these challenges.

The study possesses notable strengths, including substantial sample size and the inclusion of five distinct demographic groups for assessing second-order CASP-

12-4D measurement invariance. Nonetheless, limitations exist. While the ELSA dataset contained several variables, we only focused on four variable groups, namely gender, age, education, and wealth. This decision was made due to more missing values in the other variables in subsequent waves.

In summary, the common second-order structure factor with four first-order factors (CASP-12-4D) shows higher fit indices than the other common second-order structure factors used in other studies. Except for wealth, second-order CASP-12-4D within three separate age groups demonstrates second and first-order strong consistency across diverse demographic groups, including gender, two age categories, educational level and two-time periods increasing the accuracy of the instrument measure when used in social and public health research applications. Further work is needed to test the longitudinal measurement invariance analysis of the second-order CASP-12 model.

Author Contributions Conceptualization: AA, RW. Data curation and analysis: AA. Investigation: AA, RW, SN, FS, KB. Methodology: AA, RW, FS. Supervision: RW, SN, FS, KB. Writing – original draft: AA. Writing – review and editing: AA, RW, SN, FS, KB.

Funding This work was funded by the Cultural Bureau, Embassy of Saudi Arabia, London. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data Availability Researchers can access the ELSA dataset for free from the UK Data Service. You can assess the data here beta.ukdataservice.ac.uk/datacatalogue/series/series?id=200011.

Declarations

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Alattas, A., Nikolova, S., Shuweihdi, F., Best, K., & West, R. (2023). The impact of long-term conditions on the progression of frailty. *PLoS ONE [Electronic Resource]*, *18*(4), e0284011. <https://doi.org/10.1371/journal.pone.0284011>.
- Andrade, J. M., Drumond Andrade, F. C., de Oliveira Duarte, Y. A., & de Bof, F. (2020). Association between frailty and family functionality on health-related quality of life in older adults. *Quality of Life Research*, *29*, 1665–1674. <https://doi.org/10.1007/s11136-020-02433-5>.

- Banks, J., Phelps, A., Oskala, A., Steptoe, A., Blake, M., Oldfield, Z., & Nazroo, J. (2021). *English Longitudinal Study of Ageing: Waves 0–9, 1998–2019*. Retrieved from: <https://doi.org/10.5255/UKDA-SN-5050-23>.
- Barofsky, I. (2012). Can quality or quality-of-life be defined? *Quality of Life Research*, 21(4), 625–631. <https://doi.org/10.1007/s11136-011-9961-0>.
- Cham, H., Reshetnyak, E., Rosenfeld, B., & Breitbart, W. (2017). Full information maximum likelihood estimation for latent variable interactions with incomplete indicators. *Multivariate Behavioral Research*, 52(1), 12–30. <https://doi.org/10.1080/00273171.2016.1245660>.
- Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, 14(3), 464–504. <https://doi.org/10.1080/10705510701301834>.
- Chen, F. F., Sousa, K. H., & West, S. G. (2005). Teacher's corner: Testing measurement invariance of second-order factor models. *Structural Equation Modeling*, 12(3), 471–492. https://doi.org/10.1207/s15328007sem1203_7.
- Geessink, N., Schoon, Y., van Goor, H., Olde Rikkert, M., Melis, R., & T.-M. consortium. (2017). Frailty and quality of life among older people with and without a cancer diagnosis: Findings from TOPICS-MDS. *PLoS ONE [Electronic Resource]*, 12(12), e0189648.
- González-Blanch, C., Medrano, L. A., Muñoz-Navarro, R., Ruíz-Rodríguez, P., Moriana, J. A., Limonero, J. T., & Group, P. R. (2018). Factor structure and measurement invariance across various demographic groups and over time for the PHQ-9 in primary care patients in Spain. *PLoS ONE [Electronic Resource]*, 13(2), e0193356. <https://doi.org/10.1371/journal.pone.0193356>.
- Hamren, K., Chungkham, H. S., & Hyde, M. (2015). Religion, spirituality, social support and quality of life: Measurement and predictors CASP-12 (v2) amongst older ethiopians living in Addis Ababa. *Aging & Mental Health*, 19(7), 610–621.
- Hastie, T. (1992). Natural spline, Chap. 7 of *Statistical Models in S. Generalized additive models*. *Wadsworth & Brooks/Cole*.
- Hyde, M., Wiggins, R. D., Higgs, P., & Blane, D. B. (2003). A measure of quality of life in early old age: The theory, development and properties of a needs satisfaction model (CASP-19). *Aging & Mental Health*, 7(3), 186–194. <https://doi.org/10.1080/1360786031000101157>.
- Johnson, J. K., Louhivuori, J., Stewart, A. L., Tolvanen, A., Ross, L., & Era, P. (2013). Quality of life (QOL) of older adult community choral singers in Finland. *International Psychogeriatrics*, 25(7), 1055–1064.
- Kagan, J. (2022). What is quality of life? Why it's important and how to improve it. In: <https://www.investopedia.com/terms/q/quality-of-life.asp>.
- Kim, J. H., & Park, E. C. (2015). Impact of socioeconomic status and subjective social class on overall and health-related quality of life. *Bmc Public Health*, 15(1), 1–15.
- Ko, H., Park, Y. H., Cho, B., Lim, K. C., Chang, S. J., Yi, Y. M., & Ryu, S. I. (2019). Gender differences in health status, quality of life, and community service needs of older adults living alone. *Archives of Gerontology and Geriatrics*, 83, 239–245.
- Li, C. H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behavior Research Methods*, 48, 936–949.
- Lin, C. Y., Li, Y. P., Lin, S. L., & Chen, C. H. (2016). Measurement equivalence across gender and education in the WHOQOL-BREF for community-dwelling elderly Taiwanese. *International Psychogeriatrics*, 28(8), 1375–1382. <https://doi.org/10.1017/S1041610216000594>.
- Maslow, A. H. (2013). *Toward a psychology of being*. Simon and Schuster.
- Netuveli, G., & Blane, D. (2008). Quality of life in older ages. *British Medical Bulletin*, 85(1), 113–126. <https://doi.org/10.1093/bmb/ldn003>.
- Oliver, A., Sentandreu-Mano, T., Tomas, J. M., Fernandez, I., & Sancho, P. (2021a). Quality of life in European older adults of SHARE Wave 7: Comparing the Old and the Oldest-Old. *Journal of Clinical Medicine*, 10(13), 11. <https://doi.org/10.3390/jcm10132850>.
- Oliver, A., Sentandreu-Mañó, T., Tomás, J. M., Fernández, I., & Sancho, P. (2021b). Quality of life in European older adults of SHARE wave 7: Comparing the old and the oldest-old. *Journal of Clinical Medicine*, 10(13), 2850. <https://doi.org/10.3390/jcm10132850>.
- Robitzsch, A. (2020). *Why ordinal variables can (almost) always be treated as continuous variables: Clarifying assumptions of robust continuous and ordinal factor analysis estimation methods* Paper presented at the Frontiers in education.
- Rossee, Y. (2012). Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, 48, 1–36. <https://doi.org/10.18637/jss.v048.i02>.

- Savalei, V., & Rosseel, Y. (2022). Computational options for standard errors and test statistics with incomplete normal and nonnormal data in SEM. *Structural Equation Modeling: A Multidisciplinary Journal*, 29(2), 163–181.
- Schumacker, R. E., & Lomax, R. G. (2012). A Beginner's Guide to Structural Equation Modeling.
- Scott, J., Mazzucchelli, T., Luszcz, M., & Windsor, T. (2022). Factor structure and measurement invariance of the older people's quality of life scale. *Current Psychology*, 1–11.
- Sexton, E., King-Kallimanis, B. L., Conroy, R. M., & Hickey, A. (2013). Psychometric evaluation of the CASP-19 quality of life scale in an older Irish cohort. *Quality of Life Research*, 22, 2549–2559. <https://doi.org/10.1007/s11136-013-0388-7>.
- Sim, J., Bartlam, B., & Bernard, M. (2011). The CASP-19 as a measure of quality of life in old age: Evaluation of its use in a retirement community. *Quality of Life Research*, 20, 997–1004.
- Snitz, B. E., Unverzagt, F. W., Chang, C. C. H., Bilt, V., Gao, J., Saxton, S., & Ganguli, J., M (2009). Effects of age, gender, education and race on two tests of language ability in community-based older adults. *International Psychogeriatrics*, 21(6), 1051–1062.
- Step toe, A., & Zaninotto (2020). Lower socioeconomic status and the acceleration of aging: An outcome-wide analysis. *Proceedings of the National Academy of Sciences*, 117(26), 14911–14917. <https://doi.org/10.1073/pnas.1915741117>.
- Step toe, A., Breeze, E., Banks, J., & Nazroo, J. (2013). J. I. j. o. e. Cohort profile: the English longitudinal study of ageing. 42(6), 1640–1648.
- Van Leeuwen, K. M., Van Loon, M. S., Van Nes, F. A., Bosmans, J. E., De Vet, H. C., Ket, J. C., & Ostelo, R. W. (2019). What does quality of life mean to older adults? A thematic synthesis. *PLoS ONE [Electronic Resource]*, 14(3), e0213263. <https://doi.org/10.1371/journal.pone.0213263>.
- Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods*, 3(1), 4–70. <https://doi.org/10.1177/109442810031002>.
- Wiggins, R. D., Netuveli, G., Hyde, M., Higgs, P., & Blane, D. (2008). The evaluation of a self-enumerated scale of quality of life (CASP-19) in the context of research on ageing: A combination of exploratory and confirmatory approaches. *Social Indicators Research*, 89, 61–77. <https://doi.org/10.1007/s11205-007-9220-5>.
- Williams, A. (1977). Measuring the quality of life of the elderly. *Public Economics and the Quality of life*, 282–297.
- Wingen, T., English, B., Estal-Muñoz, V., Mareva, S., & Kassianos, A. P. (2021). Exploring the relationship between social class and quality of life: The mediating role of power and status. *Applied Research in Quality of Life*, 16(5), 1983–1998.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.