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# Longitudinal cross-lagged analysis of depression, loneliness, and quality of life in 12 European countries

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## Abstract

**Background** In the older population, depression, loneliness, and quality of life are closely related, significantly influencing health status. This paper aimed (1) to investigate autoregressive and cross-lagged associations over 2 years between depression, loneliness, and quality of life, and (2) to examine sex-related differences in the 2-year associations between depression, loneliness, and quality of life in a large sample of European citizens aged  $\geq 50$  years.

**Methods** This is a longitudinal analysis. We included 7,456 individuals ( $70.89 \pm 7.64$  years; (4,268 females) who responded to waves 7 (2017) and 8 (2019) of the SHARE project. The variables analyzed in both waves were depression, loneliness, and quality of life.

**Results** Comparatively, females indicated higher depression and loneliness scores than males and a lower perception of quality of life. Autoregressive associations pointed that past depression, loneliness, and quality of life predicted their future episodes 2 years later ( $p < 0.001$ ). The cross-lagged analysis of males showed positive and significant bidirectional associations between depression and loneliness 2 years later. Females also showed a positive and significant association between depression and loneliness, but loneliness was not associated with depression 2 years later. In turn, previous high levels of quality of life had a protective role in late depression and loneliness up to 2 years.

**Conclusions** This study highlighted the need to simultaneously assess and manage depression, loneliness, and quality of life in the older European population. It is suggested that sex-specific policies can be created, including social support, in order to reduce depression and loneliness, and promote quality of life.

**Keywords** Aging, Vulnerability, Depression, Wellbeing, Loneliness

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## Introduction

Aging is responsible for a series of bio-psycho-functional changes that can affect the physical and mental health of older adults [1]. Among the most common mental health issues depression affects a large number of the older population [2, 3]. It is estimated that by 2030 the number of depressed older adults worldwide will increase to 1.4 billion [4]. Depression is related to adverse health problems that increase the risk of morbidity and mortality [5]. In turn, when it comes to sex differences, females are twice more likely to report symptoms of depression [6]. However, the disparity between males and females, as well as its conclusions remain inconsistent [7].

During aging, the individual is also faced with life transitions that can lead to feelings of loneliness [8]. Recent review studies with meta-analyses estimated the prevalence of loneliness in older adults in high-income countries at 27.6% [9], reaching rates of 18.7% to 24.2% in eastern European countries [10]. Loneliness is a multidimensional phenomenon that can change depending on life events or transitions over time [11]. Specifically, loneliness can be expressed in two forms, situational or chronic [12]. Situational loneliness refers to feeling lonely in a specific context or after the loss of important social partners and for a specific period of time, as for instance, during the COVID-19 confinement period. In the case of older adult individuals, issues such as the reduction of social networks due to the death of a spouse or friends and the change in life routine caused by retirement are factors that can lead them to experience situational loneliness. Chronic loneliness, however, is a more stable form of loneliness that develops over a long period of time and stems from the inability of the person to create and maintain satisfying social networks. Moreover, both forms of loneliness have been found to be related to an increase risk for all-cause mortality [12].

Notably, both loneliness and depression can affect mental health, leading to changes in quality of life (QoL) [13, 14]. As QoL reflects wellbeing and satisfaction with multiple dimensions of everyday life, including physical, psychological, social aspects [15], loneliness and depression have been found to relate to lower levels of QoL in later life [16]. Specifically, investigations with older aged individuals have indicated that there is a significant mediating effect of loneliness on the relationship between depression and QoL [17], as well as a mediating effect of depression on the relationship between loneliness and QoL [16]. These findings point out that it is unclear whether QoL decreases as a direct consequence of either loneliness or depression and suggest a potential bidirectionality between loneliness and depression, drawing the attention for the need to longitudinally investigate the potential links between these constructs. The prototype model of

loneliness proposed by Horowitz [18] suggested that it is more common for a lonely individual to report depression than for a depressed person to report loneliness. However, empirical findings regarding the relationship between loneliness and depression report a bidirectional effect. The Taiwan Longitudinal Study on Aging (TLISA) showed a significant bidirectional relationship between loneliness and depression through a 14-year follow-up study [19]. In a 12-year population-based cohort study of Americans (50 years and older), higher loneliness scores at baseline were associated with higher depression symptomatology scores [20]. In turn, the Irish Longitudinal Study on Aging (TILDA) revealed a bidirectional association between feeling lonely and suffering from anxiety and major depression disorder two years later. Moreover, recent genetically-informed evidence supports the bidirectionality of loneliness and depression [21]. Finally, although there is overlap in common characteristics between loneliness and depression, they are distinct phenomena [22]. A potential factor that may explain the bidirectionality between the two constructs and their effect on QoL may be sex. A current study revealed that high levels of loneliness, at a given time, related to an accelerated increase in depressive symptomatology two weeks later in older Austrian females, but not in males [23]. In the USA, a positive and significant association was found between depression and loneliness for females, but not for males [24]. However, little is known, and a more fine-grained analysis is needed regarding the moderating effect of sex on the relationship between loneliness, depression and QoL longitudinally. Thus, to contribute to these important issues, our study aimed (1) to investigate autoregressive and cross-lagged associations over 2 years between depression, loneliness, and QoL, and (2) to examine sex-related differences in the 2-year associations between depression, loneliness, and QoL in a large sample of European citizens aged  $\geq 50$  years.

## Methods

### Data source and study sample

Data are drawn from the European interdisciplinary longitudinal Survey on Health, Aging and Retirement in Europe (SHARE) [25] ([www.share-project.org](http://www.share-project.org)). SHARE is made up of 28 countries, including Israel. It provides researchers with data on the lives of Europeans 50 years and over to understand differences in European aging trajectories. Data were collected with face-to-face interviews using a computer (CAPI) directly in the participants' homes. We extracted data from the Wave 7 (2017) and Wave 8 (2020) of SHARE. In waves 7 and 8 of the SHARE dataset there were 76,493 and 46,500 participants, respectively, aged 50 and over. Due to possible memory problems during the interviews (risk of bias),

participants with Alzheimer's disease, dementia and senility were excluded, which corresponded to 586 participants in wave 7 and 1,014 individuals in wave 8. In a second step, we excluded in both waves participants who had missing data (refusal to respond or not responding) regarding the covariates and main variables of interest in the study (depression, loneliness, quality of life), resulting in wave 7 and wave 8 in 65,226 and 38,030 participants, respectively. Finally, 10,681 and 7,456 individuals were eligible in wave 7 and wave 8, respectively. However, for the analyses we only included those with complete data at follow-up, which corresponded to 7,456 participants. Due to the exclusion of participants with missing data, from the 28 countries present in the SHARE survey, analyses were reduced to 12 countries: Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Italy, Poland, Spain, Sweden and Switzerland. It is worth noting that due to the COVID-19 outbreak, wave 8 was suspended in March 2020 with 70% of the data collected. The SHARE protocol was approved by the University of Mannheim Ethics Committee and the Max-Planck Society for the Advancement of Science Ethics Committee. The procedures followed the guidelines and ethical standards of the Declaration of Helsinki.

## Measures

### Depression

The 12-item EURO-D scale developed and validated was used to assess and cross-nationally compare depression symptoms in Europe [26]. Their questions referred to the last month about the presence or absence of depression based on 12 domains: depressed mood, pessimism, suicidal tendency, guilt, sleep, interest, irritability, appetite, fatigue, concentration, pleasure and crying. The scale's scoring system is zero (not present) or 1 (present), resulting in a total score of 0–12. The higher the score, the greater the indication of depression symptoms. The diagnosis of clinically significant depression was based on the dichotomous system of the EURO-D study centers: ideal cut-off point  $\geq 4$  points [27, 28]. The scale was considered adequately internally consistent (Cronbach=0.72) with center-specific values ranging from 0.65 in Dublin to 0.83 in Finland.

### Loneliness

Participants completed the three-item version of the Revised UCLA Loneliness Scale [29]. Scale scores range from 3 to 9 (higher values indicate greater loneliness). Our study used the total scale score and a binary measure based on previous studies [30, 31]. Thus, classified the first, second and third quartiles as non-lonely, while individuals in the fourth quartile formed the solitary group. The scale has good internal consistency

(Cronbach=0.82), with the ability to assess general feelings of loneliness both in face-to-face and telephone interviews.

### Quality of life

The CASP-12 scale was used to assess QoL, which is a shorter version of CASP-19 [32]. It has 12 items, assessed on a four-point Likert scale (1=never to 4=often). The score ranges from 12 to 48: the higher the CASP-12 score, the better the perception of QoL. The 12-item shortened version of the CASP has stronger measurement properties (Cronbach=0.87) than the original CASP-19 measure and is recommended for applications.

### Covariates

Six self-reported variables were included in the analysis as confounding factors (i.e., age, marital status, years of education, Body Mass Index [BMI], comorbidities, and level of moderate physical activity [MPA]). Age, in years, was assumed to be a confounder, as depression and loneliness are expected to possibly increase with aging [33, 34], while QoL reduces [35]. Marital status was classified into five categories (i.e., married and living with spouse, registered partnership, married and not living with spouse, never married, divorced, widowed). Education was classified based on the International Type Classification of Education (ISCED) [36]. The levels were aggregated into three categories: (1) ISCED 0–1: no education or low level, (2) ISCED 2–4: intermediate education level, and (3) ISCED 5–6: higher level. BMI was included as a control variable due to the negative association revealed by investigations between obesity and QoL [27] and positive association between obesity and depression [37]. In turn, due to stigmatization, obesity can lead to feelings of loneliness or social isolation [28]. For BMI, participants reported height and weight, after which BMI was calculated using the equation: weight in kg/m<sup>2</sup>. Categorization was as follows: underweight (< 18.5), normal weight (18.5 to 24.9), overweight (25 to 29.9) and obesity ( $\geq 30$ ) [38]. Comorbidities were obtained through a medical report (last 12 months) and we analyzed the number of chronic diseases. The literature considers this measure being reliable for categorizing general health status [39]. The group of chronic diseases collected was: diabetes, hypertension, heart disease, cholesterol, rheumatoid arthritis, osteoarthritis, morbid obesity, cancer, lung disease, kidney disease, and neurological diseases. The physical activity (PA) level was established through an interview, considering the following question: "We would like to know the type and amount of physical activity you practice daily. How often do you perform physical activities that require a lot of physical effort, such as sports, heavy household chores, or a job that requires physical labor?" Afterwards,

the different levels of PA were established by a specific question: MPA = activities that required a moderate level of energy. The response options were: (1) more than once a week, (2) once a week, (3) up to 3 times a month and (4) almost never or never. For analysis, the last two response options were grouped into “less than once a week” [40]. PA was included as a control variable because both moderate to vigorous levels of PA and a low level of PA can influence the mental health status of older adults [41]. Consequently, regular exercise is recommended in the treatment of depression and promotion of QoL [42], favoring social exchanges, preventing feelings of loneliness during aging [43]. The control of covariates was performed in W-7 (year 2017).

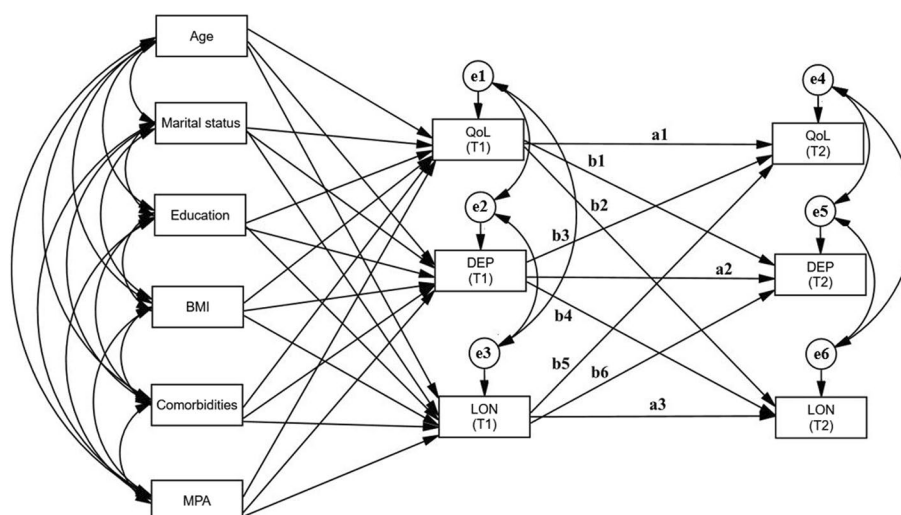
**Statistical analysis**

Descriptive statistics (means, frequencies, percentages) for the entire sample were calculated at the baseline (W-7, year 2017). Next, bidirectional temporal associations between depression, loneliness, and QoL were processed using a cross-lagged panel design (Fig. 1).

The modelling strategy is useful for causality effects over time between two or more variables in a unidirectional and bidirectional manner [44]. The analysis included autoregressive effects [45], represented with coefficient values obtained by regressing measurements at a point in time (*t*) on the same measurement at a point in time in the past (*t* - 1). The analysis totaled three paths (a1, a2, a3). In parallel, we processed cross-lagged analyses to examine a variable’s reciprocal influence at an earlier time (*t* - 1) on another variable at a later time (*t*). This

procedure totaled six lagged trajectories (b1, b2, b3, b4, b5, b6). Thus, if a path from time *t* - 1 over time *t* was significant (*p* < 0.05), this variable was a predictor. Therefore, the previous variable influenced the next variable, which also influenced the previous variable (bidirectional effect). We calculated two models: Model 1 included the entire sample and was controlled at W-7 for covariate confounders (i.e., age, marital status, years of education, Body Mass Index (BMI), comorbidities, MPA). Model 2 compared males versus females and was equally controlled in W-7 for covariates (i.e., age, marital status, years of education, Body Mass Index (BMI), comorbidities, MPA). Furthermore, in Model 2, we tested for significant differences in autoregressive and cross-lagged relationships in males vs. females: the procedure included a series of multigroup analyses with restrictions [46]. The procedures consisted of separate constraints for each of the three autoregressive paths, as well as constraints for the six cross-lagged paths. This procedure can employ standard errors for path coefficients, as well as pairwise comparisons for identical models based on different samples [47]. For all analyses, we estimated standardized coefficients.

The quality of fit was performed using the following indices and defined values: relative chi-square ( $\chi^2/df$ ), Normed Fit Index (NFI; >0.90), Comparative Fit Index (CFI; >0.90), Tucker–The Lewis (TLI; >0.90) [48], the relative fit index (RFI; >0.90), the incremental fit index (IFI; >0.90), the standard root mean square residual (SRMR; <0.08) and the Root Mean Square Error of Approximation (RMSEA; <0.08) [49], including 90%



**Fig. 1** Conceptual cross-lagged path model for depression, loneliness, and QoL over 2 years. Note: DEP, depression; QoL, quality of life; LON, loneliness; T1, year 2017; T2, year 2020; age, marital status, education, BMI, comorbidities, and MAP indicate covariates; a1, a2, a3, b1, b2, b3, b4, b5, b6 indicate path analysis labels; e1, e2, and e3 indicated the initial association between variables while controlling for covariates, and e4, e5, and e6 indicated the final association between variables while controlling for covariates

confidence interval [50]. All analyses were processed by IBM-SPSS (IBM Corp., Armonk, NY, USA) version 22.0 and an added SPSS module specific for structural equation modeling: Analysis of Moment Structures (AMOS). In all tests, we considered a two-tailed *p-value* < 0.05 to be statistically significant.

**Results**

A total of 7.456 individuals (70.89 ± 7.64 years) participated in the study (Table 1). Of these, 57.2% were females. The prevalent age groups were 60–69 (44%) and 70–79 (38.5%). The vast majority were classified as married and living with their spouse (34%), indicated 1 to 4 years of education (73.9%), were overweight (43.6%), had 1 to 3 chronic conditions (65.0%), and had MPA more than once a week (71.4%). The average QoL was 37.48 ± 6.30, the vast majority did not reveal loneliness (76.5%) and were not depressed (78.8%).

**Results for analysis of autoregressive and cross-lagged effects goodness of fit indices**

Model 1 [ $\chi^2/df=20,973, p<0.001$ ] and Model 2 [ $\chi^2/df=22,531, p<0.001$ ] fit the data well (Table 2). The analyses revealed a good overall fit in both models: RMSEA (0.038 to 0.052), SRMR (0.022 to 0.023), NFI (0.983 to 0.985), RFI (0.937 to 0.944), IFI (0.984 to 0.985), TLI (0.942 to 0.947), and CFI (0.984 to 0.985).

**Autoregressive effects**

Model 1, for the whole sample (Table 3), showed autoregressive effects of QoL, depression, and loneliness with  $\beta$ s of 0.67, 0.51, and 0.49, respectively (all *p* < 0.001). Model 2, focusing on males (Table 3), attested autoregressive effects for QoL, depression, and loneliness with  $\beta$ s of 0.65, 0.47, and 0.46, respectively (all *p* < 0.001). In turn, Model 2 for females (Table 3) showed higher autoregressive effects compared to males for QoL, depression and loneliness with  $\beta$ s of 0.69, 0.51, and 0.50, respectively (all *p* < 0.001).

**Cross-lagged effects**

**Analysis for entire population**

In Model 1, we analyzed the entire sample (Table 3), all autoregressive relationships indicated significant results (all *p* < 0.001). QoL at Time 1 negatively predicted depression at Time 2 ( $\beta=-0.13$ ) and loneliness at Time 2 ( $\beta=-0.16$ ). depression at Time 1 negatively predicted QoL at Time 2 ( $\beta=-0.05$ ). On the other hand, depression at Time 1 positively predicted loneliness at Time 2 ( $\beta=0.06$ ). Loneliness at Time 1 negatively predicted QoL at Time 2 ( $\beta=-0.07$ ). On the other hand, loneliness at Time 1 positively predicted depression at Time 2 ( $\beta=0.05$ ).

**Table 1** Baseline characteristics of the study sample (wave 7; *n* = 7.456)

| Variable                        | n     | (%)    | Mean ± SD    |
|---------------------------------|-------|--------|--------------|
| Age (years)                     |       |        | 70.89 ± 7.64 |
| 50–59                           | 245   | (3.3)  |              |
| 60–69                           | 3.282 | (44.0) |              |
| 70–79                           | 2.869 | (38.5) |              |
| 80–89                           | 982   | (13.2) |              |
| 90–99                           | 78    | (1.0)  |              |
| Sex                             |       |        |              |
| Male                            | 3.188 | (42.8) |              |
| Female                          | 4.268 | (57.2) |              |
| Marital status                  |       |        |              |
| Married: living with spouse     | 2.535 | (34.0) |              |
| Registered partnership          | 1.193 | (16.0) |              |
| Married: not living with spouse | 1.380 | (18.5) |              |
| Never married                   | 648   | (8.7)  |              |
| Divorced                        | 514   | (6.9)  |              |
| Widowed                         | 1.185 | (15.9) |              |
| Education                       |       |        |              |
| None                            | 207   | (2.8)  |              |
| 1–4 years                       | 5.511 | (73.9) |              |
| 5–12 years                      | 1.700 | (22.8) |              |
| ≥ 12 years                      | 38    | (0.5)  |              |
| BMI                             |       |        | 26.95 ± 4.40 |
| Underweight                     | 72    | (1.0)  |              |
| Normal                          | 2.536 | (34.0) |              |
| Overweight                      | 3.251 | (43.6) |              |
| Obese                           | 1.597 | (21.4) |              |
| Chronic disease                 |       |        |              |
| 0                               | 1.406 | (18.9) |              |
| 1–3                             | 4.881 | (65.5) |              |
| 4–6                             | 1.091 | (14.6) |              |
| 7–9                             | 75    | (1.0)  |              |
| 10–12                           | 3     | (0.1)  |              |
| MPA                             |       |        | 2.57 ± 0.73  |
| <Once week                      | 1.065 | (14.3) |              |
| Once week                       | 1.070 | (14.4) |              |
| >Once week                      | 5.321 | (71.4) |              |
| QoL                             |       |        | 37.48 ± 6.30 |
| LON                             |       |        | 3.90 ± 1.36  |
| Yes                             | 1.750 | (23.5) |              |
| No                              | 5.706 | (76.5) |              |
| DEP                             |       |        | 2.19 ± 2.16  |
| Yes                             | 1.727 | (23.2) |              |
| No                              | 5.729 | (76.8) |              |

BMI Body Mass Index, MPA Moderate physical activity, DEP Depression, QoL Quality of life, LON Loneliness, SD Standard deviation

**Analysis for males**

In Model 2 for males (see Fig. 2 for better visualization), cross-lagged relationships indicated significant results (all

**Table 2** Results for autoregressive and cross-lagged models, based on goodness of fit indices

| Goodness of fit index | RMSEA         | SRMR                | NFI    | RFI    | IFI    | TLI    | CFI    |
|-----------------------|---------------|---------------------|--------|--------|--------|--------|--------|
| Suggested value       | < 0.08 90% CI | < 0.08              | > 0.90 | > 0.90 | > 0.90 | > 0.90 | > 0.90 |
| $\chi^2/df$           |               |                     |        |        |        |        |        |
| Model 1               | 20,973        | 0.052 (0.047;0.056) | 0.023  | 0.985  | 0.944  | 0.985  | 0.947  |
| Model 2               | 11,531        | 0.038 (0.033;0.042) | 0.022  | 0.983  | 0.937  | 0.984  | 0.942  |

Model 2 presents the adjustment for comparison between males and females

RMSEA root-mean-square error of approximation, SRMR Standardized root-mean-square residual, NFI Normed fit index, RFI Relative fit index, IFI Incremental fit index, TLI Tucker–Lewis fit index, CFI Comparative fit index

**Table 3** Autoregressive and cross-lagged effects for depression, loneliness, and quality of life

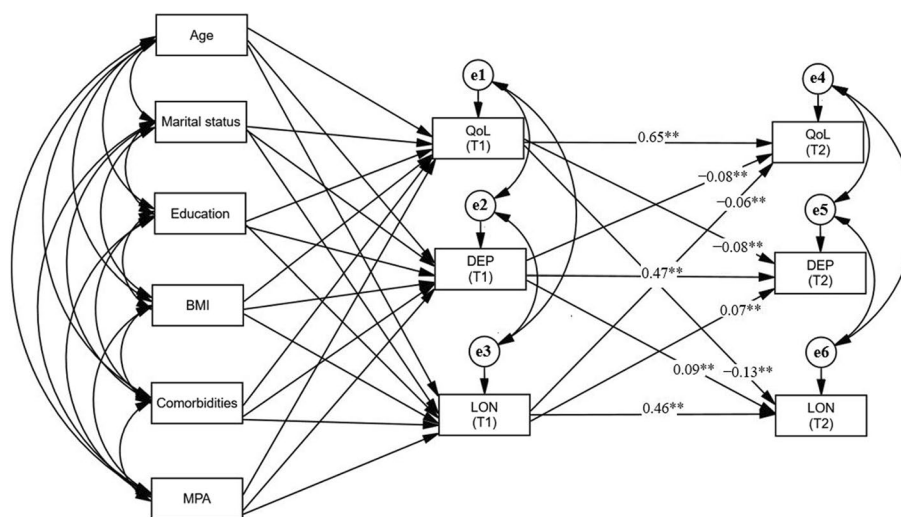
| Path              | Model 1           |         | Model 2           |         | Multigroup analysis |         |         |
|-------------------|-------------------|---------|-------------------|---------|---------------------|---------|---------|
|                   | Total (n = 7.456) |         | Males (n = 3.188) |         | Females (n = 4.268) |         | p       |
| Autoregressive    | $\beta$           | p       | $\beta$           | p       | $\beta$             | p       | p       |
| (a <sub>1</sub> ) |                   |         |                   |         |                     |         |         |
| T1 QoL → T2 QoL   | 0.67              | < 0.001 | 0.65              | < 0.001 | 0.69                | < 0.001 | 0.059   |
| (a <sub>2</sub> ) |                   |         |                   |         |                     |         |         |
| T1 DEP → T2 DEP   | 0.51              | < 0.001 | 0.47              | < 0.001 | 0.51                | < 0.001 | 0.732   |
| (a <sub>3</sub> ) |                   |         |                   |         |                     |         |         |
| T1 LON → T2 LON   | 0.49              | < 0.001 | 0.46              | < 0.001 | 0.50                | < 0.001 | 0.647   |
| Cross-lagged      |                   |         |                   |         |                     |         |         |
| (b <sub>1</sub> ) |                   |         |                   |         |                     |         |         |
| T1 QoL → T2 DEP   | - 0.13            | < 0.001 | - 0.08            | < 0.001 | - 0.11              | < 0.001 | 0.031   |
| (b <sub>2</sub> ) |                   |         |                   |         |                     |         |         |
| T1 QoL → T2 LON   | - 0.16            | < 0.001 | - 0.13            | < 0.001 | - 0.19              | < 0.001 | < 0.001 |
| (b <sub>3</sub> ) |                   |         |                   |         |                     |         |         |
| T1 DEP → T2 QoL   | - 0.05            | < 0.001 | - 0.08            | < 0.001 | - 0.28              | 0.017   | < 0.001 |
| (b <sub>4</sub> ) |                   |         |                   |         |                     |         |         |
| T1 DEP → T2 LON   | 0.06              | < 0.001 | 0.09              | < 0.001 | 0.35                | 0.011   | 0.002   |
| (b <sub>5</sub> ) |                   |         |                   |         |                     |         |         |
| T1 LON → T2 QoL   | - 0.07            | < 0.001 | - 0.06            | < 0.001 | - 0.08              | < 0.001 | 0.629   |
| (b <sub>6</sub> ) |                   |         |                   |         |                     |         |         |
| T1 LON → T2 DEP   | 0.05              | < 0.001 | 0.07              | < 0.001 | 0.28                | 0.064   | 0.045   |

$\beta$ : Standardized values; a<sub>1</sub>, a<sub>2</sub>, a<sub>3</sub>, b<sub>1</sub>, b<sub>2</sub>, b<sub>3</sub>, b<sub>4</sub>, b<sub>5</sub>, b<sub>6</sub>: indicate path analysis labels; p ≤ 0.05

DEP Depression, QoL Quality of life, LON Loneliness; Model 1 and 2 controlled by covariates (age, marital status, years of education, BMI, comorbidities, MPA)

p < 0.001). QoL at Time 1 negatively predicted depression at Time 2 ( $\beta = -0.08$ ) and QoL at Time 1 also negatively predicted loneliness at Time 2 ( $\beta = -0.13$ ). Depression at Time 1 negatively predicted QoL at Time 2 ( $\beta = -0.08$ ). On the

other hand, depression at Time 1 positively predicted loneliness at Time 2 ( $\beta = 0.09$ ). Loneliness at Time 1 negatively predicted QoL at Time 2 ( $\beta = -0.06$ ). However, loneliness at Time 1 positively predicted depression at Time 2 ( $\beta = 0.07$ ).



**Fig. 2** Cross-lagged path model for males. Note: DEP, depression; QoL, quality of life; LON, loneliness; T1, year 2017; T2, year 2020; age, marital status, education, BMI, comorbidities, and MAP indicate covariates; e1, e2, and e3 indicated the initial association between variables while controlling for covariates, and e4, e5, and e6 indicated the final association between variables while controlling for covariates; \*\* $p < 0.001$

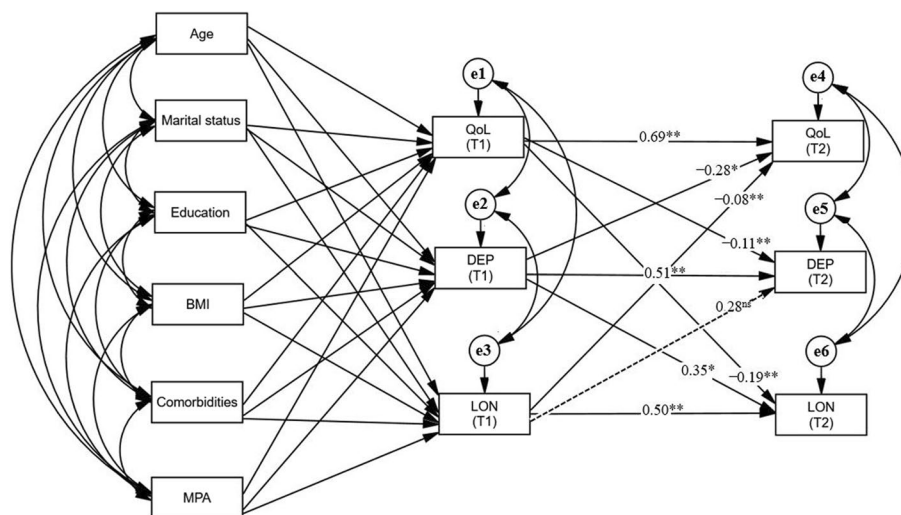
**Analysis for females**

In Model 2 for females (see Fig. 3 for better visualization), only loneliness at Time 1 did not predict depression at Time 2 ( $\beta = 0.28$ ;  $p = 0.064$ ). The other cross-lagged relationships indicated significant results (all  $p < 0.001$ ). QoL at Time 1 negatively predicted depression at Time 2 ( $\beta = -0.11$ ) and also QoL at Time 1 predicted loneliness at Time 2 ( $\beta = -0.19$ ). Depression at Time 1 negatively and significantly predicted

QoL at Time 2 ( $\beta = -0.28$ ). On the other hand, depression at Time 1 positively predicted loneliness at Time 2 ( $\beta = 0.35$ ). Finally, loneliness at Time 1 negatively predicted QoL at Time 2 ( $\beta = -0.08$ ).

**Multigroup differences according to sex**

The autoregressive paths did not show significant effects ( $p > 0.50$ ) (see Table 3). Regarding the cross-lagged analysis, no significant difference was found for the effect of



**Fig. 3** Cross-lagged path model for females. Note: DEP, depression; QoL, quality of life; LON, loneliness; T1, year 2017; T2, year 2020; age, marital status, education, BMI, comorbidities, and MAP indicate covariates; e1, e2, and e3 indicated the initial association between variables while controlling for covariates, and e4, e5, and e6 indicated the final association between variables while controlling for covariates; <sup>ns</sup> not significant; \* $p < 0.01$ ; \*\* $p < 0.001$

loneliness Time 1 on QoL Time 2 ( $p=0.629$ ). All other paths were significant ( $p<0.50$ ).

## Discussion

This study aimed to investigate autoregressive and cross-lagged associations over 2 years between depression, loneliness, and QoL, as well as to examine sex-related differences in the 2-year associations between depression, loneliness, and QoL in a large sample of European citizens aged  $\geq 50$  years. In line with previous studies, we found in both measurement times that females had a greater feeling of depression and loneliness than males [51, 52] and QoL decreased over 2 years for both sexes [15].

The main analysis showed significant autoregressive associations for both sexes. The findings confirmed that past depression, loneliness, and QoL predicted their future episodes 2 years later [19, 53, 54]. Autoregressive multigroup analyses indicated no significant differences between sexes, suggesting that the temporal potentiating effect was equal for males and females. Cross-lagged analysis revealed interesting results. Males showed positive and significant bidirectional associations between depression and loneliness, indicating that each of these variables in 2017 predicted an increase in the other in 2019 [54, 55]. Females indicated a positive and significant association of depression with loneliness 2 years later. On the other hand, although the loneliness coefficient for females was higher than for males, females did not show a significant association between loneliness and depression 2 years later. The finding contradicts review and meta-analysis studies that revealed loneliness as a precursor to future depression [9, 10].

This result may suggest that, compared to males, other factors should be taken into account to explain the impact of loneliness on female future mental adjustment. Our findings have implications as they highlight the value of testing across and within sex the explanatory power of psychological and behavioral adjustment variables in the association between loneliness, depression, and QoL. In this context, it would also be interesting to deepen the understanding of the genetic vulnerability of each sex, the impact of stressful events, as well as the roles that males and females play in the family and society [56]. It is worth highlighting that the combination between the retirement period and the series of underlying factors of aging tend to, regardless of sex, trigger emotional changes, making older adults more vulnerable to depressive disorders and voluntary exclusion from social exchanges [57]. Traditionally, females roles are more sensitive and linked to reflection, internal experiences of care, and emotional adaptability, while male value self-protection, emotional stability, instrumentality, as well as adjustments that lead

to self-expansion and self-affirmation [56]. Thus, understanding these factors can contribute to the creation of strategies and monitoring of mental health during aging.

To our knowledge, our study is the first study to provide longitudinal information on the roles of depression, loneliness, QoL in the European adult population, differentiated by sex. Therefore, the greatest magnitude explained by the analyses occurred in the depression predictor concerning loneliness. Comparatively, the females path was superior, explaining 35% of the variance, while the males path explained 9%. The results confirmed the differentiating role of depression according to the sexes, highlighting the prevalence in females [58, 59]. It is worth noting that the effect of depression on loneliness over 2 years was considerably stronger than the effect of loneliness on depression over the same period. One possible explanation is that over a short period of time, the effect of loneliness on depression may disappear, whereas the reverse effect may remain constant for up to 3 or 4 years [19].

Regarding QoL, for both sexes, negative and significant bidirectional relationships were found between depression and QoL over 2 years. These results were in line with previous studies that highlighted in older adults the negative impacts of depression symptomatology on the perception of QoL and well-being [60, 61]. Thus, it is possible that, over the course of 2 years, a lack of interpersonal relationships and social support affected QoL [13]. In old age, due to a range of demographic characteristics (i.e. income, sex, housing), including health (i.e. comorbidities, illnesses, medications) and social (i.e. loneliness, social networks, death of spouse) issues, the perception of QoL tends to decrease [62]. Our findings showed also that previous high levels of QoL had a protective role in late depression and loneliness up to 2 years. A possible explanation is that QoL consists of a multifactorial and situational subjective construction involving physical, functional, social, environmental, and emotional perceptions [63]. Therefore, the greater the perception of this multifactorial scale, the greater the chances that fewer depression and loneliness will be present. Moreover, our findings were in line with a current longitudinal study carried out with data from SHARE, which revealed lower QoL scores for females and higher depression than males [61].

Finally, multigroup cross-lagged analyses (male vs. female) showed significant differences for all paths, except for loneliness Time 1 over QoL Time 2. This result suggests that males and females did not differ in relation to the negative role that the feeling of loneliness played on QoL 2 years later, and corroborated the negative effect that loneliness and depression have on the QoL of the older population [16, 17].

### Strengths, limitations, and future directions

Among the strengths of this study is the time frame that associated information from 2 years. Second, there is the cross-national sample size and information set from 12 European countries. Third, the results suggested that previous high levels of QoL had a protective role in late depression and loneliness up to 2 years. Thus, the promotion of QoL proved to be a possible contributing strategy to mental illnesses in the older population [16]. Fourth, the data presented were collected using highly reliable and globally recognized scales. Furthermore, to our knowledge, this is the first study that tested temporal and bidirectional associations between depression, loneliness, and QoL in the European population aged  $\geq 50$  years based on data from the SHARE survey from 2017 and 2019, bringing to light information differentiated by sex. On the other hand, the study has limitations: First, it is possible that potential covariates that were not present in the SHARE survey that affect depression, loneliness, and QoL may have generated biases in the interpretation of the results. Secondly, our results clarified the temporal relationship between the variables studied, but not the cause and effect between them. Third, self-reported information may have generated discrepancies between what participants believed they were doing or feeling and what they reported or felt. Fourth, our results cannot be generalized to populations outside the European continent. Fifth, we acknowledge that some of the cross-lagged effects observed are relatively small. This suggests that aging is complex and driven by many multifaceted mechanisms, which we unfortunately cannot address entirely in the present study. Future longitudinal research is needed to further scrutinize the pattern of results observed. Sixth, it must be taken into account that over the 2-year period, study participants may have experienced a series of situations capable of influencing their mental state. Therefore, these events may have generated fluctuations in depression, loneliness, and mainly in QoL, consequently influencing the autoregressive or cross-lagged effects. Seventh, there is a recommendation to use three or more waves to provide a powerful analysis [64]. Therefore, the inclusion of two measurement points (2017–2019) may not have allowed us to effectively test reciprocal associations, as well as the direction of relationships. Finally, gender is not measured in SHARE, and thus, we were not able to include it in our analysis.

Our findings indicate practical implications. Cross-lagged analyses showed that high previous QoL scores reduced depression and loneliness symptoms 2 years later. Therefore, the finding suggested creating strategies that seek to promote the QoL of the European older adult population. Our findings suggested that there is unequal directionality of the effects of loneliness and depression

over 2 years between older males and females. Consequently, the information offers practical implications for being aware of the problem of depression among lonely individuals. Therefore, it is suggested to simultaneously assess loneliness, depression, and QoL. We also suggest that future studies explore our results, deepening the analyses by marital status, country or region of Europe, income, education and if they are not born in Europe, it would be interesting to include the country of birth.

### Conclusion

The results of the present study shed light on important insights into 2-year longitudinal associations between depression, loneliness, and QoL in a large sample of older adults from 12 European countries. Females indicated higher depression and loneliness scores than males and a low score of QoL. Multigroup autoregressive analyses indicated no significant differences between sexes. In the cross-lagged analysis, males showed significant positive bidirectional associations between depression and loneliness 2 years later. On the other hand, female previous loneliness was not significantly associated with later depression. Finally, we found that in both sexes, previous levels of QoL played a protective role in both depression and loneliness after 2 years. These observed sex differences may reflect underlying gendered factors, highlighting the importance of considering gender dynamics in future research.

### Abbreviations

|       |   |
|-------|---|
| BMI   | Body Mass Index                         |
| CFI   | Comparative fit index                   |
| DEP   | Depression                              |
| IFI   | Incremental fit index                   |
| LON   | Loneliness                              |
| MPA   | Moderate physical activity              |
| NFI   | Normed fit index                        |
| QoL   | Quality of life                         |
| RFI   | Relative fit index                      |
| RMSEA | Root-mean-square error of approximation |
| SRMR  | Standardized root-mean-square residual  |
| TLI   | Tucker–Lewis fit index                  |

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### Authors' contributions

MMN and AM conceived the study; MMN did the analysis and drafted the manuscript; MMN performed the statistical analysis; CL, AM and AI helped draft the manuscript; AI, JCA and ERG revised the manuscript. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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### Availability of data and materials

The data is freely accessible. The data can be accessed through the SHARE project website – [www.share-project.org](http://www.share-project.org).

## Declarations

### Ethics approval and consent to participate

The SHARE study is continuously reviewed with regards to ethics. The first 4 waves were reviewed by the Ethics Committee of the University of Mannheim and since then the project is reviewed and approved by the Ethics Council of the Max Planck Society. In addition, the respective country ethics committees or institutional boards regularly review the study when required. The various reviews confirmed that the SHARE project is compliant with all current relevant legal norms and its procedures are in line with international ethical standards for research with human subjects. All participants provided informed consent prior to their participation.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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