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Original Research Article

National trends in osteoporosis in the general older population and postmenopausal women, to the COVID-19 pandemic by related factors, 2001-2021: a nationwide study in South Korea

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Abstract

Objective: Changes in the prevalence of osteoporosis, especially among the older population in South Korea, remain under-investigated, particularly during the COVID-19 pandemic. Thus, we aimed to analyze trends in osteoporosis and risk factors among Korean older adults, with a specific focus on the general population and postmenopausal women aged 50 years and above, spanning the period from 2001 to 2021.

Methods: To estimate the prevalence and identify the determinants of osteoporosis, our study employed weighted complex sampling to ensure an accurate representation of menopausal status. We utilized linear and logistic regression to compute beta coefficients and evaluate associated factors. The weighted prevalence of osteoporosis by age, sex, menopausal status, socioeconomic status, and other sociodemographic variables was deduced from self-reporting.

Results: This cross-sectional study utilized data from 38,341 older individuals in South Korea, collected through a nationwide survey. The overall sex distribution consisted of 21,836 (56.95%) females. The prevalence of osteoporosis in the general older population increased before the pandemic, as indicated by a β coefficient of 0.328 (95% CI, 0.061 to 0.596); however, it did not continue to increase significantly in the preceding pandemic years. The prevalence among menopausal women also increased, with a β coefficient of 0.912 (0.472 to 1.352) before the pandemic. However, the pandemic slowed the increase, as indicated by a β_{diff} of -1.90 (-3.31 to -0.49). Compared to the pre-pandemic, age of 80 years or above (ratio of wOR, 1.67; 95% CI, 1.29 to 2.16), higher income (1.29; 1.11 to 1.50), obesity (1.54; 1.05 to 2.27), and higher education (1.37; 1.15 to 1.63) stand out as influential factors increasing osteoporosis prevalence during the pandemic.

Conclusions: Osteoporosis trends exhibited notable shifts during the study period within the COVID-19 pandemic. Further research is essential to monitor these trends and inform future healthcare strategies on the COVID-19 pandemic.

Key words: Osteoporosis, Prevalence, Postmenopausal, KNHANES.

1. Introduction

Osteoporosis, a significant health concern marked by reduced bone mass and quality, is particularly prevalent among postmenopausal women due to hormonal changes like decreased estrogen levels.[1, 2] This silent condition, known for increasing the risk of fractures, impacts quality of life and incurs high healthcare costs.[3] The World Health Organization classifies it based on bone mineral density, highlighting its importance.[4-6]

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The COVID-19 pandemic has significantly altered global public health dynamics.[7] Lockdowns and social distancing measures, while essential for managing the pandemic, have led to a decline in physical activity. This reduction in activity was observed worldwide, with specific demographics such as older and female populations, and urban residents showing more significant declines.[8, 9] In South Korea, the drop in physical activity was notably acute, affecting various groups, including those with a history of depressive episodes. This is significant as these individuals might already face challenges in maintaining physical activity, crucial for managing bone health.[8, 9]

Informed by previous research, which has indicated a discernible decline in physical activity during the pandemic, one may question its impact on bone health and osteoporosis, which poses a greater risk to older or postmenopausal female individuals.[10] Distinctively, both the older and female population groups, already observed as vulnerable to activity reductions during the pandemic, are concurrently more susceptible to osteoporosis.[10] These intersections in vulnerability dynamics have informed the present study to investigate trends in osteoporosis prevalence, especially when comparing before and during the COVID-19 pandemic.

Building on this, we hypothesized that there would be variation in osteoporosis prevalence from before to during the COVID-19 pandemic. Thus, the present study focuses on understanding the trends of osteoporosis prevalence among South Koreans aged over 50 years from 2001 to 2021. Utilizing comprehensive datasets, we aimed to identify potential changes in osteoporosis susceptibility before and during the COVID-19 pandemic, providing valuable insights for healthcare strategies and policy implications.

2. Methods

2.1 Data collection and study population

In our research, we sourced data from KNHANES, an annual survey undertaken by the Korea Disease Control and Prevention Agency (KDCA) from 2001 to 2021.[7] Our research primarily focused on the elderly demographic, especially those aged 50 years and above, and aimed to acquire an in-depth understanding of the trend dynamics and prevalence of osteoporosis within South Korea.[2]

Our analysis incorporated various factors such as age, sex, region of residence, education level, household income, smoking status, and BMI, following the Asian-Pacific guidelines.[7, 11] Menopausal status and osteoporosis diagnosis were also considered as main factors. These factors were crucial in evaluating the potential influences on the prevalence of osteoporosis.[12]

Our primary aim was to examine the general prevalence of osteoporosis and its prevalence in postmenopausal women over time. This was achieved using a nationally representative sample gathered from the KNHANES database. The longitudinal design of this survey enabled us to observe and analyze the long-term trends and patterns in the prevalence of osteoporosis.

The research was conducted in accordance with ethical standards, and written consent was obtained from all participants. The study utilized publicly accessible KNHANES data, which

enriched our epidemiological understanding and enabled the exploration of various factors influencing osteoporosis. Our research protocol was approved by the Institutional Review Board of the KDCA.

3. Ascertainment of osteoporosis and menopause

We conducted an extensive survey with a considerable sample of 38,341 participants.

Participants were asked whether they had ever been diagnosed with osteoporosis and their current menopause status, specifically: "Have you ever received a clinical diagnosis of osteoporosis by a medical professional?" and "Have you experienced menopause?" Considering the critical impact of menopause on bone health due to the drastic decrease in estrogen level, our investigation employed a dual-faceted approach: examining the overall prevalence of osteoporosis over 20 years, and analyzing the prevalence of osteoporosis specifically among postmenopausal women during the same duration.[13]

4. Covariates

In our research analysis, we incorporated diverse covariates to create a comprehensive evaluation of factors that could affect the prevalence of osteoporosis over time. These covariates included age, grouped into 50-59, 60-69, 70-79, and 80 years and above, sex (male and female), and region of residence, categorized by urban and rural areas.[14] The data we collected were segmented into four categories for both household income (lowest, second, third, and highest quartiles) and education level (elementary school or lower, middle school, high school, and college or higher). However, to streamline our analysis, we consolidated these into binary categorization to relatively ‘higher’ and ‘lower’ groups, including two levels each, enabling a more focused examination of osteoporosis prevalence and risk factors. BMI was classified into three groups based on Asian-Pacific guidelines: underweight (<18.5 kg/m^2), normal weight, and overweight (18.5-24.9 kg/m^2), and obese (≥25.0 kg/m^2). Menopause status was an essential covariate and was categorized as either premenopausal or postmenopausal.[2, 15]

5. Statistical analysis

The outcomes of our study were presented using data expressed as proportions or percentages. To achieve the main objective of this research, which is to analyze the prevalence of osteoporosis among the general population and specifically among postmenopausal women aged 50 years and above from 2001 to 2021, we employed linear and logistic regression models, complemented by weighted complex sampling to ensure precise estimations.[6, 7] To provide a holistic perspective, we merged and filtered the data across eight distinct intervals: 2001-2005, 2007-2008, 2009-2010, 2011-2015, 2016-2017, 2018-2019, 2020, and 2021. KNHANES serves as a comprehensive data repository, reflecting a broad cross-section of the South Korean population, ensuring representativeness and reliability of key variables for our study. We excluded Bone Mineral Density (BMD) measurements from our analysis. This was because BMD data were gathered from an independent survey separate from the primary data and were only collected for a limited

number of years. To ensure data consistency across our study period, we focused on integrating survey data that consistently included self-reported osteoporosis assessments, allowing for a more uniform analysis of trends. Moreover, we had to exclude the datasets from 2012, 2013, and 2014 because they lacked osteoporosis prevalence data.

Our estimates were generated using wORs paired with their respective 95% CI.[11, 16] By leveraging a weighted complex sampling analysis, we could ascertain that our results genuinely represented the South Korean demographic.[2] This strategy effectively adjusted any discrepancies between our sample and the South Korean demographic distribution, culminating in results that were both representative and precise.[16]

To determine the prevalence of osteoporosis in the general population aged 50 years and older, particularly in postmenopausal women, we used linear logistic regression models. This allowed us to calculate the wORs, complemented with a 95% CI. We further assessed the beta (β) difference, revealing the evolution in osteoporosis prevalence over the 20-year. Enhancing the credibility of our discoveries, we undertook a risk factor analysis. This incorporated variables such as age, sex, educational attainment, residential area, household income, BMI, and menopausal status, which remained constant in all regression models.[12]

Our analytical process relied on a variety of tools. The core statistical assessments were conducted using SAS software (version 9.4; SAS Institute, Cary, NC, USA). All estimations emerged as statistically significant, with a p-value ≤ 0.05 set as the criterion for significance.[11] The β coefficients and the 95% CIs were computed through the weighted generalized linear model.[16]

6. Results

A total of 162,857 participants were evaluated in the Korea National Health and Nutrition Examination Survey (KNHANES) from 2001 to 2021. However, to maintain consistency in the standard for osteoporosis observation and menopausal status, 130,237 participants were omitted due to missing data and age restrictions, prioritizing participants aged 50 and over (Fig. 1). Consequently, the final sample for the study consisted of 38,341 participants. Participant distribution across the study periods was as follows: 4,353 in 2001-2005, 4,343 in 2007-2008, 6,546 in 2009-2010, 3,147 in 2011-2015, 6,562 in 2016-2017, and 6,814 in 2018-2019, for the pre-pandemic period. During the pandemic, the numbers were 3,281 in 2020 and 3,295 in 2021. The overall sex distribution consisted of a higher proportion of females (56.95%) compared to males (43.05%) (Table 1).

Table 2 and Fig. 2 illustrate the prevalence of osteoporosis among the South Korean population over 50 years and postmenopausal women over 50 years from 2001 to 2021, with regression slope coefficients denoted by β coefficients and 95% confidence intervals (CI). The overall prevalence of osteoporosis among the general population increased from 9.56% (95% CI, 8.62 to 10.49) in 2001 to 11.73% (95% CI, 10.78 to 12.67) in 2018-2019, followed by 10.74%

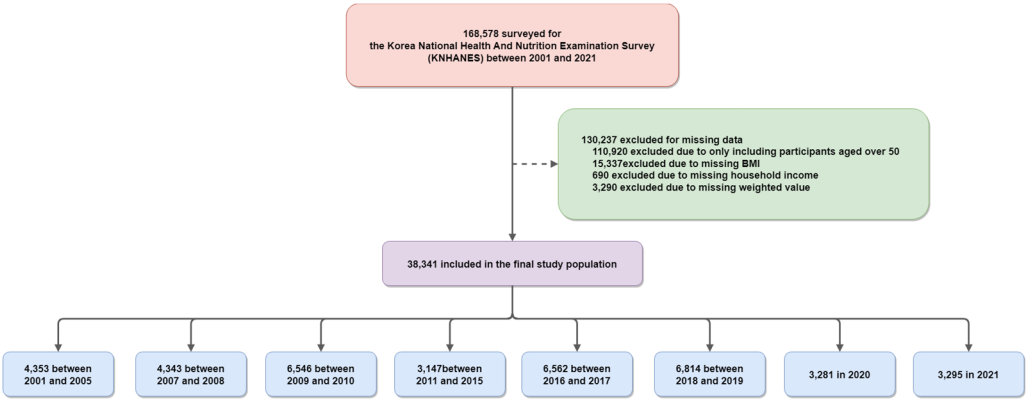

Fig. 1. Study population. BMI, body mass index. The KNHANES data from 2012, 2013, and 2014 were excluded.

Table 1. General characteristics of South Korean older population, in the data obtained from the KNHANES from 2001 to 2021 (n=38,341)

	Total	Pre-pandemic						During the pandemic	
		2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021
					Crude rate, (95% CI)				
Overall, n	38,341	4,353	4,343	6,546	3,147	6,562	6,814	3,281	3,295
					Age group, years, n (95% CI)				
50-59	13,676 (35.67)	1,788 (41.08)	1,579 (36.36)	2,400 (36.66)	1,152 (36.61)	2,317 (35.31)	2,367 (34.74)	1,058 (32.25)	1,015 (30.80)
60-69	12,815 (33.42)	1,553 (35.68)	1,492 (34.35)	2,210 (33.76)	1,020 (32.41)	2,111 (32.17)	2,225 (32.65)	1,105 (33.68)	1,099 (33.35)
70-79	9,012 (23.50)	821 (18.86)	1,037 (23.88)	1,578 (24.11)	751 (23.86)	1,577 (24.03)	1,610 (23.63)	819 (24.96)	819 (24.86)
≥80	2,838 (7.40)	191 (4.39)	235 (5.41)	358 (5.47)	224 (7.12)	557 (8.49)	612 (8.98)	299 (9.11)	362 (10.99)
					Sex, n (95% CI)				
Male	16,505 (43.05)	1,866 (42.87)	1,800 (41.45)	2,837 (43.34)	1,370 (43.53)	2,839 (43.26)	2,927 (42.96)	1,457 (44.41)	1,409 (42.76)
Female	21,836 (56.95)	2,487 (57.13)	2,543 (58.55)	3,709 (56.66)	1,777 (56.47)	3,723 (56.74)	3,887 (57.04)	1,824 (55.59)	1,886 (57.24)
					Region of residence, n (95% CI)				
Urban	27,405 (71.48)	2,866 (65.84)	2,688 (61.89)	4,421 (67.54)	2,396 (76.14)	4,967 (75.69)	5,227 (76.71)	2,478 (75.53)	2,362 (71.68)
Rural	10,936 (28.52)	1,487 (34.16)	1,655 (38.11)	2,125 (32.46)	751 (23.86)	1,595 (24.31)	1,587 (23.29)	803 (24.47)	933 (28.32)
					Household income, n (95% CI)				
Lowest quartile	12,262 (31.98)	1,692 (38.87)	1,578 (36.33)	2,254 (34.43)	917 (29.14)	2,016 (30.72)	1,968 (28.88)	888 (27.06)	949 (28.80)
Second quartile	9,842 (25.67)	1,029 (23.64)	1,219 (28.07)	1,625 (24.82)	833 (26.47)	1,700 (25.91)	1,768 (25.95)	829 (25.27)	839 (25.46)

Table 1. Continued

	Total	Pre-pandemic						During the pandemic	
		2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021
Third quartile	7,995 (20.85)	839 (19.27)	770 (17.73)	1,325 (20.24)	692 (21.99)	1,379 (21.01)	1,483 (21.76)	778 (23.71)	729 (22.12)
Highest quartile	8,242 (21.50)	793 (18.22)	776 (17.87)	1,342 (20.50)	705 (22.40)	1,467 (22.36)	1,595 (23.41)	786 (23.96)	778 (23.61)
Education level, n (95% CI)									
Elementary school or lower	16,546 (43.15)	2,440 (56.05)	2,442 (56.23)	3,275 (50.03)	1,347 (42.8)	2,540 (38.71)	2,310 (33.9)	1,097 (33.43)	1,095 (33.23)
Middle school	6,509 (16.98)	746 (17.14)	761 (17.52)	1,201 (18.35)	527 (16.75)	1,139 (17.36)	1,117 (16.39)	518 (15.79)	500 (15.17)
High school	9,156 (23.88)	798 (18.33)	748 (17.22)	1,323 (20.21)	762 (24.21)	1,651 (25.16)	1,986 (29.15)	921 (28.07)	967 (29.35)
College or higher	6,130 (15.99)	369 (8.48)	392 (9.03)	747 (11.41)	511 (16.24)	1,232 (18.77)	1,401 (20.56)	745 (22.71)	733 (22.25)
BMI, kg/m^2, n (95% CI)*									
Underweight	1,099 (2.87)	158 (3.63)	140 (3.22)	209 (3.19)	75 (2.38)	176 (2.68)	156 (2.29)	85 (2.59)	100 (3.03)
Normal and overweight	23,098 (60.24)	2,588 (59.45)	2,615 (60.21)	4,031 (61.58)	1,852 (58.85)	3,922 (59.77)	4,202 (61.67)	1,916 (58.4)	1,972 (59.85)
Obese	14,144 (36.89)	1,607 (36.92)	1,588 (36.56)	2,306 (35.23)	1,220 (38.77)	2,464 (37.55)	2,456 (36.04)	1,280 (39.01)	1,223 (37.12)
Presence of osteoporosis, n (95% CI)									
Present	5,169 (13.48)	437 (10.04)	558 (12.85)	898 (13.72)	467 (14.84)	983 (14.98)	959 (14.07)	435 (13.26)	432 (13.11)
Absent	33,172 (86.52)	3,916 (89.96)	3,785 (87.15)	5,648 (86.28)	2,680 (85.16)	5,579 (85.02)	5,855 (85.93)	2,846 (86.74)	2,863 (86.89)
Menopausal status, n (95% CI)									
Male	16,505 (43.05)	1,866 (42.87)	1,800 (41.45)	2,837 (43.34)	1,370 (43.53)	2,839 (43.26)	2,927 (42.96)	1,457 (44.41)	1,409 (42.76)
Postmenopausal	18,504 (48.26)	2,120 (48.70)	2,188 (50.38)	3,330 (50.87)	1,495 (47.51)	3,288 (50.11)	3,222 (47.29)	1,390 (42.37)	1,471 (44.64)
Premenopausal	3,332 (8.69)	367 (8.43)	355 (8.17)	379 (5.79)	282 (8.96)	435 (6.63)	665 (9.76)	434 (13.23)	415 (12.59)
Weighted rate, (95% CI)									
Overall, n	38,341	4,353	4,343	6,546	3,147	6,562	6,814	3,281	3,295
Age group, years, weighted % (95% CI)									
50-59	44.68 (43.89 to 45.48)	42.32 (40.51 to 44.13)	47.15 (44.89 to 49.41)	47.05 (45.11 to 48.99)	46.42 (44.01 to 48.83)	45.73 (43.85 to 47.60)	43.88 (41.86 to 45.91)	42.71 (39.64 to 45.77)	41.03 (38.05 to 44.01)

Table 1. Continued

	Total	Pre-pandemic						During the pandemic	
		2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021
60-69	30.36 (29.74 to 30.97)	34.66 (32.98 to 36.33)	29.83 (28.11 to 31.56)	28.34 (27.03 to 29.64)	27.97 (26.07 to 29.87)	29.11 (27.70 to 30.53)	30.32 (28.71 to 31.93)	31.60 (29.41 to 33.79)	33.37 (31.30 to 35.43)
70-79	18.58 (18.08 to 19.08)	18.51 (17.18 to 19.83)	18.28 (16.80 to 19.76)	19.27 (17.94 to 20.60)	19.51 (17.84 to 21.18)	18.52 (17.41 to 19.64)	18.26 (17.04 to 19.48)	18.48 (16.64 to 20.32)	17.96 (16.15 to 19.78)
≥80	6.39 (6.07 to 6.70)	4.51 (3.82 to 5.20)	4.74 (3.96 to 5.52)	5.35 (4.65 to 6.04)	6.10 (5.06 to 7.14)	6.64 (5.97 to 7.31)	7.54 (6.68 to 8.39)	7.21 (5.93 to 8.49)	7.64 (6.40 to 8.89)
Sex, weighted % (95% CI)									
Male	46.74 (46.28 to 47.20)	43.32 (42.32 to 44.32)	46.62 (45.35 to 47.89)	46.42 (45.35 to 47.50)	46.61 (44.94 to 48.28)	47.01 (45.89 to 48.14)	47.30 (46.16 to 48.43)	47.60 (46.10 to 49.11)	47.73 (46.18 to 49.28)
Female	53.26 (52.80 to 53.72)	56.68 (55.68 to 57.68)	53.38 (52.11 to 54.65)	53.58 (52.50 to 54.65)	53.39 (51.72 to 55.06)	52.99 (51.86 to 54.11)	52.70 (51.57 to 53.84)	52.40 (50.89 to 53.90)	52.27 (50.72 to 53.82)
Region of residence, weighted % (95% CI)									
Urban	76.92 (75.17 to 78.67)	67.39 (64.92 to 69.86)	73.83 (68.61 to 79.05)	70.67 (65.25 to 76.09)	78.33 (72.19 to 84.48)	79.85 (75.73 to 83.96)	80.74 (76.41 to 85.07)	81.35 (75.02 to 87.67)	78.07 (71.76 to 84.39)
Rural	23.08 (21.33 to 24.83)	32.61 (30.14 to 35.08)	26.17 (20.95 to 31.39)	29.33 (23.91 to 34.75)	21.67 (15.52 to 27.81)	20.15 (16.04 to 24.27)	19.26 (14.93 to 23.59)	18.65 (12.33 to 24.98)	21.93 (15.61 to 28.24)
Household income, weighted % (95% CI)									
Lowest quartile	27.06 (26.23 to 27.89)	38.12 (35.54 to 40.69)	29.78 (27.19 to 32.38)	30.47 (28.35 to 32.60)	26.47 (23.90 to 29.03)	26.01 (24.01 to 28.01)	24.98 (22.99 to 26.97)	22.32 (19.21 to 25.44)	21.93 (19.18 to 24.68)
Second quartile	25.09 (24.40 to 25.78)	23.81 (21.91 to 25.72)	28.38 (26.09 to 30.67)	24.94 (23.31 to 26.58)	25.49 (23.14 to 27.83)	24.17 (22.60 to 25.75)	25.55 (23.88 to 27.22)	23.93 (21.30 to 26.57)	24.76 (22.62 to 26.90)
Third quartile	22.74 (22.07 to 23.41)	19.62 (17.88 to 21.36)	19.82 (18.00 to 21.63)	21.38 (19.83 to 22.93)	23.44 (21.00 to 25.87)	23.29 (21.72 to 24.85)	23.29 (21.60 to 24.99)	25.49 (23.08 to 27.90)	24.58 (22.46 to 26.70)
Highest quartile	25.11 (24.18 to 26.04)	18.45 (16.59 to 20.32)	22.02 (19.26 to 24.78)	23.21 (21.15 to 25.26)	24.61 (21.76 to 27.46)	26.53 (24.27 to 28.78)	26.18 (23.99 to 28.37)	28.25 (24.19 to 32.31)	28.73 (24.81 to 32.64)
Education level, weighted % (95% CI)									
Elementary school or lower	37.31 (36.48 to 38.15)	55.04 (52.52 to 57.55)	49.08 (46.39 to 51.77)	46.46 (44.19 to 48.73)	40.13 (37.33 to 42.94)	33.62 (31.78 to 35.46)	29.85 (27.88 to 31.83)	28.31 (25.37 to 31.24)	26.73 (23.70 to 29.75)

Table 1. Continued

	Total	Pre-pandemic						During the pandemic	
		2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021
Middle school	16.49 (15.99 to 16.99)	17.37 (15.94 to 18.80)	19.01 (17.52 to 20.50)	19.38 (18.09 to 20.67)	15.97 (14.41 to 17.52)	17.07 (15.73 to 18.41)	15.18 (14.10 to 16.26)	14.05 (12.36 to 15.74)	13.69 (12.12 to 15.25)
High school	27.09 (26.44 to 27.73)	18.83 (17.15 to 20.51)	20.61 (18.77 to 22.46)	21.93 (20.46 to 23.40)	26.00 (24.07 to 27.93)	27.27 (25.74 to 28.80)	32.03 (30.43 to 33.62)	31.68 (29.33 to 34.02)	33.55 (31.17 to 35.93)
College or higher	19.11 (18.31 to 19.91)	8.76 (7.57 to 9.96)	11.29 (9.26 to 13.33)	12.23 (10.50 to 13.96)	17.90 (15.38 to 20.42)	22.04 (20.03 to 24.05)	22.94 (20.88 to 25.00)	25.97 (22.50 to 29.43)	26.04 (22.99 to 29.08)
BMI, kg/m^2, weighted % (95% CI)*									
Under-weight	2.62 (2.44 to 2.81)	3.57 (2.98 to 4.15)	2.84 (2.28 to 3.40)	2.72 (2.24 to 3.19)	2.27 (1.70 to 2.83)	2.55 (2.14 to 2.97)	2.21 (1.78 to 2.64)	2.71 (1.96 to 3.47)	2.68 (2.08 to 3.28)
Normal and over-weight	60.05 (59.45 to 60.65)	59.65 (58.25 to 61.05)	59.53 (57.88 to 61.17)	60.95 (59.57 to 62.34)	59.01 (56.87 to 61.14)	59.93 (58.47 to 61.39)	61.44 (59.96 to 62.91)	57.90 (55.88 to 59.92)	60.05 (57.91 to 62.19)
Obese	37.33 (36.73 to 37.93)	36.79 (35.26 to 38.31)	37.64 (35.87 to 39.40)	36.33 (34.93 to 37.73)	38.73 (36.59 to 40.86)	37.52 (36.07 to 38.96)	36.35 (34.91 to 37.79)	39.39 (37.45 to 41.33)	37.27 (35.12 to 39.43)
Presence of osteoporosis, weighted % (95% CI)									
Present	11.52 (11.15 to 11.90)	9.56 (8.62 to 10.49)	10.45 (9.43 to 11.47)	11.87 (10.91 to 12.83)	12.78 (11.45 to 14.11)	12.49 (11.56 to 13.42)	11.73 (10.78 to 12.67)	11.15 (10.08 to 12.23)	10.74 (9.46 to 12.02)
Absent	88.48 (88.10 to 88.85)	90.44 (89.51 to 91.38)	89.55 (88.53 to 90.57)	88.13 (87.17 to 89.09)	87.22 (85.89 to 88.55)	87.51 (86.58 to 88.44)	88.27 (87.33 to 89.22)	88.85 (87.77 to 89.92)	89.26 (87.98 to 90.54)
Menopausal status, weighted % (95% CI)									
Male	46.74 (46.28 to 47.20)	43.32 (42.32 to 44.32)	46.62 (45.35 to 47.89)	46.42 (45.35 to 47.50)	46.61 (44.94 to 48.28)	47.01 (45.89 to 48.14)	47.30 (46.16 to 48.43)	47.60 (46.10 to 49.11)	47.73 (46.18 to 49.28)
Postme-nopausal	44.08 (43.55 to 44.60)	47.99 (46.75 to 49.23)	44.55 (42.99 to 46.10)	47.41 (46.19 to 48.62)	44.08 (42.22 to 45.93)	45.87 (44.66 to 47.08)	42.66 (41.33 to 43.98)	39.13 (37.20 to 41.07)	40.08 (38.43 to 41.74)
Preme-nopausal	9.18 (8.82 to 9.55)	8.69 (7.85 to 9.53)	8.84 (7.81 to 9.86)	6.17 (5.45 to 6.89)	9.31 (8.00 to 10.62)	7.12 (6.32 to 7.91)	10.05 (9.13 to 10.96)	13.26 (11.74 to 14.79)	12.19 (10.92 to 13.46)

BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.
The KNHANES data from 2012, 2013, and 2014 were excluded.
*According to the Asian-Pacific guidelines, the BMI is divided into three groups: underweight (> 18.5 kg/m^2), normal and overweight (18.5-24.9 kg/m^2), and obese (≥ 25.0 kg/m^2).

Table 2. National trends of the prevalence of and β-coefficients of odds ratios before and during the COVID-19 pandemic in South Korean older population, weighted % (95% CI), in the data obtained from the KNHANES

	Pre-pandemic						During the pandemic		Trends in the pre-pandemic era, β (95 CI)	Trends in the pande-mic era, β (95 CI)	β diff between 2001-2019 and 2018-2021 (95 CI)
	2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021			
Prevalence of osteoporosis, weighted % (95% CI)											
Overall	9.56 (8.62 to 10.49)	10.45 (9.43 to 11.47)	11.87 (10.91 to 12.83)	12.78 (11.45 to 14.11)	12.49 (11.56 to 13.42)	11.73 (10.78 to 12.67)	11.15 (10.08 to 12.23)	10.74 (9.46 to 12.02)	0.328 (0.061 to 0.596)	-0.499 (-1.287 to 0.290)	-0.83 (-1.66 to 0.01)
Age group, years											
50-59	5.88 (4.72 to 7.04)	5.03 (3.99 to 6.08)	6.26 (5.17 to 7.35)	4.52 (3.29 to 5.76)	4.91 (3.98 to 5.84)	4.17 (3.38 to 4.96)	4.25 (2.83 to 5.66)	3.16 (2.06 to 4.27)	-0.323 (-0.585 to -0.061)	-0.455 (-1.124 to 0.213)	-0.13 (-0.85 to 0.59)
60-69	11.69 (9.97 to 13.40)	14.82 (12.75 to 16.90)	14.25 (12.73 to 15.77)	15.81 (13.49 to 18.13)	14.84 (13.19 to 16.49)	11.79 (10.16 to 13.43)	13.96 (11.92 to 16.00)	11.46 (9.19 to 13.73)	-0.401 (-0.884 to 0.082)	-0.018 (-1.398 to 1.363)	0.38 (-1.08 to 1.85)
70-79	14.75 (12.09 to 17.40)	17.74 (14.95 to 20.54)	20.69 (18.17 to 23.22)	26.33 (22.62 to 30.05)	23.90 (21.27 to 26.53)	24.61 (22.23 to 26.99)	19.18 (16.11 to 22.25)	20.51 (17.14 to 23.88)	1.713 (1.006 to 2.419)	-2.315 (-4.356 to -0.273)	-4.03 (-6.19 to -1.87)
≥80	6.38 (2.40 to 10.37)	8.70 (5.12 to 12.27)	16.90 (12.40 to 21.40)	18.37 (12.15 to 24.59)	22.52 (18.55 to 26.48)	24.23 (20.27 to 28.20)	19.21 (13.81 to 24.62)	25.29 (20.37 to 30.21)	3.501 (2.339 to 4.663)	0.135 (-3.045 to 3.315)	-3.37 (-6.75 to 0.02)
Sex											
Male	0.86 (0.38 to 1.33)	1.90 (1.18 to 2.62)	1.79 (1.23 to 2.36)	1.83 (1.12 to 2.53)	1.70 (1.17 to 2.23)	1.44 (1.03 to 1.84)	2.27 (1.38 to 3.16)	1.13 (0.45 to 1.80)	-0.057 (-0.209 to 0.095)	-0.080 (-0.469 to 0.310)	-0.02 (-0.44 to 0.40)
Female	16.21 (14.59 to 17.82)	17.92 (16.15 to 19.68)	20.61 (18.95 to 22.27)	22.35 (20.05 to 24.64)	22.07 (20.49 to 23.64)	20.96 (19.31 to 22.62)	19.23 (17.26 to 21.20)	19.52 (17.25 to 21.78)	0.781 (0.321 to 1.242)	-0.800 (-2.191 to 0.591)	-1.58 (-3.05 to -0.12)
Region of residence											
Urban	8.80 (7.78 to 9.82)	10.14 (8.96 to 11.33)	10.94 (9.86 to 12.02)	12.26 (10.73 to 13.78)	11.63 (10.60 to 12.65)	10.82 (9.82 to 11.83)	11.04 (9.78 to 12.30)	10.36 (8.92 to 11.80)	0.225 (-0.077 to 0.526)	-0.195 (-1.061 to 0.671)	-0.42 (-1.34 to 0.50)

Table 2. Continued

	Pre-pandemic						During the pandemic		Trends in the pre-pandemic era, β (95 CI)	Trends in the pandemic era, β (95 CI)	β diff between 2001-2019 and 2018-2021 (95 CI)
	2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021			
Rural	11.12 (9.21 to 13.02)	11.32 (9.32 to 13.32)	14.13 (12.11 to 16.15)	14.68 (12.26 to 17.09)	14.68 (12.26 to 17.09)	15.90 (13.69 to 18.11)	15.51 (13.27 to 17.74)	11.65 (9.87 to 13.43)	0.991 (0.418 to 1.563)	-1.825 (-3.554 to -0.096)	-2.82 (-4.64 to -0.99)
Household income											
Lowest and second quartile	10.21 (9.02 to 11.40)	12.66 (11.26 to 14.06)	14.54 (13.14 to 15.94)	14.90 (13.12 to 16.68)	17.51 (16.10 to 18.93)	16.73 (15.30 to 18.16)	15.63 (13.78 to 17.48)	15.62 (13.52 to 17.71)	1.176 (0.792 to 1.560)	-0.601 (-1.852 to 0.650)	-1.78 (-3.09 to -0.47)
Third and highest quartile	8.49 (7.10 to 9.88)	7.38 (6.07 to 8.69)	8.56 (7.33 to 9.79)	10.49 (8.77 to 12.21)	7.43 (6.42 to 8.44)	6.62 (5.67 to 7.56)	7.30 (6.03 to 8.57)	6.47 (5.14 to 7.80)	-0.356 (-0.670 to -0.041)	-0.022 (-0.826 to 0.782)	0.33 (-0.53 to 1.20)
Education level											
High school or lower education	10.26 (9.27 to 11.26)	11.44 (10.31 to 12.57)	12.96 (11.89 to 14.02)	14.23 (12.70 to 15.77)	14.70 (13.61 to 15.79)	13.83 (12.69 to 14.96)	13.38 (12.02 to 14.75)	12.68 (11.08 to 14.29)	0.673 (0.365 to 0.981)	-0.562 (-1.533 to 0.408)	-1.24 (-2.25 to -0.22)
College or higher education	2.19 (0.84 to 3.54)	2.66 (1.14 to 4.18)	4.11 (2.80 to 5.42)	6.11 (3.93 to 8.29)	4.67 (3.28 to 6.05)	4.67 (3.52 to 5.82)	4.79 (3.30 to 6.29)	5.23 (3.37 to 7.08)	0.351 (-0.036 to 0.737)	0.268 (-0.801 to 1.337)	-0.08 (-1.22 to 1.05)
BMI, kg/m^{2*}											
Underweight	11.14 (6.01 to 16.27)	10.15 (3.95 to 16.35)	14.05 (8.03 to 20.07)	17.00 (6.99 to 27.01)	13.67 (8.14 to 19.20)	22.94 (15.18 to 30.69)	15.59 (7.39 to 23.80)	19.93 (10.58 to 29.29)	2.300 (0.459 to 4.142)	-1.826 (-7.847 to 4.195)	-4.13 (-10.42 to 2.17)
Normal and overweight	9.23 (8.07 to 10.39)	10.79 (9.48 to 12.09)	12.07 (10.97 to 13.18)	13.78 (12.06 to 15.49)	13.02 (11.85 to 14.19)	12.38 (11.28 to 13.48)	12.06 (10.55 to 13.57)	10.82 (9.23 to 12.40)	0.441 (0.115 to 0.768)	-0.747 (-1.695 to 0.201)	-1.19 (-2.19 to -0.19)
Obese	9.93 (8.49 to 11.38)	9.94 (8.33 to 11.56)	11.38 (9.77 to 12.98)	11.02 (9.00 to 13.03)	11.56 (10.15 to 12.97)	9.94 (8.65 to 11.22)	9.52 (7.92 to 11.12)	9.95 (7.99 to 11.92)	0.011 (-0.384 to 0.407)	-0.024 (-1.182 to 1.134)	-0.04 (-1.26 to 1.19)

Table 2. Continued

	Pre-pandemic						During the pandemic		Trends in the pre-pandemic era, β (95 CI)	Trends in the pande-mic era, β (95 CI)	β diff between 2001-2019 and 2018-2021 (95 CI)
	2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021			
Menopausal status											
Male	0.86 (0.38 to 1.33)	1.90 (1.18 to 2.62)	1.79 (1.23 to 2.36)	1.83 (1.12 to 2.53)	1.70 (1.17 to 2.23)	1.44 (1.03 to 1.84)	2.27 (1.38 to 3.16)	1.13 (0.45 to 1.80)	-0.057 (-0.209 to 0.095)	-0.080 (-0.469 to 0.310)	-0.02 (-0.44 to 0.40)
Post-menopausal	17.55 (15.74 to 19.36)	19.18 (17.22 to 21.14)	21.95 (20.19 to 23.70)	26.01 (23.35 to 28.67)	24.79 (23.01 to 26.56)	24.25 (22.36 to 26.13)	23.54 (21.19 to 25.88)	23.24 (20.33 to 26.15)	1.291 (0.777 to 1.805)	-0.520 (-2.227 to 1.187)	-1.81 (-3.59 to -0.03)
Premenopausal	8.80 (5.68 to 11.92)	11.55 (7.48 to 15.63)	10.30 (6.86 to 13.75)	5.01 (2.52 to 7.50)	4.53 (2.20 to 6.87)	7.01 (4.93 to 9.09)	6.51 (3.95 to 9.07)	7.27 (4.70 to 9.84)	-1.119 (-1.942 to -0.295)	0.094 (-1.539 to 1.727)	1.21 (-0.62 to 3.04)
Prevalence of osteoporosis in menopausal women, weighted % (95% CI)											
Overall	14.86 (13.29 to 16.43)	16.01 (14.36 to 17.65)	19.42 (17.83 to 21.01)	21.47 (19.20 to 23.74)	21.46 (19.90 to 23.01)	19.63 (18.03 to 21.23)	17.58 (15.69 to 19.47)	17.82 (15.66 to 19.98)	0.912 (0.472 to 1.352)	-0.989 (-2.325 to 0.346)	-1.90 (-3.31 to -0.49)
Age group, years											
50-59	8.99 (7.09 to 10.88)	8.07 (6.19 to 9.96)	9.78 (7.93 to 11.62)	7.75 (5.44 to 10.06)	8.58 (6.87 to 10.29)	6.50 (5.07 to 7.93)	5.83 (3.69 to 7.97)	4.59 (2.76 to 6.43)	-0.451 (-0.917 to 0.014)	-0.929 (-2.086 to 0.229)	-0.48 (-1.72 to 0.77)
60-69	18.98 (16.05 to 21.91)	23.01 (19.60 to 26.41)	25.00 (22.18 to 27.81)	28.49 (24.34 to 32.65)	26.47 (23.58 to 29.36)	20.61 (17.72 to 23.50)	24.12 (20.70 to 27.54)	19.40 (15.84 to 22.96)	-0.155 (-0.982 to 0.672)	-0.349 (-2.628 to 1.929)	-0.19 (-2.62 to 2.23)
70-79	21.39 (17.57 to 25.21)	24.72 (20.51 to 28.92)	30.79 (27.00 to 34.57)	39.26 (33.42 to 45.09)	38.09 (34.23 to 41.96)	39.08 (35.33 to 42.83)	26.78 (21.80 to 31.77)	34.09 (28.85 to 39.32)	3.545 (2.477 to 4.614)	-3.327 (-6.525 to -0.129)	-6.87 (-10.24 to -3.50)
≥80	8.44 (2.66 to 14.21)	10.75 (6.25 to 15.25)	22.95 (16.46 to 29.43)	24.59 (15.34 to 33.84)	30.04 (24.59 to 35.48)	33.84 (28.30 to 39.37)	28.73 (21.02 to 36.45)	34.14 (27.22 to 41.06)	5.109 (3.526 to 6.691)	-0.198 (-4.637 to 4.241)	-5.31 (-10.02 to -0.59)
Sex											
Male	.	.	.	.	.	.	.	.	.	.	.

Table 2. Continued

	Pre-pandemic						During the pandemic		Trends in the pre-pandemic era, β (95 CI)	Trends in the pandemic era, β (95 CI)	β diff between 2001-2019 and 2018-2021 (95 CI)
	2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021			
Female	14.86 (13.29 to 16.43)	16.01 (14.36 to 17.65)	19.42 (17.83 to 21.01)	21.47 (19.20 to 23.74)	21.46 (19.90 to 23.01)	19.63 (18.03 to 21.23)	17.58 (15.69 to 19.47)	17.82 (15.66 to 19.98)	0.912 (0.472 to 1.352)	-0.989 (-2.325 to 0.346)	-1.90 (-3.31 to -0.49)
Region of residence											
Urban	13.80 (12.14 to 15.46)	15.62 (13.68 to 17.56)	17.83 (16.01 to 19.65)	20.34 (17.76 to 22.92)	19.98 (18.26 to 21.70)	17.98 (16.32 to 19.65)	17.26 (15.05 to 19.48)	17.10 (14.66 to 19.55)	0.681 (0.185 to 1.176)	-0.463 (-1.916 to 0.990)	-1.14 (-2.68 to 0.39)
Rural	16.92 (13.65 to 20.19)	17.11 (13.95 to 20.26)	23.16 (19.89 to 26.42)	25.69 (21.17 to 30.20)	27.37 (23.77 to 30.97)	26.57 (22.56 to 30.59)	19.00 (15.94 to 22.06)	20.47 (16.03 to 24.91)	2.248 (1.285 to 3.211)	-3.314 (-6.323 to -0.305)	-5.56 (-8.72 to -2.40)
Household income											
Lowest and second quartile	15.42 (13.55 to 17.29)	18.61 (16.46 to 20.75)	22.40 (20.22 to 24.57)	24.83 (21.83 to 27.84)	27.41 (25.22 to 29.59)	26.09 (23.89 to 28.28)	23.61 (20.47 to 26.75)	23.91 (20.71 to 27.11)	2.057 (1.473 to 2.641)	-1.202 (-3.125 to 0.721)	-3.26 (-5.27 to -1.25)
Third and highest quartile	13.80 (11.31 to 16.28)	11.79 (9.37 to 14.21)	15.05 (12.76 to 17.33)	17.47 (14.42 to 20.52)	14.26 (12.36 to 16.17)	11.73 (9.94 to 13.51)	11.74 (9.45 to 14.02)	11.54 (9.04 to 14.03)	-0.271 (-0.854 to 0.312)	-0.089 (-1.605 to 1.428)	0.18 (-1.44 to 1.81)
Education level											
High school or lower education	15.03 (13.45 to 16.61)	16.43 (14.72 to 18.14)	20.04 (18.40 to 21.68)	22.68 (20.20 to 25.17)	23.03 (21.35 to 24.72)	21.55 (19.74 to 23.36)	19.98 (17.72 to 22.23)	20.21 (17.64 to 22.77)	1.329 (0.854 to 1.804)	-0.746 (-2.295 to 0.803)	-2.08 (-3.70 to -0.45)
College or higher education	10.00 (3.90 to 16.09)	8.44 (3.13 to 13.75)	9.50 (5.32 to 13.68)	12.16 (7.40 to 16.92)	11.51 (7.79 to 15.23)	9.53 (6.92 to 12.15)	7.54 (4.77 to 10.31)	8.65 (5.32 to 11.99)	0.063 (-1.041 to 1.167)	-0.511 (-2.609 to 1.586)	-0.57 (-2.94 to 1.80)
BMI, kg/m^{2*}											

Table 2. Continued

	Pre-pandemic						During the pandemic		Trends in the pre-pandemic era, β (95 CI)	Trends in the pande-mic era, β (95 CI)	β diff between 2001-2019 and 2018-2021 (95 CI)
	2001-2005	2007-2008	2009-2010	2011-2015	2016-2017	2018-2019	2020	2021			
Under-weight	20.59 (10.82 to 30.37)	19.88 (7.54 to 32.22)	21.38 (10.52 to 32.24)	28.99 (11.02 to 46.96)	22.60 (13.21 to 31.98)	29.13 (18.92 to 39.33)	27.33 (11.83 to 42.84)	23.95 (12.82 to 35.07)	1.827 (-1.114 to 4.767)	-2.547 (-10.115 to 5.022)	-4.37 (-12.49 to 3.75)
Normal and over-weight	15.46 (13.35 to 17.56)	16.28 (14.26 to 18.30)	20.01 (18.02 to 21.99)	22.92 (20.19 to 25.65)	21.78 (19.78 to 23.78)	20.07 (18.20 to 21.94)	18.17 (15.53 to 20.81)	17.94 (15.24 to 20.63)	0.869 (0.327 to 1.411)	-1.133 (-2.753 to 0.487)	-2.00 (-3.71 to -0.29)
Obese	13.60 (11.56 to 15.64)	15.38 (12.69 to 18.07)	18.37 (15.77 to 20.98)	18.91 (15.32 to 22.50)	20.85 (18.42 to 23.29)	18.10 (15.80 to 20.40)	15.85 (12.98 to 18.73)	17.11 (13.61 to 20.61)	0.861 (0.190 to 1.532)	-0.619 (-2.678 to 1.441)	-1.48 (-3.65 to 0.69)

BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.
The KNHANES data from 2012, 2013, and 2014 were excluded.
* According to the Asian-Pacific guidelines, the BMI is divided into three groups: underweight (> 18.5 kg/m^2), normal and overweight (18.5-24.9 kg/m^2), and obese (≥ 25.0 kg/m^2).
Bolded data indicate significant differences in the regression model (P <0.05).

(95% CI, 9.46 to 12.02) in 2021. The pre-pandemic upward trend, indicated by a β coefficient of 0.328 (95% CI, 0.061 to 0.596), did not significantly continue into the preceding pandemic years.

In more detailed subgroup analyses, the trend before the pandemic showed an increase, particularly in rural areas, with a β coefficient of 0.991 (95% CI, 0.418 to 1.563). Yet, during the pandemic, this trend shifted to a β coefficient of -1.825 (95% CI, -3.554 to -0.096), and the β difference of -2.82 (95% CI, -4.64 to -0.99) highlighted a significant reversal. Among the 70-79 age group, the β coefficient changed from 1.713 (95% CI, 1.006 to 2.419) pre-pandemic to -2.315 (95% CI, -4.356 to -0.273) during the pandemic, with a β difference of -4.03 (95% CI, -6.19 to -1.87), indicating a decline in prevalence. Other subgroups did not show significant changes in β coefficients during the pandemic.

The overall prevalence of osteoporosis among menopausal women evolved from 14.86% (95% CI, 13.29 to 16.43) in 2001 to 19.63% (95% CI, 18.03 to 21.23) in 2018-2019, then to 17.82% (95% CI, 15.66 to 19.98) in 2021. Before the pandemic, there was a consistently increasing trend in prevalence; however, during the pandemic, the trend decelerated, as indicated by the β difference of -1.90 (95% CI, -3.31 to -0.49).

Similarly, the subgroup trends in menopausal women mirrored the overall pattern. Before the pandemic, an increase in prevalence was observed across age and residence categories. However, during the pandemic, this increasing trend appeared to decelerate. For example, among those

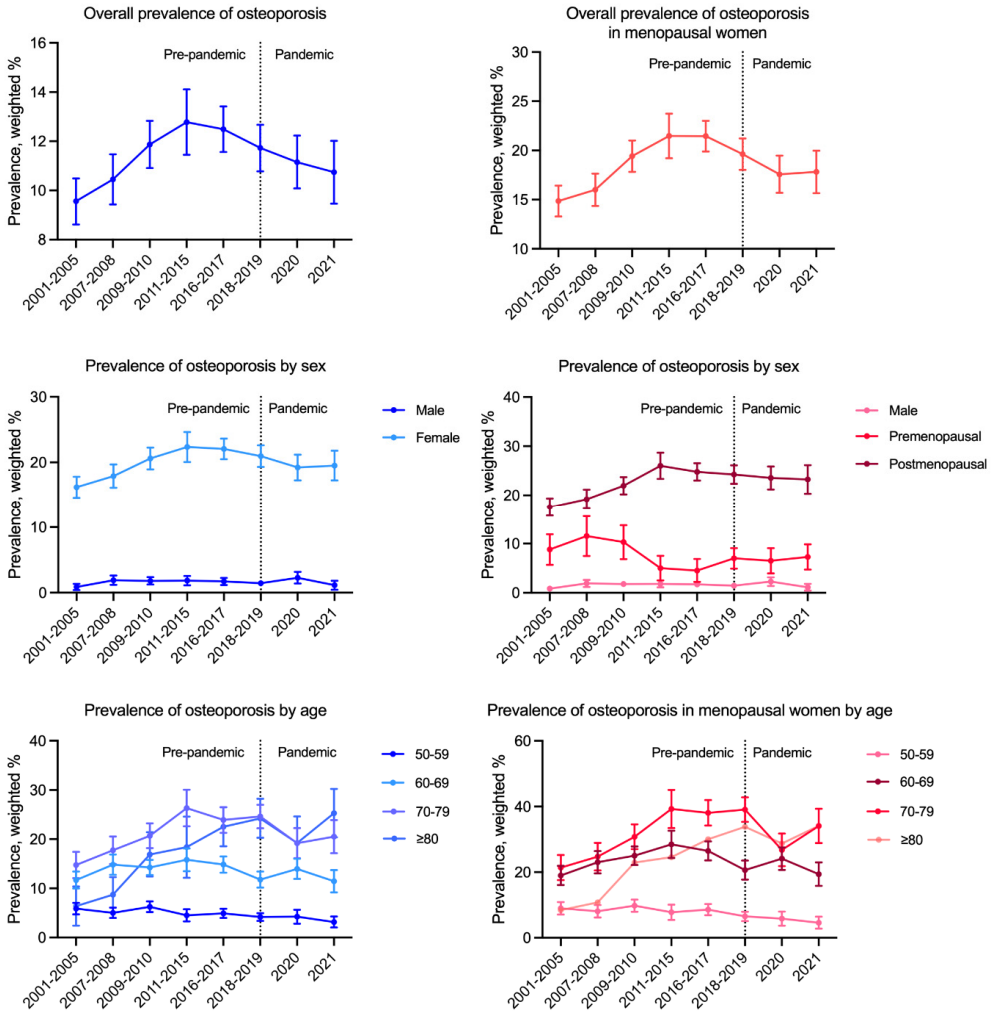

Fig. 2. 20-year trends of osteoporosis prevalence among South Korean older population. BMI, body mass index.

aged 70-79 years, the β coefficient significantly decreased from 3.545 (95% CI, 2.477 to 4.614) before the pandemic to -3.327 (95% CI, -6.525 to -0.129) during the pandemic with the β difference of -6.87 (95% CI, -10.24 to -3.50). Similar to the subgroup trend among the general population, the subgroup trend among the menopausal women also experienced a rise before the pandemic, followed by a deceleration during the pandemic.

Table 3 presents the risk factor analysis based on weighted odds ratios (wOR), specifically highlighting wORs with the COVID-19 pandemic. Specific demographic factors distinctly influence the overall vulnerability to osteoporosis. Age stands out as a primary determinant in osteoporosis vulnerability, with higher age groups showing an increased tendency in odds ratios during the pandemic. Specifically, the ratio of wOR in the age group of 60-69 years is 1.14 (95% CI, 0.92 to 1.42); the venerability is more pronounced in the age group of 70-79 years with the ratio of wOR of 1.31 (95% CI, 1.05 to 1.63) and 80 years or above with the ratio of wOR of 1.67

Table 3. Difference between before and during the COVID-19 pandemic by the ratio of wORs on osteoporosis, weighted % (95% CI), in the data obtained from the KNHANES

	Overall		Pre-pandemic (2001-2019)		During-pandemic (2019-2021)		Ratio of wORs (95% CI)	
	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value
Osteoporosis								
Age group, years								
50-59	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
60-69	3.09 (2.79 to 3.42)	<0.001	2.98 (2.68 to 3.32)	<0.001	3.40 (2.81 to 4.12)	<0.001	1.14 (0.92 to 1.42)	0.239
70-79	5.49 (4.94 to 6.10)	<0.001	5.33 (4.77 to 5.96)	<0.001	6.97 (5.78 to 8.41)	<0.001	1.31 (1.05 to 1.63)	0.016
≥ 80	4.95 (4.34 to 5.65)	<0.001	4.46 (3.84 to 5.17)	<0.001	7.44 (6.02 to 9.20)	<0.001	1.67 (1.29 to 2.16)	<0.001
Sex								
Male	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Female	15.39 (13.37 to 17.71)	<0.001	15.72 (13.52 to 18.27)	<0.001	15.99 (12.60 to 20.30)	<0.001	1.02 (0.77 to 1.35)	0.906
Region of residence								
Urban	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Rural	1.29 (1.19 to 1.40)	<0.001	1.33 (1.21 to 1.45)	<0.001	1.31 (1.14 to 1.51)	<0.001	0.98 (0.83 to 1.16)	0.859
Household income								
Lowest and second quartile	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Third and highest quartile	2.15 (2.00 to 2.32)	<0.001	2.07 (1.91 to 2.25)	<0.001	2.67 (2.35 to 3.03)	<0.001	1.29 (1.11 to 1.50)	0.001
Education level								
High school or lower education	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
College or higher education	3.33 (3.06 to 3.62)	<0.001	3.39 (3.08 to 3.72)	<0.001	3.87 (3.40 to 4.39)	<0.001	1.14 (0.97 to 1.34)	0.102
BMI, kg/m^{2*}								
Underweight	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	

Table 3. Continued

	Overall		Pre-pandemic (2001-2019)		During-pandemic (2019-2021)		Ratio of wORs (95% CI)	
	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	*p*-value	wORs (95% CI)
Normal and overweight	1.16 (1.08 to 1.24)	<0.001	1.15 (1.07 to 1.24)	<0.001	1.24 (1.10 to 1.39)	<0.001	1.08 (0.94 to 1.24)	0.286
Obese	1.59 (1.30 to 1.95)	<0.001	1.50 (1.20 to 1.87)	<0.001	2.31 (1.68 to 3.17)	<0.001	1.54 (1.05 to 2.27)	0.029
Menopausal status								
Postmenopausal	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Premenopausal	3.76 (3.24 to 4.36)	<0.001	3.65 (3.08 to 4.33)	<0.001	4.19 (3.36 to 5.23)	<0.001	1.15 (0.87 to 1.52)	0.333
Osteoporosis with menopause								
Age group, years								
50-59	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
60-69	3.65 (3.26 to 4.09)	<0.001	3.46 (3.07 to 3.91)	<0.001	4.30 (3.47 to 5.33)	<0.001	1.24 (0.97 to 1.59)	0.084
70-79	5.99 (5.31 to 6.75)	<0.001	5.69 (5.01 to 6.47)	<0.001	8.57 (6.88 to 10.68)	<0.001	1.51 (1.17 to 1.94)	0.002
≥ 80	4.51 (3.87 to 5.25)	<0.001	3.89 (3.27 to 4.63)	<0.001	7.84 (6.17 to 9.96)	<0.001	2.02 (1.50 to 2.71)	<0.001
Region of residence								
Urban	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Rural	1.34 (1.22 to 1.47)	<0.001	1.37 (1.23 to 1.52)	<0.001	1.41 (1.19 to 1.66)	<0.001	1.03 (0.84 to 1.25)	0.775
Household income								
Lowest and second quartile	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Third and highest quartile	1.98 (1.82 to 2.16)	<0.001	1.89 (1.73 to 2.07)	<0.001	2.52 (2.18 to 2.91)	<0.001	1.33 (1.12 to 1.58)	0.001
Education level								
High school or lower education	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	

Table 3. Continued

	Overall		Pre-pandemic (2001-2019)		During-pandemic (2019-2021)		Ratio of wORs (95% CI)	
	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value	wORs (95% CI)	*p*-value
College or higher education	2.57 (2.34 to 2.82)	<0.001	2.47 (2.23 to 2.75)	<0.001	3.38 (2.93 to 3.89)	<0.001	1.37 (1.15 to 1.63)	<0.001
BMI, kg/m^{2*}								
Underweight	1.00 (reference)		1.00 (reference)		1.00 (reference)		1.00 (reference)	
Normal and overweight	1.13 (1.04 to 1.22)	0.005	1.13 (1.03 to 1.23)	0.007	1.13 (0.99 to 1.29)	0.080	1.00 (0.85 to 1.17)	1.000
Obese	1.50 (1.19 to 1.90)	0.001	1.45 (1.11 to 1.88)	0.006	1.79 (1.24 to 2.57)	0.002	1.23 (0.79 to 1.94)	0.359

BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.
The KNHANES data from 2012, 2013, and 2014 were excluded.
* According to the Asian-Pacific guidelines, the BMI is divided into three groups: underweight (> 18.5 kg/m^2), normal and overweight (18.5-24.9 kg/m^2), and obese (≥ 25.0 kg/m^2).
Bolded data indicate significant differences in the regression model (P <0.05)

(95% CI, 1.29 to 2.16). For household income levels, the lowest and second quartiles experienced an increase, with a ratio of wOR of 1.29 (95% CI, 1.11 to 1.50). Additionally, obese individuals saw an increase in the ratio of wOR of 1.54 (95% CI, 1.05 to 2.27).

In menopausal women, age is a strong risk factor for osteoporosis, with ratio of wOR of 1.24 (95% CI, 0.97 to 1.59) in the 60-69 years to 1.51 (95% CI, 1.17 to 1.94) for those 70-79 years, and 2.02 (95% CI, 1.50 to 2.71) for ages 80 years and above. College education is associated with the ratio of wOR of 1.37 (95% CI, 1.15 to 1.63), and higher income quartiles have the ratio of wOR of 1.33 (95% CI, 1.12 to 1.58), indicating that both education and income levels influence osteoporosis risk.

7. Discussion

This study provides a comprehensive examination of osteoporosis trends and related risk factors among both the general Korean population and postmenopausal women aged over 50 from 2001 to 2021. The analysis leverages nationwide data collected from a considerable sample size of 38,341 Korean older population. Specifically, we conducted a comparative investigation into the circumstances surrounding the COVID-19 pandemic, comparing them to the pre-pandemic period.

The significant findings of our research are as follows. Firstly, the study reveals a long-term trend in osteoporosis prevalence from 2001 to 2021. There was an upward trend from 2001 to 2015, followed by a gradual decline until 2021. Crucially, there was a slight oscillation related to

the COVID-19 pandemic in these trends.[17] Secondly, the research indicates that the risk of osteoporosis is considerably higher among females than among males, and higher among postmenopausal women in comparison to premenopausal women. In addition, three significant sociodemographic variables were closely linked to osteoporosis prevalence: individuals with rural residency, lower economic status, and lesser educational attainment were found to be at a distinctly higher risk of osteoporosis compared to their counterparts.[18] Thirdly, during the COVID-19 pandemic, older age groups, individuals in lower income quartiles, and those underweight were particularly vulnerable to osteoporosis. In contrast, regardless of the pandemic's influence, rural residents, those with lower education, and postmenopausal women consistently showed a higher susceptibility. Among these, individuals aged 70 and above, along with the underweight category, emerged as the most critical vulnerable groups.

Between 2000 and 2015, South Korea experienced a notable increase in the prevalence of osteoporosis among individuals aged 50 years and older. This pattern, however, was followed by a declining trend that emerged between 2015 and 2021. Such fluctuations in prevalence, although multifaceted, can be primarily attributed to the dramatic changes in South Korea's medical care system. As medical infrastructure proliferated and became increasingly sophisticated, an enhanced emphasis was placed on proactive medical strategies and preventive diagnostics.[19] Consequently, a larger portion of the older demographic gained diagnostic services promptly, facilitating early detection of osteoporosis and subsequently leading to prompt treatments that might have mitigated the disease's progression.

The demographic landscape offers further insights into this phenomenon. For instance, females are often disadvantaged by an inherently lower bone density.[4, 20, 21] The onset of menopause introduces expansive vulnerability, where the rapid reduction in estrogen levels can considerably intensify the susceptibility to osteoporosis.[5, 13] Similarly, South Koreans aged 70 and above, due to various physiological changes associated with aging, confront diminished absorption rates of critical nutrients such as Vitamin D, potentially exacerbating their risk for osteoporosis.[3, 22]

Moreover, the role of socioeconomic disparities in health outcomes remains essential. Those within lower socioeconomic tiers, encompassing rural residents, individuals with limited educational backgrounds, and those with lower incomes, often confront amplified risk in osteoporosis as a vulnerable group.[6, 12] These individuals, positioned at the intersection of limited resources and access, often grapple with a myriad of barriers when seeking healthcare. For instance, rural residents might have limited access to specialized healthcare facilities, while those with lower educational attainment may lack awareness or understanding of preventive measures and early symptoms of osteoporosis.[23, 24] Furthermore, individuals with limited income might forgo essential diagnosis or treatments due to financial problems. This confluence of socioeconomic factors not only emphasizes the disparities in healthcare access but also underscores the pressing need for equitable healthcare solutions to these vulnerable populations.[24]

The intricate dynamics were further destabilized by the unforeseen COVID-19 pandemic.

With medical facilities across South Korea redirecting their focus and resources towards managing the COVID-19 pandemic, diseases not deemed immediately critical, including osteoporosis, might have inadvertently been sidelined. Possible delays in identifying osteoporosis, interruptions in treatment, or even the overlooking of osteoporosis symptoms were plausible ramifications. The subsequent underdiagnosis and underreporting during this time highlight how external issues, such as global pandemics, affect the health trends of a national older population. [25]

In the broader context of the COVID-19 pandemic's far-reaching effects, our in-depth analysis within the older population of South Korea unveils critical policy implications.[26] The pandemic not only intensified general health susceptibilities but also highlighted the particular vulnerability of specific demographics, notably those aged 70 and above, and those with underweight classification. These vulnerabilities, intricately associated with factors such as rural residency, limited educational attainment, and menopausal status, have consistently influenced osteoporosis dynamics.

Thus, we advocate for a dual approach: a concentrated focus on these vulnerable groups and an expansive strategy to address overarching osteoporosis concerns. Actions, from specialized health awareness to strengthening rural health infrastructures, warrant thoughtful recalibration based on our insights. This should also include promoting regular physical activity through community initiatives, weaving osteoporosis awareness into educational curriculums, and allocating resources for persistent research on osteoporosis trends, particularly those triggered by global crises like the COVID-19 pandemic.

Furthermore, specialized interventions tailored for the female population, considering their distinct osteoporosis risks, ought to be the significant aim for our policy endeavors. By synergizing these specific strategies, we stand poised to sculpt a resilient and informed stance against osteoporosis in South Korea. In summary, this research highlights the complex relationship between inherent demographic factors and unforeseen global phenomena, suggesting a need to reevaluate our health policy paradigms.

This study, while comprehensive, has several inherent limitations. Firstly, our data was sourced from the KNHANES database, which predominantly relies on self-reported information, potentially affecting the accuracy of osteoporosis diagnoses.[27] This self-reporting methodology might lead to inaccuracies or biases, especially in the interpretation and recording of osteoporosis diagnoses. We specifically hypothesized that the COVID-19 pandemic's unique social and health dynamics might have affected individuals' perceptions and reports of their bone health. Furthermore, behavioral and dietary factors such as participants' dietary calcium and vitamin D intake, as well as physical activity, were not taken into account, potentially overlooking crucial interactions that influence bone health.[2, 22] Another notable omission is the non-consideration of treatment interventions, like hormone replacement therapy, which can significantly impact bone density. Notably, the study did not utilize the quantitative T-score, a standard measure for bone mineral density and a crucial metric in confirming osteoporosis.[28] Instead, osteoporosis diagnoses were based on patient responses and physician evaluations, introducing potential

uncertainties about the precision and consistency of these diagnoses. The self-reported nature of the study also extends to the menopausal status survey, which might not be entirely precise in verifying the genuine menopausal status. Moreover, the dataset lacks data for the years 2012, 2013, and 2014, leading to a discontinuity of the trend analysis. Furthermore, by focusing solely on individuals aged 50 and above, the study excluded potential insights from younger population. As the study is contextually centered on South Korea, its findings may not be directly translatable to global dynamics.[3, 6, 15] Additionally, while the KNHANES data is representative, it might overlook niche groups, especially those in settings like elderly care facilities. This highlights the need for broader datasets in research. Given the limitations of the KNHANES data, further studies utilizing more diverse datasets, particularly including marginalized populations such as those in elderly care facilities, are warranted to ensure a comprehensive understanding of osteoporosis trends in South Korea.

Despite these limitations, the study possesses significant strengths. The extensive KNHANES database ensures a representative sample base that reinforces the credibility to our findings.[11] Spanning a considerable duration from 2001 to 2021, our research offers a sophisticated perspective on osteoporosis trends, particularly in the time of COVID-19. Moreover, our investigation covers a broad spectrum of variables, from age and sex to socioeconomic factors, osteoporosis and menopausal status, and the facilitation of the elaborate interpretation of the impact of the COVID-19 pandemic.[12] Uniquely, our study initiated the examination of postmenopausal women's osteoporosis patterns, providing a novel contribution.

8. Conclusion

This study conducted a comprehensive analysis of osteoporosis trends and associated risk factors in South Korean older population from 2001 to 2021. Our findings reveal an overall increase in osteoporosis prevalence before the pandemic, followed by deceleration during the pandemic. This pattern underscores the unique impact of the pandemic on this demographic. The study highlights the heightened vulnerability of individuals aged 70 and above, and those who are underweight, necessitating targeted healthcare policies. The need for specialized interventions, such as educational efforts, enhanced rural healthcare infrastructure, and dedicated funding for ongoing osteoporosis research, is crucial to effectively address these challenges.

Capsule Summary

This study reveals an overall increase in osteoporosis prevalence before the pandemic, followed by deceleration during the pandemic.

Ethical Statement

The research protocol was approved by the Institutional Review Board of the Korea Disease Control and Prevention Agency.

Patient and public involvement

None of the patients were directly involved in designing the research questions or conducting the research. Patients were not asked for advice on the interpretation or writing of the results. There were no plans to involve patients or the relevant patient community in the dissemination of study findings.

Data availability statement

Data are available on reasonable request.

Transparency statement

The leading author (Dr. JK) is an honest, accurate, and transparent account of the study being reported.

Contributors

Dr JSK had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. All authors approved the final version before submission. *Study concept and design*: HK, JP, and JSK; *Acquisition, analysis, or interpretation of data*: HK, JP, and JSK; *Drafting of the manuscript*: HK, JP, and JSK; *Critical revision of the manuscript for important intellectual content*: all authors; *Statistical analysis*: HK, JP, and JSK; *Study supervision:* JK. JK supervised the study and is guarantor for this study. HK and JP contributed equally as co-first authors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Provenance and peer review

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