Fixed-Effects Panel Time-Series Modeling of Osteoporosis Belief Dynamics and Preventive Behaviors among Women in Iraq

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Abstract

Background: Osteoporosis is rapidly becoming a serious global issue, especially for women. This is particularly true for women in Iraq, where a lack of health beliefs towards osteoporosis in addition to a low awareness of the disease, leads to an increased burden of disease.

Methods: This study obtained a balanced panel data set of the health beliefs (e.g., perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and perceived self-efficacy) and preventive behaviors for osteoporosis for 250 postmenopausal women in Iraq for a period of 12 months. To control for the unobserved individual heterogeneity, a Fixed-Effects (FE) panel time-series model was used. As part of the analysis, a number of diagnostic checks, including the Wooldridge test for autocorrelation, were performed.

Results: The FE model demonstrated that perceived susceptibility ($\beta = 0.34$, $p < 0.001$), perceived severity ($\beta = 0.28$, $p < 0.001$), and self-efficacy ($\beta = 0.45$, $p < 0.001$) significantly enhance preventive behaviors over time, while perceived barriers ($\beta = -0.22$, $p = 0.015$) reduce them.

Conclusion: Long-term changes in health beliefs translate directly to improvements in osteoporosis prevention. Fixed-effects modeling offers an excellent framework for analyzing these trends in behavioral changes in women in Iraq.

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Keywords: Osteoporosis, Health Beliefs, Preventive Behaviors, Iraqi Women, Time Series Analysis

Introduction

Osteoporosis is a disease that causes the human body to have fewer compact bones and creates weak vulnerable microfractures in spongy bones [1, 2]. Current research states that this disease is more common in women that have gone through menopause as they have a much more increased chance of sustaining fragile bone fractures. This disease has a huge impact on the healthcare system everywhere including Iraq [3]. Recent research has been telling those women in Iraq have a pretty high number of osteoporosis and osteopenia cases [4]. This has a lot to do with women in Iraq having an early menopause and many people in Iraq being vitamin D poor. There is a huge need for Iraqis to change their diets in order to consume more Calcium as well as create more vitamin D in their body through physical exercise. There are many low osteoporosis preventive strategies that are needed in Iraq [5, 6]. A research study in 2022 conducted a systematic review and a study entitled a meta-analysis stated that there a serious variation of the number of people suffering with osteoporosis. The study cited that in the Netherlands the amount of osteoporosis patients was at 4.1%, where the same number in Turkey came to 52% [7] In 2024 a research study in Iraq cited that woman in Iraq osteopenia were diagnosed with osteoporosis at a rate of 36.2% and 24.5%, respectively [8].

The Health Belief Model is a conceptual framework that is utilized frequently to support the rationale of choice and engagement in health promoting behavior [9]. The model also defines people's behavior in terms of the beliefs the person holds [10, 11].
Prior cross-sectional studies have associated the HBM constructs to the prevention of osteoporosis. These studies typically neglect the changing belief system dynamics over time and are prone to omitted variable bias. Fixed-effects modeling of population panel data has recently gained traction in public health for explaining behavioral changes beyond the scope of time-invariant individual characteristics. To fill this methodological gap, the study uses a panel time-series approach and a predicted model of the women's health beliefs to examine the osteoporosis prevention behaviors of women in Iraq.

Materials and Methods

Study Population and Data Collection

Data were collected using a longitudinal panel design. The study participants were postmenopausal women aged 45–65 who visited primary healthcare centers in urban and semi-urban areas of Baghdad and Al Diwaniyah, Iraq. Only the women who volunteered to participate in the study were included. Participants were required to be able to communicate effectively and provide full and reliable responses to the study questionnaire.
The exclusion criteria included women who were outside the designated age range or women who were yet to reach menopause. Women who had serious medical conditions or complications that could affect the study outcomes were also excluded from the study. Participants who decided to withdraw from the study after they had completed the questionnaire, and participants who did not complete the questionnaire, were excluded from the final analysis. The study had a total of 250 women participants. Data were collected at four time intervals, 3 months (T1), 6 months (T2), and 12 months (T3) in addition to the baseline (T0), within one year.
To assess various factors such as perceived susceptibility, perceived severity, perceived self-efficacy, and perceived barriers along with other health action cues, a questionnaire was developed. Based on the Health Belief Model (HBM), a 33-item questionnaire, culturally adapted, was structured, and its Arabic version was developed. The 33 items included susceptibility (items 1–4), severity (items 5–8), benefits (items 9–13), barriers (items 14–18), self-efficacy (items 19–23), internal (items 24 and 25) and external (items 26–30) cues to action. The 5-point Likert scale was used with the value "1" for "strongly disagree" and "5" for "strongly agree." The author of the scale has justified the validity and reliability of the tool.
The 10 items on preventive behaviors for osteoporosis were assessed using a 4-point Likert scale with "1" as "never," and "4" as "always." Ethical approval was obtained, and informed consent was acquired prior to data collection. Participants were informed that they had the right to withdraw from the study anytime without providing a reason. Participants were also informed that the study was voluntary and that they had the right to leave the study anytime without giving a reason. It was ensured that the study did not impose any negative consequences on the participants.

Panel Data Structure

The dataset in this study is organized as a panel data structure with two dimensions. The first dimension consists of a cross-sectional sample of 250 Iraqi postmenopausal women, while the second dimension includes four repeated observations (T = 4) collected from each participant over time. In this study, data were collected from the same participants at four different instances to examine the developments in their health-related beliefs and behaviors. This design enables the analysis of changes and differences both, across the participants, and overtime. This way, it is possible to find the changes in health beliefs of each individual woman at each of the four times, and the differences between the participants. Traditional designs, that are based on single instances and measure the beliefs and behaviors of a population only once, are less informative and descriptive compared with this design. This design is more informative and flexible with respect to the measurements of behavioral and cognitive changes. It allows the identification of patterns in the beliefs of postmenopausal women and helps in understanding the beliefs of postmenopausal women and how they change.

Model Specification (Fixed-Effects)

To estimate how dynamic health beliefs causally influence osteoporosis preventive behaviors, a Fixed-Effects (FE) panel data model is outlined. This model can be expressed mathematically as follows:

$$Y_{it} = \beta X_{it} + \alpha_i + \varepsilon_{it}$$

Where Y_{it} the variable denoting the preventive behavior score of women i at time t is represented by; X_{it} it is the set of time-dependent HBM predictors; α_i is the unobserved, time-invariant individual heterogeneity (for example, innate health consciousness); and ε_{it} it is the error term.
The principal difference in the application of the Fixed Effects (FE) and Random Effects (RE) models is in the assumptions they make regarding unobserved effects (α_i). It is assumed in the RE model that α_i is uncorrelated with the predictors and is taken to be random. In the FE model, it is assumed that α_i can be correlated with the predictors. In the application of the FE model to this study, it is considered that the innate personal characteristics of the women in the sample affect both the women's health beliefs and their preventive health behaviors.

Diagnostic Tests

To maintain statistical integrity, we checked for the presence of autocorrelation of the unknown error term caused by the idiosyncratic error term. If present, autocorrelation would lead to standard errors, and thus the results of the tests, becoming invalid. We used the Wooldridge test for autocorrelation. Although the Durbin-Watson statistic is the most common way to test for autocorrelation, it is bound by a number of demands, which, if present, would make the test invalid for most panel datasets. The Wooldridge test is a robust test with few requirements for a valid test, and it is the most suitable test for a case where the number of panels is less than the number of time observations. The null hypothesis states that first-order autocorrelation does not exist. The diagnostic test showed that the errors of the model were independent, and the autocorrelation null hypothesis was accepted, i.e., there was no significant p-value.

Data Analysis

IBM SPSS Statistics was utilized for analysis of the data to assess descriptive statistics such as means, standard deviations, and frequencies. Because the data were longitudinal in nature with four repeated measurements for each participant, the Linear Mixed Model (LMM) was employed for the primary analysis as this model is designed to accommodate correlated data for each participant. Moreover, the LMM was designed to evaluate the fixed effects of time-varying predictors and the random effects of the Health Belief Model on Behavioral Intention. In the model, participant IDs were set to random effects for account of the unobserved heterogeneity, and time was set to a repeated effects factor to account for within-participant changes across the four measurement periods. In addition, a fixed-effects estimation was also employed using time dummy variables in a linear regression to account for within-participant variance. Time dummy variables were set in a linear regression framework as a fixed-effects approximation to account for variance within participants. All statistically significant results were set to $p < 0.05$ in this analysis.

Results

Most of the participants were married women between the ages of 30-39 with at least a secondary school education. Most women were either unemployed or housewives. They lived in an urban setting. Most participants were considered overweight with an average height, weight, and BMI of 158.4 cm (± 6.3), 69.2 kg (± 11.5), and 27.6 kg/m² (± 4.3), respectively. Sociodemographic and anthropometric data for study participants are shown in Table 1. Results from the fixed-effects model are shown in Table 2. Perceived susceptibility, perceived severity, perceived benefits, cues to action, and perceived self-efficacy are the Health Belief Model (HBM) constructs that all positively and significantly influence osteoporosis prevention behavior (all $p < 0.001$). Of the listed constructs, perceived self-efficacy had the largest impact ($\beta = 0.45$). Perceived barriers made a significant negative impact on osteoporosis preventive behavior ($\beta = -0.22$, $p = 0.015$). The HBM scores in each of the four periods are shown in Table 3. Most of the HBM Constructs improved over time, with scores for perceived susceptibility, perceived severity, perceived benefits, cues to action, and perceived self-efficacy rising from T0 to T3. Perceived barriers scores declined over time from 3.25 (± 0.63) to 2.60 (± 0.55) between T0 and T3, respectively.

Notably, behaviors aimed at preventing osteoporosis also improved, moving from a score of 2.40 ± 0.55 at baseline to a score of 3.30 ± 0.48 at 12 months. This indicated an increase in such behaviors over the course of the study. Figure 1 describes the Health Belief Model (HBM) constructs and osteoporosis prevention behaviors over four time periods (baseline, 3 months, 6 months, and 12 months). Overall, the figure shows improvement in an individual's perception of risk, the severity of the condition, the benefits of the action, readiness to act, and their belief in their ability to perform the behavior. In contrast, perceived barriers decreased over the study period.

Table 1: Socio-demographic and anthropometric characteristics of participants (n = 250)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	< 30	60	24.0
	30–39	90	36.0
	40–49	70	28.0
	≥ 50	30	12.0
Education level	Primary	80	32.0
	Secondary	100	40.0
	Higher education	70	28.0
Marital status	Married	190	76.0
	Single	30	12.0
	Widowed/Divorced	30	12.0
Employment status	Employed	95	38.0
	Unemployed / Housewife	155	62.0
Residence	Urban	160	64.0
	Rural	90	36.0
Height (cm)	Mean ± SD	158.4 ± 6.3	—
Weight (kg)	Mean ± SD	69.2 ± 11.5	—
Body Mass Index (BMI) (kg/m²)	Mean ± SD	27.6 ± 4.3	—
BMI classification	Normal (<25)	85	34.0
	Overweight (25–29.9)	110	44.0
	Obese (≥30)	55	22.0

Table 2: Fixed-Effects Model Estimation Results for Osteoporosis Belief Dynamics

Independent Variable	Coefficient (β)	Standard Error (SE)	t-value	p-value	95% Confidence Interval
Perceived Susceptibility	0.34	0.05	6.80	< 0.001	[0.24, 0.44]
Perceived Severity	0.28	0.04	7.00	< 0.001	[0.20, 0.36]
Perceived Benefits	0.31	0.05	6.20	< 0.001	[0.21, 0.41]
Perceived Barriers	-0.22	0.05	-4.40	0.015	[-0.32, -0.12]
Cues to Action	0.19	0.04	4.75	< 0.001	[0.11, 0.27]
Perceived Self-Efficacy	0.45	0.06	7.50	< 0.001	[0.33, 0.57]

Note: The dependent variable is the composite score of osteoporosis preventive behaviors. Significance is established at $p < 0.05$.

Table 3: Mean scores of Health Belief Model constructs and preventive behaviors over time:

Variable	T0 (Baseline) Mean ± SD	T1 (3 months) Mean ± SD	T2 (6 months) Mean ± SD	T3 (12 months) Mean ± SD
Perceived Susceptibility	2.81 ± 0.62	3.05 ± 0.60	3.22 ± 0.58	3.40 ± 0.55
Perceived Severity	3.10 ± 0.57	3.25 ± 0.55	3.40 ± 0.52	3.55 ± 0.50
Perceived Benefits	2.95 ± 0.60	3.20 ± 0.58	3.38 ± 0.54	3.60 ± 0.51
Perceived Barriers	3.25 ± 0.63	3.05 ± 0.60	2.85 ± 0.58	2.60 ± 0.55
Cues to Action	2.70 ± 0.65	2.95 ± 0.62	3.15 ± 0.59	3.35 ± 0.56
Perceived Self-Efficacy	2.88 ± 0.61	3.10 ± 0.58	3.35 ± 0.55	3.58 ± 0.52
Osteoporosis Preventive Behaviors	2.40 ± 0.55	2.75 ± 0.52	3.05 ± 0.50	3.30 ± 0.48

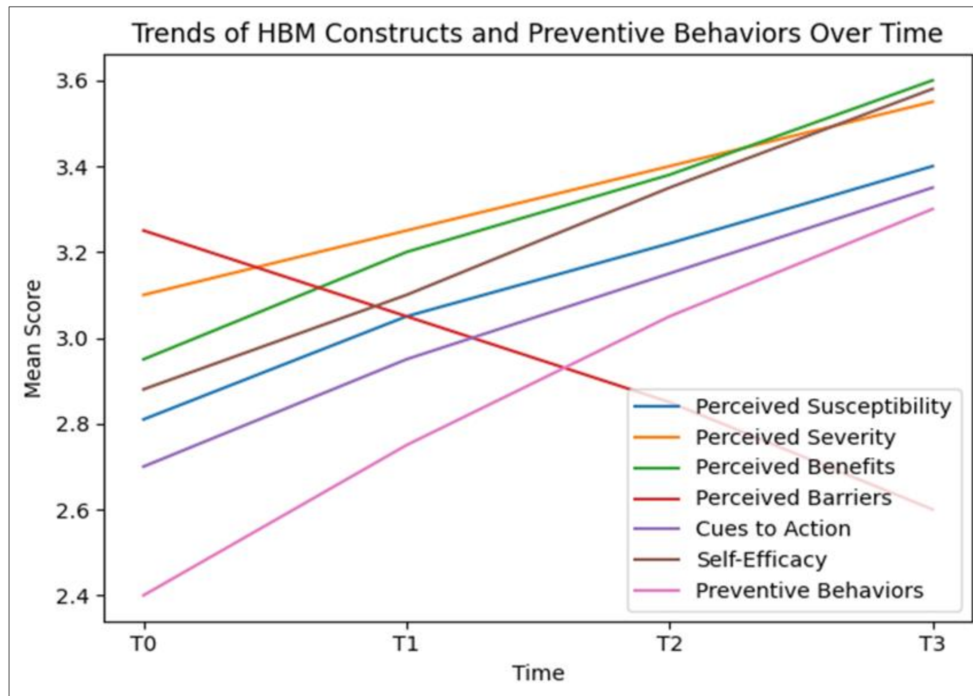

Fig 1: Trend of HBM construct and preventive behaviour over time

Discussion

The findings of this study indicate that constructs of the Health Belief Model significantly predict osteoporosis preventive behaviors, with perceived self-efficacy emerging as the most important determinant of behavior. This result is theoretically consistent with recent developments in the Health Belief Model, in which self-efficacy is considered the main driving force that translates awareness into actual behavior [12, 13]. Many similar studies have also reported that even when individuals have a high perception of risk, if they do not feel capable of performing the behavior (such as engaging in physical activity or taking calcium supplements), the likelihood of behavior change remains low. For example, studies conducted among postmenopausal women in world has consistently identified self-efficacy as either the strongest or one of the strongest predictors of osteoporosis preventive behaviors [14-16].

In contrast, perceived susceptibility and perceived severity also had a statistically significant positive effect. This finding is consistent with previous research, which shows that risk perception primarily plays an initial motivational role and is not sufficient on its own to produce sustained behavioral change [17-19]. Many systematic review studies have also reported that these two constructs are generally effective at the cognitive level, but play a secondary role at the action stage.

Perceived benefits also showed a significant positive effect, which is consistent with the existing literature, as most studies have found that an increased perception of the advantages of preventive behaviors—such as physical activity and calcium intake—is associated with a higher likelihood of performing those behaviors [17, 20]. In contrast, perceived barriers had a significant negative effect, which is considered one of the most consistent findings in research based on the Health Belief Model. In similar studies, barriers are usually reported as the strongest inhibiting factor of behavior [20, 21]; however, in the present study, the effect of self-efficacy was stronger than that of barriers, which may indicate the relative effectiveness of the educational intervention in reducing these barriers.

In the longitudinal results section, it was also observed that over time, preventive behaviors steadily increased, while self-efficacy, perceived benefits, perceived severity, and perceived susceptibility improved, and perceived barriers decreased. This pattern is consistent with findings from intervention studies based on health education in the field of osteoporosis, which have shown that educational interventions typically first influence knowledge and beliefs, and then these cognitive changes lead to improvements in behavior [22-24]. In particular, reductions in barriers and increases in self-efficacy have been reported in similar studies as the most important pathways for behavioral change.

When compared to older studies, it is clear that the findings

of this study corroborate existing literature. By analyzing osteoporosis prevention, it is clear the existing literature fails to give appropriate weight to the complexity of the situation. Increased self-efficacy and risk perception are needed. Additionally, the removal of barriers is needed to achieve sustained behavioral change.

Limitations of the Study

The findings for this study should be approached cautiously. The first limitation is the sample size, with only 250 women, all postmenopausal, who came from several primary healthcare centers, which only included urban and semi-urban populations within Baghdad and Al Diwaniyah. The findings might not apply to rural populations or other areas in Iraq, for example. The second limitation is that even though the design of the research has a strong panel design with four repeated measurements, the relationships between health beliefs and health-seeking behaviors could have been affected by unobserved time-varying confounding factors. The third limitation is the use of research instruments that relied on self-reporting, which resulted in potential recall bias. The fourth limitation is that even though the time-invariant individual heterogeneity is accounted for when assessing the Health Belief Model constructs, a fixed-effects model may still have some unobserved measurement error. The fifth and final limitation is that a 12-month follow-up could be seen as sufficient to determine short- or medium-term changes, and beyond that, it may not be considered adequate in order to determine the long-term goal of sustaining the changed behaviors that focus on the prevention of Osteoporosis.

Conclusion

This study explores the empirical effects of changing health beliefs on the preventive behaviors Iraqi women exhibit towards osteoporosis. The fixed-effects panel time-series model was able to control for unobserved individual heterogeneity. This assures us that public health interventions aimed to increase Iraqi women's self-efficacy and awareness of the disease, while simultaneously decreasing cultural and institutional barriers, will lead to significant longitudinal changes in women's bone health.

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