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Longitudinal Trends in Multi-Dimensional Health Literacy Scores: A Nine-Year Joinpoint and Mixed-Model Analysis from Zhejiang, China — A Repeated Cross-Sectional Study

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Abstract

Background

Health literacy is a critical determinant of health outcomes and a key indicator for public health promotion. Understanding its long-term trends and domain-specific patterns is essential for targeted health education strategies, yet evidence from comprehensive multi-dimensional assessments remains limited. This study aimed to evaluate the longitudinal trends in health literacy scores—overall, across three dimensions, and across six aspects—among residents of Zhejiang Province, China, from 2016 to 2024.

Methods

Nine annual repeated cross-sectional surveys were conducted from 2016 to 2024 using a stratified multistage random sampling design across 30 counties in Zhejiang, China. A total of 152,988 valid respondents aged 15–69 years were included. Health literacy was assessed using the nationally standardized Chinese Resident Health Literacy Questionnaire (total score 66). weighted to the census population: the 2010 Zhejiang census data for 2016–2018 surveys and the 2020 Zhejiang census data for 2019–2024 surveys. Joinpoint regression was used to identify inflection points in temporal trends, and linear mixed models were fitted to examine factors associated with health literacy scores, with monitoring site as a random effect.

Results

All indicators showed significant upward trends over the nine-year period (all $P < 0.001$). The overall score increased from 39.09 in 2016 to 44.66 in 2024 (annual percent change [APC] = 1.69%, 95% confidence interval [CI]: 1.48–1.92). Among the three dimensions, behaviour and lifestyle showed the largest increase (APC = 2.15%), followed by skills (APC = 1.87%) and knowledge (APC = 1.41%). Among the six aspects, heterogeneous patterns were observed: Chronic Diseases exhibited an inflection point in 2018, and Health Information exhibited an inflection point in 2020, while Infectious Diseases showed a steady linear increase with no joinpoints detected. Urban residents consistently scored higher than rural residents across all indicators, with disparities remaining stable over time.

Conclusions

Health literacy scores among residents of Zhejiang Province demonstrated sustained and broad-based improvements from 2016 to 2024, though the pace and patterns varied across dimensions and aspects. The findings highlight the need for continued, domain-specific health education efforts, with particular attention to narrowing persistent urban–rural gaps.

Background

Health literacy—defined as the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions—is a critical determinant of individual and population health outcomes [1, 2]. It encompasses the cognitive, behavioral, and skills-based competencies that enable individuals to engage in preventive behaviors, navigate complex healthcare systems, adhere to treatment regimens, and communicate effectively with healthcare providers [3]. Over the past two decades, a robust body of evidence has established that limited health literacy is consistently associated with poorer health outcomes, including higher rates of hospitalization, increased emergency care utilization, reduced medication adherence, and elevated mortality, particularly among older adults and those with chronic conditions [4–6]. Furthermore, low health literacy has been identified as a key pathway through which socioeconomic disadvantage translates into health disparities, partially mediating the relationship between educational attainment, income, and health status across diverse populations [7, 8].

Recognizing the profound impact of health literacy on public health, the World Health Organization has designated health literacy as a core pillar of health promotion, emphasizing its role in enabling individuals to take greater control over their health and its social determinants [9]. In alignment with this global recognition, China has elevated health literacy to a national strategic priority. The Healthy China 2030 blueprint explicitly sets health literacy improvement as a key national target, aiming to raise the proportion of residents with adequate health literacy to 30% by 2030 [10]. This policy commitment reflects an understanding that health literacy is not merely an individual skill but a population-level resource that underpins the effectiveness of health systems and the success of public health interventions.

To monitor progress toward this goal, China has maintained a nationally standardized health literacy surveillance system since 2012. Annual cross-sectional surveys are conducted across 31 provinces using the validated Chinese Resident Health Literacy Questionnaire, which assesses health literacy across three dimensions—knowledge and attitudes, behaviour and lifestyle, and health-related skills—and six health issue domains: scientific views of health, infectious diseases, chronic diseases, safety and first aid, medical care, and health information [11, 12]. This comprehensive framework enables systematic monitoring of both overall and domain-specific health literacy trends, providing critical evidence for health policy and program planning.

National surveillance data have documented a steady upward trajectory in health literacy among Chinese residents over the past decade [13]. Provincial-level analyses have confirmed similar trends, including in Zhejiang Province, one of China's most economically developed regions with a population exceeding 64 million [14]. However, most existing studies have relied on dichotomous classifications of "adequate" versus "inadequate" health literacy, which may obscure incremental but meaningful changes in population-level health literacy capabilities. Moreover, limited research has systematically

examined domain-specific trajectories—how different dimensions and aspects of health literacy evolve over time in response to policy interventions, public health events, and societal changes.

Understanding these multi-dimensional trends is essential for several reasons. First, different dimensions of health literacy may respond differently to health education initiatives: knowledge acquisition may occur more rapidly than behavioural change or skill acquisition, reflecting the well-documented knowledge–behaviour gap in health promotion [15]. Second, domain-specific variations can reveal whether health education efforts have been broadly effective or concentrated in specific areas, thereby informing resource allocation and program design. Third, identifying temporal inflection points can pinpoint periods of accelerated or decelerated progress, enabling evaluation of the impact of major policy initiatives—such as China's chronic disease prevention plan—and public health events, such as the COVID-19 pandemic [16, 17]. Notably, the pandemic period created an unprecedented context for health communication, with intensive messaging on infectious disease prevention potentially reshaping public health literacy in ways that warrant careful examination [18, 19]. Prior studies from Zhejiang Province have documented domain-specific changes in infectious disease literacy using two-round cross-sectional data, but a comprehensive nine-year analysis across all dimensions and aspects has not been conducted [18, 19].

Against this backdrop, the present study addresses three key research gaps: (1) the limited use of continuous health literacy scores as a more sensitive measure of population-level change; (2) the lack of systematic analysis of domain-specific trajectories across an extended time period (2016–2024)—which encompasses the implementation of the Healthy China 2030 strategy and the full COVID-19 pandemic cycle; and (3) the need for robust statistical methods—Joinpoint regression and linear mixed models—to identify inflection points and examine sociodemographic determinants while accounting for hierarchical data structure.

Specifically, this study aimed to: (1) describe longitudinal trends in health literacy scores—overall, across three dimensions, and across six domains—among residents of Zhejiang Province from 2016 to 2024; (2) identify significant inflection points in these trends using Joinpoint regression; and (3) examine the sociodemographic factors associated with health literacy scores using linear mixed models with random intercepts and random slopes for monitoring sites.

Methods

Study Design

This study employed a repeated cross-sectional design, conducting independent annual surveys from 2016 to 2024 across 30 counties in Zhejiang Province, China. Given the observational, repeated cross-sectional design without a control group, all findings are interpreted as population-level temporal associations rather than causal effects.

Setting

The surveys were conducted in Zhejiang Province, a coastal province in eastern China with a population of over 64 million. Field investigations were carried out annually between August 1 and October 31. Surveillance sites were established in 30 representative counties/districts, selected using stratified cluster random sampling based on per capita GDP (tertiles) to ensure representativeness. The sampling frame and survey methods were consistent with those described in our previous publications using data from the same surveillance system [14, 19].

Participants

Eligibility criteria were: (1) age 15–69 years, (2) ability to communicate in Mandarin or the local dialect, and (3) permanent residency status (having resided in the survey area for at least six months). Residents living collectively in institutions such as hospitals, dormitories, or nursing homes were excluded. No additional exclusion criteria were applied.

Sampling Procedures

A stratified multistage random sampling approach was consistently applied across all survey years. The sampling design underwent minor adjustments between 2016–2017 and 2018–2024, when the protocol was refined according to national surveillance guidelines. Specifically, in 2016–2017, approximately 60 households were selected per segment with a target of 400 respondents per site; from 2018 onward, the number of households per segment was increased to approximately 100, with a target sample size of 640 respondents per site (total ~ 19,200 annually). Of note, the number of surveillance sites remained constant at 30 counties throughout the entire study period. Despite these operational adjustments, the core sampling framework—stratified multistage random sampling with probability proportionate to size (PPS) and Kish grid selection—remained consistent across all years, and all analyses incorporated sampling weights post-stratified to the census population to ensure comparability over time. The sampling procedure followed five stages: (1) county selection by GDP tertiles; (2) township selection using PPS; (3) community/village selection; (4) household selection from complete address lists; and (5) individual selection using a Kish grid (for details, see Fig. 1).

Measurements

Health literacy assessment:

Health literacy was assessed using the nationally standardized Chinese Resident Health Literacy Questionnaire, developed by the Chinese Center for Health Education and widely used in China's National Health Literacy Surveillance System. The questionnaire encompasses three dimensions—knowledge and attitudes (KAA), behaviour and lifestyle (BAL), and health-related skills (HRS)—and covers six health issue domains: scientific views of health (SVH), infectious diseases (ID), chronic diseases (CD), safety and first aid (SAFA), medical care (MC), and health information (HI) [14].

The questionnaire consists of true/false items, single-choice items, and multiple-choice items. For scoring, multiple-choice items with all correct answers receive 2 points, while single-choice and true/false items receive 1 point each, yielding a total score of 66 points. Higher scores indicate better health literacy. The scale has demonstrated strong reliability and validity in the Chinese population, with a Cronbach's α coefficient of 0.95 and a Spearman–Brown coefficient of 0.94[11].

Covariates:

Sociodemographic data were collected, including sex, age group (15–29, 30–39, 40–49, 50–59, 60–69 years), ethnicity (Han vs. minority), education level (illiterate/limited literacy, primary school, middle school, high school/vocational/technical, college and above), occupation (farmer, worker, agency/institutional personnel, student, other), and urban/rural residence.

Data Collection

Data were collected via household visits. In 2016, paper-based questionnaires were administered, followed by double-data entry using EpiData software. From 2017 to 2024, tablet computers (Android system) were used for face-to-face interviews, with data, audio recordings, and photographs uploaded in real time to the system backend.

Prior to household visits, community workers or community health physicians (investigators) contacted the sampled household head by telephone, informed them of the selected family member, and scheduled an appointment. If three consecutive attempts to schedule a successful visit failed, the household was replaced with the next household on the sampling list.

Questionnaire administration followed two modes: if the respondent was capable of self-completion, the investigator remained present to provide assistance and correct obvious errors. If the respondent could not complete the questionnaire independently, the investigator administered it through face-to-face interviewing.

Quality Control

To ensure data authenticity and quality, the following measures were implemented:

Training

All investigators, supervisors, and quality control personnel underwent a standardized training program consisting of collective lectures, on-site demonstrations, role-playing/simulation exercises, and pre-survey pilot assessments. Trainers were staff members from the Zhejiang Provincial Center for Disease Control and Prevention with over five years of experience in health literacy surveillance.

Audio recording and photography

Audio recording was activated throughout each survey session. Upon completion, investigators took photographs of the setting for subsequent verification.

Multi-dimensional quality checks: Supervisors reviewed audio recordings, survey duration, and on-site photos. A questionnaire was deemed invalid and replaced if: (1) leading questions were present in the audio recording; (2) survey duration was less than 10 minutes (a threshold established during pilot testing as the minimum reasonable time); or (3) inconsistency was found between on-site photos and actual survey conditions. In addition, electronic quality control early warning systems were used to flag and review questionnaires with potential issues at the provincial, municipal, and county levels [20].

Electronic information system

Questionnaire administration, data collection, storage, and quality control were managed through an integrated electronic information system throughout the study period.

Statistical Analysis

Data were analyzed using SPSS (version 27.0) and Joinpoint Regression Program (version 5.4.0, National Cancer Institute).

Weighting

To ensure the representativeness of provincial estimates, all analyses—descriptive statistics, group comparisons, Joinpoint regression, and linear mixed models—incorporated sampling weights. Weights were calculated as the inverse probability of selection and post-stratified to the Zhejiang census

population. Specifically, the 2010 Zhejiang census data were used for weighting the 2016–2018 surveys, and the 2020 Zhejiang census data were used for weighting the 2019–2024 surveys, stratified by age group (15–29, 30–39, 40–49, 50–59, 60–69 years) and urban/rural residence.

Given that the sociodemographic characteristics of participants varied significantly across survey years (Table 1), direct comparisons of raw estimates over time would be biased. We therefore applied sampling weights to all analyses to adjust for these annual compositional differences, thereby ensuring that the temporal trends observed reflect genuine changes in health literacy rather than shifts in sample demographics.

Descriptive statistics

Sociodemographic characteristics were presented as frequencies (percentages). Health literacy scores (overall, three dimensions, and six aspects) were presented as means and standard deviations (SD).

Group comparisons

The Kruskal–Wallis H test was used to compare distributions of sociodemographic characteristics across years. One-way ANOVA was employed to compare weighted mean health literacy scores across years, with post-hoc Least Significant Difference (LSD) tests for pairwise comparisons.

Joinpoint regression

Joinpoint regression was employed to model the temporal trends in health literacy scores from 2016 to 2024 and to identify significant inflection points (joinpoints). Given the limited number of time points (nine annual surveys), the maximum number of joinpoints was set to 2. The annual percent change (APC) and average annual percent change (AAPC) with 95% confidence intervals were calculated for the overall score, each dimension, and each aspect.

Linear mixed models

To investigate the factors associated with health literacy scores while accounting for the hierarchical data structure (individuals nested within monitoring sites), we fitted linear mixed models separately for the overall score, three dimensions, and six aspects. Each model included year (centered), urban–rural status, ethnicity, education level, occupation, age group, chronic disease status, and self-rated health as fixed effects, with monitoring site as a random effect (random intercept and random slope for year). All models converged successfully with no warnings. The year effect, urban–rural disparities, and random effects were examined. Bonferroni correction was applied for multiple comparisons across the 10 indicators, with statistical significance set at $P < 0.005$ (0.05/10). A two-tailed $P < 0.05$ was considered statistically significant for other analyses.

Visualization of temporal trends

To illustrate the longitudinal changes in health literacy scores, line charts were generated using Microsoft Excel. For each indicator (overall, three dimensions, and six aspects), the annual observed mean scores and modeled values from Joinpoint regression were extracted and plotted against survey year (2016–2024). Observed values were presented as scatter points, and modeled values were presented as smoothed or segmented lines fitted by Joinpoint regression. Vertical dashed lines were added at the identified joinpoint years to indicate significant inflection points. All figures were formatted consistently with standardized axis ranges and labels for comparability across indicators.

Multiple imputation

Missing data were minimal (< 2% of sampled households replaced due to quality issues); thus, no imputation was performed.

Results

Principal Findings

A total of 152,988 valid respondents were included across the nine annual surveys from 2016 to 2024, with annual sample sizes ranging from 11,088 to 19,257. Significant differences were observed across years in the distributions of sex, age, education, occupation, ethnicity, urban–rural status, self-rated health, and chronic disease status (all $P < 0.001$). Detailed sociodemographic characteristics are presented in Table 1. Detailed sociodemographic characteristics are presented in Table 1.

Table 1
Sociodemographic characteristics of participants in nine annual cross-sectional surveys (2016–2024), Zhejiang Province, China (N = 152,988)

Content and group	2016 (n = 11,088) n(%)	2017 (n = 11,976) n(%)	2018 (n = 19,007) n(%)	2019 (n = 19,257) n(%)	2020 (n = 19,180) n(%)	2021 (n = 17,131) n(%)	2022 (n = 18,857) n(%)	2023 (n = 17,545) n(%)	2024 (n = 18,947) n(%)	H^+(df)	P value
Sex										58.215 (8)	< 0.001
Male	5,551 (50.06)	5,686 (47.48)	9,065 (47.69)	9,175 (47.65)	9,298 (48.48)	8,020 (46.82)	8,762 (46.47)	8,237 (46.95)	8,807 (46.48)		
Female	5,537 (49.94)	6,290 (52.52)	9,942 (52.31)	10,082 (52.35)	9,882 (51.52)	9,111 (53.18)	10,095 (53.53)	9,308 (53.05)	10,140 (53.52)		
Urban–rural status										82.969	< 0.001
Urban	4,358 (39.30)	5,184 (43.29)	8,236 (43.33)	8,340 (43.31)	8,311 (43.33)	7,642 (44.61)	8,114 (43.03)	7,512 (42.82)	8,177 (43.16)		
Rural	6,730 (60.70)	6,792 (56.71)	10,771 (56.67)	10,917 (56.69)	10,869 (56.67)	9,489 (55.39)	10,743 (56.97)	10,033 (57.18)	10,770 (56.84)		
Ethnicity										73.005 (8)	< 0.001
Han	11,017 (99.36)	11,874 (99.15)	18,858 (99.22)	19,050 (98.93)	18,917 (98.63)	16,909 (98.70)	18,634 (98.82)	17,342 (98.84)	18,702 (98.71)		
Minority	71 (0.64)	102 (0.85)	149 (0.78)	207 (1.07)	263 (1.37)	222 (1.30)	223 (1.18)	203 (1.16)	245 (1.29)		
Age group										321.826 (8)	< 0.001
15–29	1,152 (10.39)	938 (7.83)	1,255 (6.60)	1,961 (10.18)	1,534 (8.00)	1,278 (7.46)	1,529 (8.11)	1,568 (8.94)	1,624 (8.57)		
30–39	1,589 (14.33)	1,534 (12.81)	2,230 (11.73)	2,530 (13.14)	2,486 (12.96)	2,470 (14.42)	2,626 (13.93)	2,354 (13.42)	2,540 (13.41)		
40–49	2,666 (24.04)	2,773 (23.15)	4,144 (21.80)	3,691 (19.17)	3,890 (20.28)	3,502 (20.44)	3,572 (18.94)	3,361 (19.16)	3,301 (17.42)		
50–59	2,966 (26.75)	3,252 (27.15)	5,704 (30.01)	5,642 (29.30)	6,001 (31.29)	5,508 (32.15)	6,091 (32.30)	5,245 (29.89)	5,546 (29.27)		
60–69	2,715 (24.49)	3,479 (29.05)	5,674 (29.85)	5,433 (28.21)	5,269 (27.47)	4,373 (25.53)	5,039 (26.72)	5,017 (28.60)	5,936 (31.33)		
Education										2,563.007 (8)	< 0.001
Illiterate/limited literacy	1,433 (12.92)	1,782 (14.88)	2,850 (14.99)	2,447 (12.71)	2,077 (10.83)	1,687 (9.85)	1,837 (9.74)	1,396 (7.96)	1,328 (7.01)		
Primary school	2,950 (26.61)	3,263 (27.25)	4,990 (26.25)	4,573 (23.75)	4,566 (23.81)	3,707 (21.64)	4,050 (21.48)	3,467 (19.76)	3,869 (20.42)		
Middle school	3,496 (31.53)	3,904 (32.60)	6,224 (32.75)	6,196 (32.18)	6,580 (34.31)	5,735 (33.48)	6,254 (33.17)	5,974 (34.05)	6,313 (33.32)		
High school/vocational/technical	1,709 (15.41)	1,766 (14.75)	2,718 (14.30)	3,130 (16.25)	3,000 (15.64)	2,906 (16.96)	3,134 (16.62)	3,057 (17.42)	3,399 (17.94)		
College and above	1,500 (13.53)	1,261 (10.53)	2,225 (11.71)	2,911 (15.12)	2,957 (15.42)	3,096 (18.07)	3,582 (19.00)	3,651 (20.81)	4,038 (21.31)		
Occupation										1,344.334 (8)	< 0.001
Farmers	5,279 (47.61)	6,154 (51.39)	9,113 (47.95)	8,738 (45.38)	8,979 (46.81)	6,667 (38.92)	7,600 (40.30)	6,466 (36.85)	5,945 (31.38)		
Workers	1,457 (13.14)	1,449 (12.10)	2,479 (13.04)	2,581 (13.40)	2,451 (12.78)	2,409 (14.06)	2,681 (14.22)	2,840 (16.19)	3,326 (17.55)		
Agency/institutional personnel	2,262 (20.40)	1,957 (16.34)	3,269 (17.20)	4,565 (23.71)	4,786 (24.95)	4,855 (28.34)	5,175 (27.44)	5,179 (29.52)	5,873 (31.00)		

Notes: Data are presented as n (%). Percentages are column percentages. H^+ values are Kruskal–Wallis test statistics with degrees of freedom (df) in parentheses, comparing distributions across years. "—" indicates not applicable; P values for urban–rural status and chronic disease were not calculated in the original analysis.

Content and group	2016 (n = 11,088) n(%)	2017 (n = 11,976) n(%)	2018 (n = 19,007) n(%)	2019 (n = 19,257) n(%)	2020 (n = 19,180) n(%)	2021 (n = 17,131) n(%)	2022 (n = 18,857) n(%)	2023 (n = 17,545) n(%)	2024 (n = 18,947) n(%)	H^+(df)	P value
Students	235 (2.12)	135 (1.13)	174 (0.92)	671 (3.48)	530 (2.76)	251 (1.47)	442 (2.34)	586 (3.34)	514 (2.71)		
Others	1,855 (16.73)	2,281 (19.05)	3,972 (20.90)	2,702 (14.03)	2,434 (12.69)	2,949 (17.21)	2,959 (15.69)	2,474 (14.10)	3,289 (17.36)		
Self-rated health										196.777 (8)	< 0.001
Excellent	3,422 (30.86)	3,952 (33.00)	6,116 (32.18)	6,133 (31.85)	6,994 (36.47)	5,685 (33.19)	6,359 (33.72)	5,753 (32.79)	6,030 (31.83)		
Very good	3,816 (34.42)	3,846 (32.11)	5,744 (30.22)	5,823 (30.24)	5,984 (31.20)	5,382 (31.42)	5,773 (30.61)	5,770 (32.89)	6,231 (32.89)		
Good	3,452 (31.13)	3,465 (28.93)	6,046 (31.81)	6,242 (32.41)	5,342 (27.85)	5,336 (31.15)	5,906 (31.32)	5,277 (30.08)	5,904 (31.16)		
Fair	340 (3.07)	588 (4.91)	873 (4.59)	815 (4.23)	674 (3.51)	589 (3.44)	644 (3.42)	596 (3.40)	608 (3.21)		
Poor	58 (0.52)	125 (1.04)	227 (1.19)	244 (1.27)	186 (0.97)	139 (0.81)	175 (0.93)	149 (0.85)	174 (0.92)		
Chronic disease										606.455 (8)	< 0.001
No	8,627 (77.80)	8,275 (69.10)	12,558 (66.07)	14,042 (72.92)	13,941 (72.69)	12,133 (70.82)	13,203 (70.02)	12,443 (70.92)	13,013 (68.68)		
Yes	2,461 (22.20)	3,701 (30.90)	6,449 (33.93)	5,215 (27.08)	5,239 (27.31)	4,998 (29.18)	5,654 (29.98)	5,102 (29.08)	5,934 (31.32)		

Notes: Data are presented as n (%). Percentages are column percentages. H^+ values are Kruskal–Wallis test statistics with degrees of freedom (df) in parentheses, comparing distributions across years. "—" indicates not applicable; P values for urban–rural status and chronic disease were not calculated in the original analysis.

Table 2 presents the weighted mean scores for overall health literacy, its three dimensions, and six aspects from 2016 to 2024. All indicators showed significant upward trends (all $P < 0.001$). The overall score increased from 39.09 in 2016 to 44.66 in 2024. Among the three dimensions, Behaviour and Lifestyle showed the largest increase, while Health Information grew most substantially among the six aspects.

Table 2
Mean scores (SD) for overall, three dimensions, and six aspects of health literacy, 2016–2024

Indicator	2016	2017	2018	2019	2020	2021	2022	2023	2024	F(df)	P
Overall	39.09 (13.06)	39.61 (12.82)	40.23 (13.44)	41.19 (13.26)	42.35 (13.42)	42.73 (13.49)	43.24 (13.41)	43.82 (13.22)	44.66 (12.89)	331.419 (8)	< 0.001
Dimensions											
Knowledge (KAA)	17.41 (5.91)	17.71 (5.85)	17.90 (6.02)	18.36 (5.91)	18.69 (5.95)	18.84 (5.92)	19.02 (5.87)	19.25 (5.83)	19.54 (5.66)	207.437 (8)	< 0.001
Behaviour (BAL)	12.24 (4.67)	12.83 (4.73)	12.97 (4.94)	13.29 (4.95)	13.87 (5.00)	14.00 (5.07)	14.16 (5.08)	14.44 (4.99)	14.70 (4.91)	413.362 (8)	< 0.001
Skills (HRS)	8.84 (3.81)	9.07 (3.57)	9.36 (3.70)	9.54 (3.61)	9.79 (3.66)	9.89 (3.65)	10.06 (3.61)	10.12 (3.54)	10.41 (3.49)	250.500 (8)	< 0.001
Aspects											
Scientific Views (SVH)	6.85 (2.78)	7.02 (2.76)	7.07 (2.83)	7.26 (2.76)	7.39 (2.75)	7.47 (2.76)	7.57 (2.76)	7.65 (2.71)	7.82 (2.65)	208.114 (8)	< 0.001
Infectious Diseases (ID)	3.69 (1.70)	3.75 (1.78)	3.82 (1.83)	3.93 (1.81)	4.21 (1.87)	4.24 (1.87)	4.20 (1.87)	4.26 (1.84)	4.29 (1.85)	203.870 (8)	< 0.001
Chronic Diseases (CD)	6.46 (2.88)	7.00 (2.97)	7.16 (3.08)	7.35 (3.08)	7.50 (3.08)	7.61 (3.09)	7.71 (3.08)	7.86 (3.04)	8.02 (3.01)	352.376 (8)	< 0.001
Safety & First Aid (SAFA)	9.85 (3.46)	10.00 (3.34)	10.02 (3.43)	10.21 (3.38)	10.29 (3.37)	10.32 (3.38)	10.51 (3.31)	10.59 (3.30)	10.83 (3.16)	120.915 (8)	< 0.001
Medical Care (MC)	7.58 (2.89)	7.69 (2.77)	7.83 (2.89)	7.95 (2.89)	8.28 (2.95)	8.31 (2.93)	8.37 (2.94)	8.53 (2.94)	8.65 (2.86)	241.331 (8)	< 0.001
Health Information (HI)	3.99 (2.19)	4.16 (2.11)	4.35 (2.11)	4.49 (2.08)	4.68 (2.10)	4.80 (2.09)	4.88 (2.07)	4.92 (2.03)	5.05 (2.04)	446.120 (8)	< 0.001

Notes: Data are presented as mean (SD). F values are from one-way ANOVA with degrees of freedom (df) in parentheses, comparing mean scores across years. All P values < 0.001.

The overall score demonstrated a steady upward trajectory, with no significant joinpoints detected (APC = 1.69%, 95% CI: 1.48–1.92, P < 0.001) (Fig. 2).

All three dimensions showed significant upward trends with no joinpoints. Behaviour and Lifestyle increased fastest (APC = 2.15%, 95% CI: 1.76–2.60, P < 0.001), followed by Health-related Skills (APC = 1.87%, 95% CI: 1.66–2.12, P < 0.001) and Knowledge and Attitudes (APC = 1.41%, 95% CI: 1.24–1.61, P < 0.001) (Fig. 3).

Heterogeneous patterns were observed across the six aspects. Chronic Diseases exhibited a joinpoint in 2018, with a rapid increase during 2016–2018 (APC = 5.12%, 95% CI: 3.36–6.45, P < 0.001) followed by a deceleration during 2018–2024 (APC = 1.74%, 95% CI: 1.26–2.02, P < 0.001). Health Information exhibited a joinpoint in 2020, with rapid growth during 2016–2020 (APC = 4.08%, 95% CI: 3.49–5.44, P < 0.001) followed by slower but sustained growth during 2020–2024 (APC = 1.81%, 95% CI: 0.97–2.33, P = 0.001). In contrast, Infectious Diseases, Scientific Views of Health, Safety and First Aid, and Medical Care showed steady linear increases with no joinpoints detected. Notably, Infectious Diseases demonstrated a consistent upward trend throughout the study period (AAPC = 2.16%, 95% CI: 1.26–3.41, P < 0.001) without significant inflection points (Fig. 4).

Detailed APC, AAPC, and joinpoint estimates for all indicators are presented in Table 3.

Table 3
Joinpoint Regression Trends in Health Literacy Scores, 2016–2024

Indicator	Period	APC/AAPC (95% CI)	P	Joinpoint
Overall	2016–2024	1.69% (1.48–1.92)	< 0.001	None
Dimensions				
Knowledge and Attitudes	2016–2024	1.41% (1.24–1.61)1	< 0.001	None
Behaviour and Lifestyle	2016–2024	2.15% (1.76–2.60)	< 0.001	None
Health-related Skills	2016–2024	1.87% (1.66–2.12)	< 0.001	None
Aspects				
Scientific Views of Health	2016–2024	1.58% (1.35–1.85)	< 0.001	
Infectious Diseases	2016–2024	2.16% (1.26–3.41)	< 0.001	
Chronic Diseases	2016–2024	2.58% (2.24–2.87)1	< 0.001	2018
	2016–2018	5.12% (3.36–6.45)2	< 0.001	
	2018–2024	1.74% (1.26–2.02)2	< 0.001	
Safety and First Aid	2016–2024	1.13% (0.90–1.38)	< 0.001	None
Medical Care	2016–2024	1.68% (1.45–1.94)	< 0.001	None
Health Information	2016–2024	2.94% (2.67–3.35)1	< 0.001	2020
	2016–2020	4.08% (3.49–5.44)2	< 0.001	
	2020–2024	1.81% (0.97–2.33)2	0.001	
Notes: ¹AAPC for the entire 2016–2024 period; ²APC for the specific segment.				
Figure Titles				

Dots = observed values; solid line = modeled values from Joinpoint regression.

Linear Mixed Model Results

Table 4 presents the key findings from the linear mixed models examining factors associated with health literacy scores. After adjusting for all covariates, the year effect was statistically significant for all 10 indicators (all $P < 0.005$ after Bonferroni correction). The overall health literacy score increased by an average of 0.505 points per year (95% CI: 0.261–0.749, $P < 0.001$). Among the three dimensions, Behaviour and Lifestyle showed the largest annual increase ($\beta = 0.241$, $P < 0.001$), followed by Knowledge ($\beta = 0.153$) and Skills ($\beta = 0.111$). Among the six aspects, Chronic Diseases ($\beta = 0.128$), Health Information ($\beta = 0.094$), and Medical Care ($\beta = 0.092$) showed the most rapid improvements.

The significant year effects across all 10 indicators confirm that the observed improvements were not merely due to demographic shifts but represent genuine population-level gains in health literacy capabilities. The largest annual increases were observed in Behaviour and Lifestyle among the dimensions, and in Chronic Diseases, Health Information, and Medical Care among the aspects, consistent with the Joinpoint regression findings.

Table 4
Linear mixed model results: year effects, urban–rural disparities, and random effects

Dependent Variable	Year Effect β (95% CI)	P	Urban-rural β	Year×Urban P	Random Intercept Variance (Site)	Random Slope Variance (Year)
Overall score	0.505 (0.261, 0.749)	< 0.001	5.082***	0.378	10.258***	0.237***
Dimensions						
Knowledge (KAA)	0.153 (0.054, 0.252)	0.004	1.866***	0.360	1.655***	0.039***
Behaviour (BAL)	0.241 (0.159, 0.323)	< 0.001	1.701***	0.351	1.112***	0.027***
Skills (HRS)	0.111 (0.044, 0.177)	0.002	1.379***	0.464	0.737***	0.018***
Aspects						
Scientific Views (SVH)	0.082 (0.038, 0.126)	0.001	0.765***	0.266	0.281***	0.008***
Infectious Diseases (ID)	0.041 (0.018, 0.064)	0.001	0.320***	0.698	0.078***	0.002***
Chronic Diseases (CD)	0.128 (0.080, 0.176)	< 0.001	0.941***	0.231	0.363***	0.009***
Safety & First Aid (SAFA)	0.068 (0.012, 0.124)	0.025	1.155***	0.360	0.570***	0.012***
Medical Care (MC)	0.092 (0.042, 0.141)	0.001	1.137***	0.609	0.510***	0.010***
Health Information (HI)	0.094 (0.060, 0.128)	< 0.001	0.495***	0.468	0.139***	0.005***

Notes: *** P < 0.001 (Bonferroni-corrected threshold: P < 0.005). All models adjusted for age group, ethnicity, education, occupation, chronic disease, and self-rated health. Random intercept and slope variances all significant at P < 0.001, indicating substantial heterogeneity across monitoring sites. β = unstandardized coefficient.

Urban residents consistently scored higher than rural residents across all indicators (all P < 0.001), with the largest gap observed for the overall score (β = 5.082, P < 0.001) and the smallest for Infectious Diseases (β = 0.320, P < 0.001). None of the year–urban interaction terms were significant (all P > 0.05). Significant random intercept and random slope variances across monitoring sites were observed (all P < 0.001). Detailed fixed effects for all other covariates are presented in Supplementary Table S1.

Discussion

The evolving concept of health literacy has been extensively discussed in the literature, with contemporary frameworks emphasizing its role not only as an individual skill but also as a population-level asset for health promotion [21–23]. This nine-year repeated cross-sectional study provides comprehensive evidence that health literacy scores among residents of Zhejiang Province demonstrated sustained and significant improvements from 2016 to 2024 across all indicators. The overall score increased steadily over the study period, with linear progress observed for the overall measure and all three dimensions. However, the six health domains displayed heterogeneous patterns: Chronic Diseases exhibited a distinct inflection point in 2018, with rapid early growth followed by deceleration; Health Information showed an inflection point in 2020, with accelerated growth during the pandemic period followed by slower progress; and Infectious Diseases demonstrated a consistent linear increase throughout the study period without significant inflection points, suggesting sustained improvements in infectious disease literacy that were not temporally concentrated.

Among the three dimensions, behaviour and lifestyle showed the most rapid growth, while knowledge and attitudes—despite having the highest baseline scores—exhibited the slowest growth. This pattern aligns with the knowledge–attitude–practice framework, suggesting that health education efforts have been particularly effective in translating knowledge into actionable lifestyle modifications, possibly through community-based interventions and the integration of health promotion into routine healthcare services [24, 25].

The persistent urban–rural disparities observed in our study underscore the influence of socioeconomic and educational contexts on health literacy outcomes [26].

Domain-Specific Trajectories

Health information showed the most substantial growth over the entire period, with a significant acceleration followed by deceleration. This pattern likely reflects the proliferation of health information through digital platforms during the COVID-19 pandemic, which substantially expanded public exposure to health-related content, followed by a natural waning of momentum as pandemic-related messaging subsided [27, 28]. The rapid digitalization of health

communication during the pandemic highlighted the importance of eHealth literacy, particularly among younger and more educated populations, while also exposing persistent digital divides that may have left older and less-educated populations behind [29].

Chronic diseases exhibited the most dramatic early increase, followed by a significant deceleration. This pattern corresponds closely with the implementation of China's medium- and long-term plan for chronic disease prevention (2017–2025), which catalyzed extensive health education campaigns [17]. The sharp initial increase likely reflects concentrated efforts during the early implementation phase, while the subsequent slowdown suggests that further improvements require more intensive, targeted interventions for populations with persistent gaps in chronic disease knowledge and self-management skills [30].

Infectious diseases demonstrated a consistent upward trend throughout the study period with no significant inflection points identified. Notably, unlike the pattern observed in some previous studies focusing on the proportion of residents with adequate infectious disease literacy [18], our analysis of continuous scores revealed a steady, linear improvement rather than a pandemic-induced surge followed by stagnation. This discrepancy may reflect the greater sensitivity of continuous scores in capturing gradual, cumulative improvements that are not dependent on crossing a dichotomous threshold. The sustained upward trajectory suggests that infectious disease literacy has been consistently reinforced through routine health education and public health messaging, which was further amplified during the pandemic but did not exhibit a discrete temporal shift. This pattern is encouraging, as it indicates that gains in infectious disease literacy have been maintained over time without the erosion observed in some pandemic-salient behaviors in other settings [19]. Public health measures implemented during the pandemic, including mask-wearing, hand hygiene, and social distancing, not only reduced the transmission of COVID-19 but also contributed to the decline of other respiratory infectious diseases [31, 32], potentially reinforcing the public's awareness of infectious disease prevention.

Safety and first aid and medical care showed steady, linear improvements throughout the study period. Safety and first aid consistently maintained the highest scores among all aspects, reflecting the long-standing emphasis on emergency preparedness in Chinese health education. Medical care, despite its relatively low baseline, demonstrated steady growth, suggesting gradual improvements in public understanding of healthcare services and health system navigation. Given the well-documented association between limited health literacy and adverse health outcomes in older populations [33, 34], these improvements are particularly meaningful for aging societies. Scientific Views of Health also demonstrated steady linear growth without inflection points, reflecting consistent progress in foundational health knowledge that may be less sensitive to specific policy or event-driven shocks.

Factors Associated with Health Literacy

The linear mixed models provided important insights into the factors driving changes in health literacy. The significant year effects across all 10 indicators confirm that the observed improvements were not merely due to demographic shifts but represent genuine population-level gains in health literacy capabilities. The largest annual increases were observed in Behaviour and Lifestyle among the dimensions, and in Chronic Diseases, Health Information, and Medical Care among the aspects, consistent with the Joinpoint regression findings.

Urban–rural disparities emerged as a significant determinant of health literacy. Urban residents consistently scored higher than rural residents across all indicators, with the largest gap observed for the overall score ($\beta = 5.082$, $P < 0.001$) and the smallest for Infectious Diseases ($\beta = 0.320$, $P < 0.001$). Notably, none of the year–urban interaction terms were significant (all $P > 0.05$), indicating that urban–rural disparities remained stable over time and that general population-level improvements have not narrowed the gap. This persistent disparity reflects cumulative advantages of urban environments in healthcare access, information exposure, and educational attainment, and highlights the critical need for targeted, sustained interventions in rural populations [35, 36].

The significant random intercept and random slope variances across monitoring sites indicate substantial heterogeneity in both baseline health literacy levels and rates of change among the 30 sites. This finding supports the use of random effects in our models and underscores the importance of local-level surveillance and tailored interventions, as province-wide averages may mask important local variations that require differentiated approaches. Detailed fixed effects for all other covariates—including education, age, ethnicity, occupation, and self-rated health—are presented in Supplementary Table S1.

The persistent urban–rural disparities observed in our study underscore the influence of socioeconomic and educational contexts on health literacy outcomes [26]. Education level emerged as one of the strongest predictors of health literacy, consistent with previous studies demonstrating that educational attainment is a fundamental determinant of health literacy capabilities. Age also showed significant associations, with younger adults generally scoring higher than older adults, reflecting generational differences in educational opportunities and exposure to health information.

Implications for Policy and Practice

These findings carry several important implications. First, the sustained improvements across all indicators demonstrate the effectiveness of China's health literacy promotion efforts over the past decade and should be maintained through continued investment. Second, the heterogeneous domain-specific patterns highlight the need for balanced health education strategies—ensuring that gains in one area do not come at the expense of others. Third, the persistent urban–rural disparities underscore the need for targeted interventions for rural populations, particularly given that the gap has not narrowed over time. Fourth, the strong education–health literacy association highlights the importance of integrating health literacy into school curricula as a foundational life skill. Finally, the significant site-level heterogeneity suggests that decentralized, community-tailored approaches are warranted.

Limitations and Strengths

Several limitations should be acknowledged. First, the repeated cross-sectional design cannot establish causality. Second, the study was conducted in a single economically developed province, limiting generalizability to other settings. Third, the tool primarily measures functional health literacy and does not

capture critical or interactive dimensions, nor digital health literacy. Fourth, self-reported data may be subject to social desirability bias. Fifth, while weighting adjusted for complex survey design, residual bias may remain. Finally, the COVID-19 pandemic created exceptional conditions unlikely to be replicated.

Despite these limitations, this study has notable strengths: a nine-year time series with consistent methodology, large sample size, comprehensive assessment across multiple dimensions and domains, Joinpoint regression for objective inflection point identification, and linear mixed models accounting for hierarchical data structure.

Conclusions

This study demonstrates sustained and significant improvements in health literacy scores among Zhejiang residents from 2016 to 2024. Domain-specific trajectories varied substantially: Chronic Diseases exhibited an inflection point in 2018, Health Information in 2020, while Infectious Diseases showed consistent linear improvement without significant inflection points, reflecting differential impacts of policy initiatives and public health events. Education, urban–rural status, and age emerged as the strongest predictors, with persistent urban–rural disparities underscoring the need for targeted interventions for rural populations. Sustained investment in health literacy promotion—particularly for rural residents, older adults, and lagging domains—is essential to maintain progress and achieve health equity.

Abbreviations

Abbreviation
Full term
AAPC
Average annual percent change
APC
Annual percent change
BAL
Behaviour and lifestyle
CD
Chronic diseases
CI
Confidence interval
GDP
Gross domestic product
HI
Health information
HRS
Health-related skills
ID
Infectious diseases
KAA
Knowledge and attitudes
MC
Medical care
PPS
Probability proportionate to size
SAFA
Safety and first aid
SD
Standard deviation
SVH
Scientific views of health
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the Zhejiang Provincial Center for Disease Control and Prevention (Approval No. 2022-027-01). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the survey. For participants younger than 16 years of age, written informed consent was obtained from their parents or legal guardians before the

survey. For participants who could not read or write, the investigator explained the purpose, procedures, risks, and rights in plain oral language before the survey. The participant's verbal informed consent was obtained after confirming understanding. Participants were informed about the purpose of the study, the procedures (including audio recording and photography for quality control), the voluntary nature of participation, and their right to withdraw at any time. All data were anonymized prior to analysis; no personal identifiers were retained in the analytic dataset. Audio recordings and photographs were used solely for real-time quality control and were deleted upon completion of data validation.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form (including individual details, images, or videos).

Competing interests

The authors declare that they have no competing interests.

Authors' information

Not applicable.

Generative AI statement

Generative AI tools (specifically DeepSeek 3.2) were used under full human supervision during the research and writing process. According to the GAIDeT taxonomy (2025), delegated tasks included proofreading and editing, formulation of conclusions, and translation. The authors take full responsibility for the content of this manuscript. AI tools are not listed as authors and bear no responsibility for the final outcomes.

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Author Contribution

Xinwei Zhang and Xuehai Zhang conceived and designed the study; Xinwei Zhang and Yue Xu participated in the design and coordination; Lei Wang, Qingqing Wu, Xiujing Hu, Yusui Zhao, and Dingming Yao collected the data; Yusui Zhao and Lei Wang and interpreted the data; Yusui Zhao drafted the manuscript; Xinwei Zhang and Xuehai Zhang critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to restrictions set by the ethics committee of the Zhejiang Provincial Center for Disease Control and Prevention, as the consent obtained from participants did not cover unrestricted public data sharing. However, anonymized data are available from the corresponding author upon reasonable request and with permission from the ethics committee.

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Figures

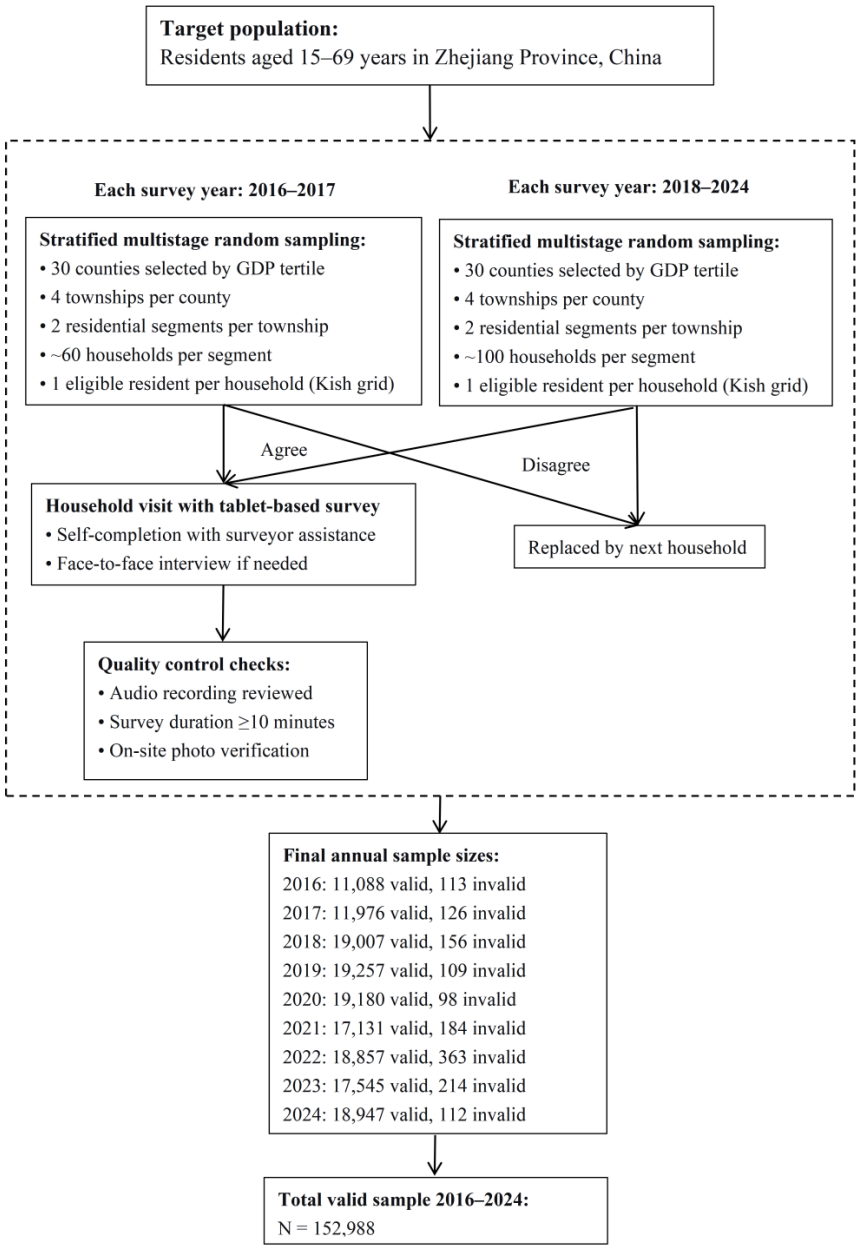


Figure 1

Participant flow diagram for the nine rounds of cross-sectional surveys (2016–2024)

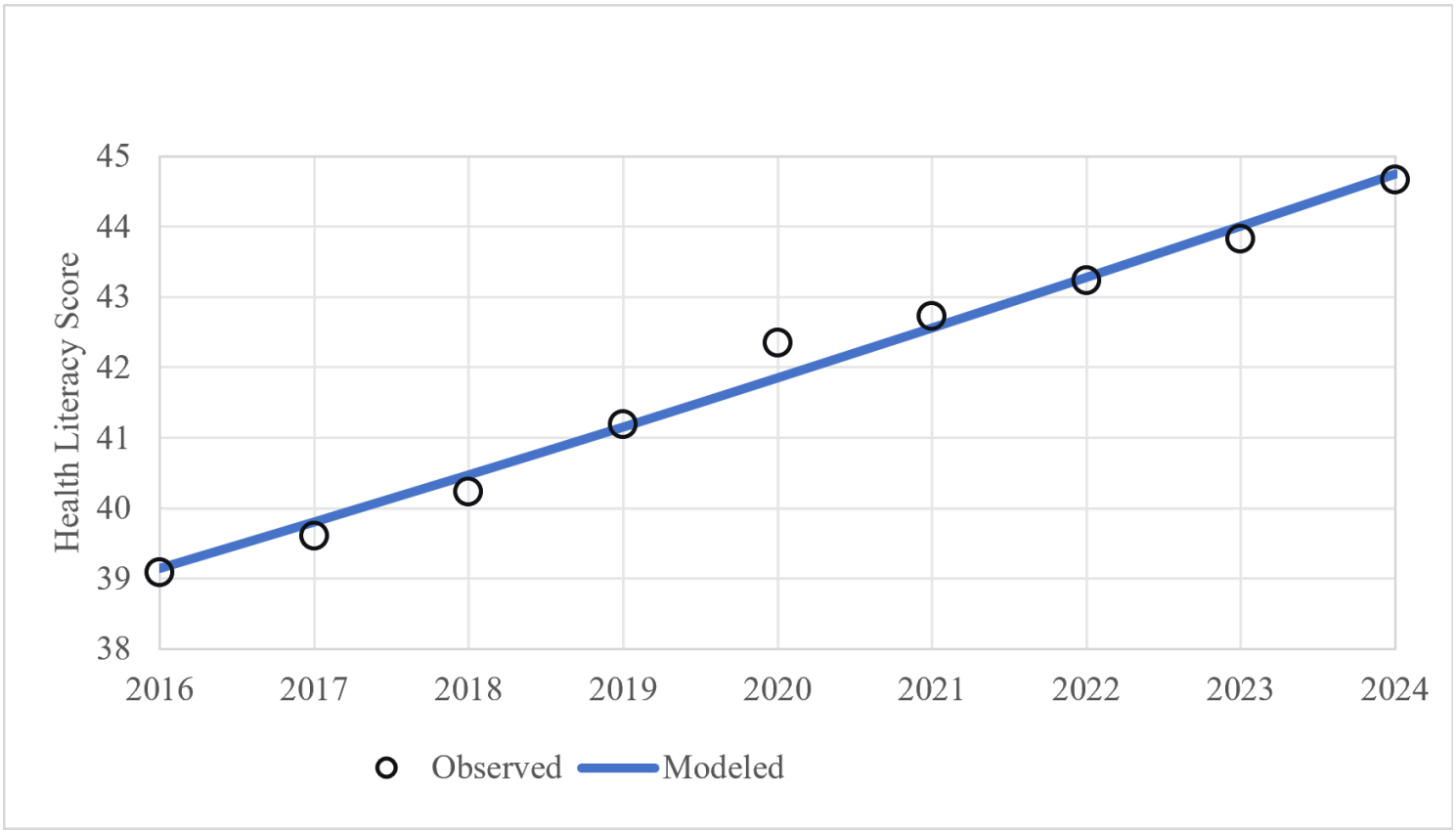


Figure 2

Trend in overall health literacy score among residents, 2016–2024.

Dots = observed values; solid line = modeled values from Joinpoint regression.

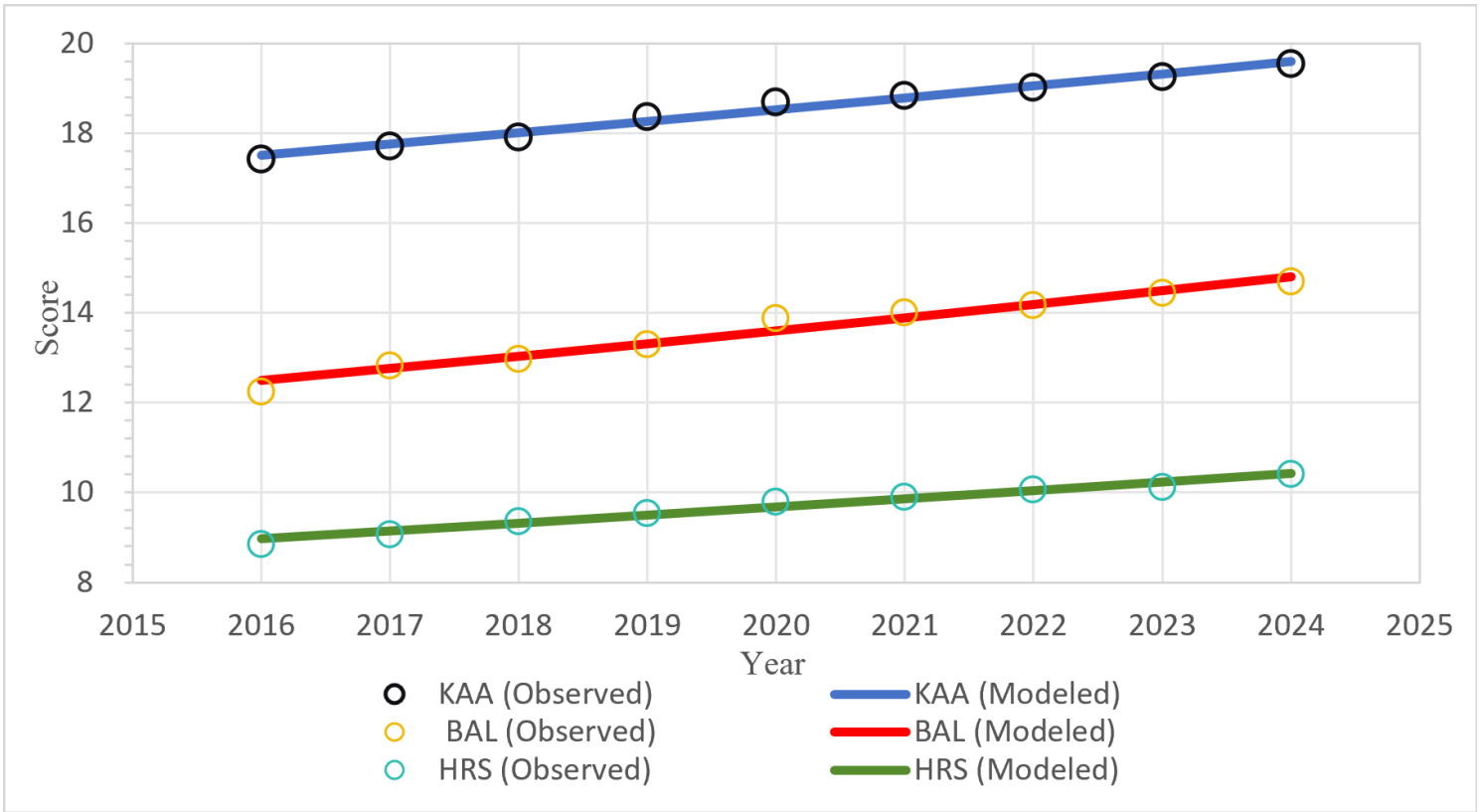


Figure 3

Trends in Scores of Three Dimensions of Health Literacy among Residents, 2016–2024.

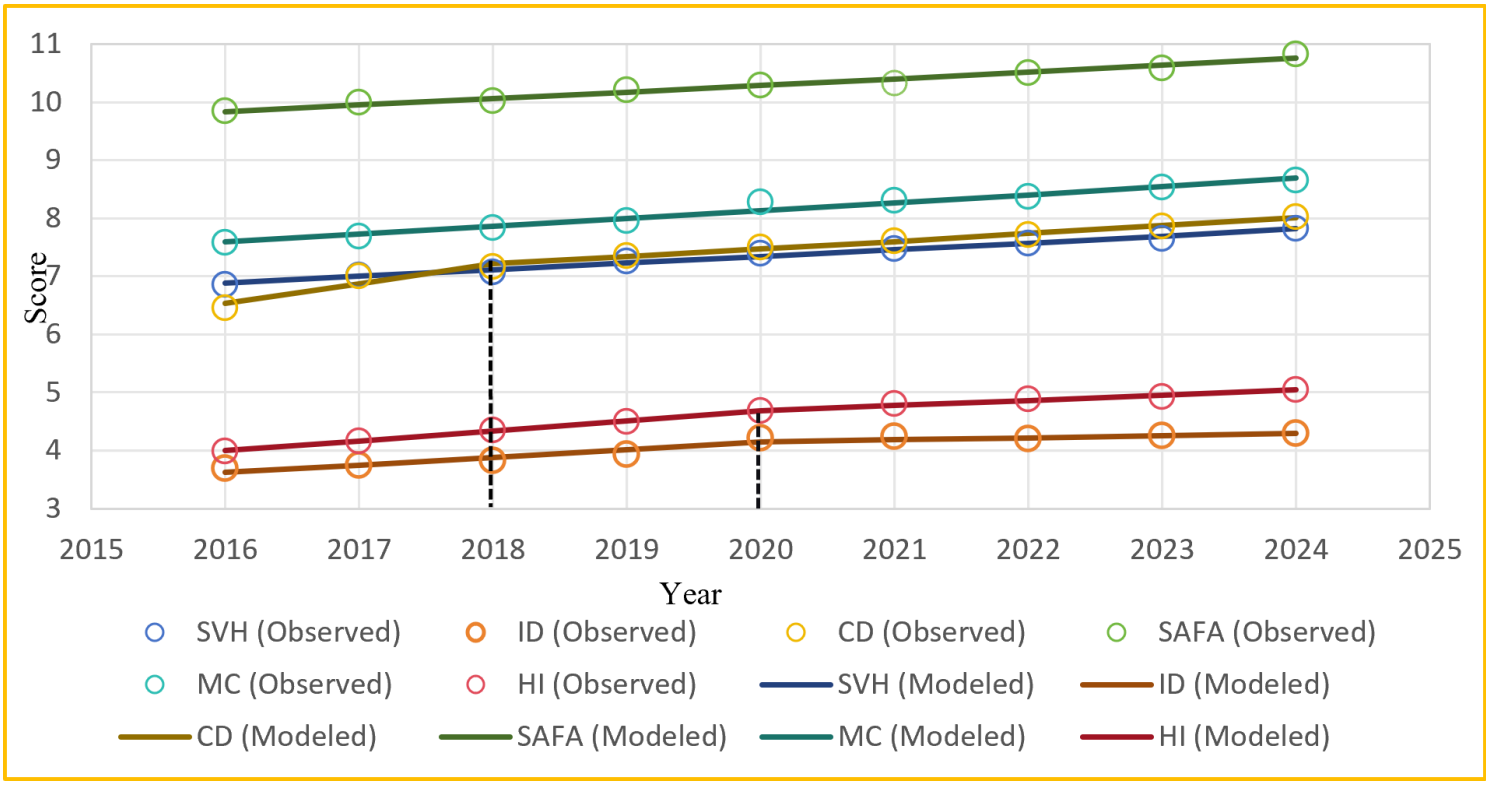


Figure 4

Trends in Scores of Six Aspects of Health Literacy among Residents, 2016–2024.

Supplementary Files

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- TableS1.docx