

# Structural barriers drive the intention-action gap in hepatitis B prevention: a triangulated study of serological, spatial, and behavioral data among migrant workers in China

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## Research Article

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# Abstract

**Background:** Hepatitis B virus (HBV) infection remains a major public health challenge in China. Migrant workers constitute a highly vulnerable population due to high geographic mobility and occupational vulnerability. Despite public health education efforts, a notable intention-action gap disrupts the HBV care cascade. This study integrates serological, spatial, and behavioral data to investigate whether this gap is primarily driven by cognitive deficits or interrupted by underlying structural barriers.

**Methods:** A triangulated cross-sectional study was conducted in Yantai, China, involving structured questionnaire surveys (N = 1,184) and serological testing (N = 2,364). The spatial distribution of regional anti-HBs positive rates was mapped using Geographic Information Systems (GIS). An adapted Health Belief Model was tested using Structural Equation Modeling (SEM) with a Robust Maximum Likelihood estimator to evaluate the disruptive effects of objective structural constraints—specifically, time poverty, economic constraints, and systemic lack of medical insurance.

**Results:** The serologically confirmed anti-HBs positive rate was 51.10% (1,208/2,364), substantially lower than the 70% threshold recommended by the World Health Organization. Spatial analysis revealed significant geographic heterogeneity ( $\chi^2 = 74.38$ ,  $P < 0.001$ ), with higher immunity concentrated in large-scale industrial belts (67.33%) and lower immunity clustered in dispersed service-sector districts (36.81%). SEM results indicated that while external cues strongly predicted HBV knowledge ( $\beta = 0.894$ ), knowledge had only a marginal effect on preventive intention ( $\beta = 0.192$ ). Preventive intention significantly predicted actual behavior ( $\beta = 0.655$ ). However, this motivational process was severely undermined by structural barriers, predominantly time poverty ( $\beta = -0.563$ ,  $P < 0.001$ ), followed by economic constraints ( $\beta = -0.278$ ,  $P < 0.001$ ) and lack of medical insurance ( $\beta = -0.056$ ,  $P = 0.030$ ).

**Conclusions:** The intention-action gap in HBV prevention among migrant workers is primarily driven by socioeconomic structural barriers—most notably time poverty—rather than insufficient knowledge or poor motivation. Achieving the goal of viral hepatitis elimination requires a shift from individual cognitive persuasion to structural interventions, emphasizing workplace-based service delivery, spatially targeted resource allocation, and insurance reforms to alleviate out-of-pocket and opportunity costs.

## Background

Hepatitis B virus (HBV) infection remains a pressing global public health challenge. China currently bears the world's heaviest burden of HBV, accounting for approximately one-third of all global chronic infections [1, 2]. Although historic progress has been made through universal neonatal vaccination programs, existing adult infections and horizontal transmission continue to pose substantial public health concerns. Notably, rapid urbanization in China has generated a massive population of internal migrant workers. Characterized by high geographic mobility, heavy occupational burdens, and systemic barriers to medical insurance coverage, this demographic constitutes a highly vulnerable link in the HBV prevention network [3].

Achieving the World Health Organization's (WHO) 2030 goal of eliminating viral hepatitis depends fundamentally on the integration of the "prevention, screening, diagnosis, and treatment" care cascade [4, 5]. Current public health interventions targeting high-risk populations frequently utilize sociopsychological frameworks, such as the Health Belief Model (HBM) [6], to enhance behavioral motivation through external cues to action. However, public health practice reveals a critical discrepancy: individuals' high self-reported willingness to undergo screening and vaccination often fails to translate into actual clinical protective behaviors. This notable "intention-action gap" forms a major bottleneck disrupting the HBV care cascade [7]. Yet, whether this discrepancy is primarily driven by cognitive dimensions or forcibly interrupted by underlying "structural barriers"—such as severe time constraints, economic limitations, and lack of medical insurance—remains insufficiently quantified in current literature [8, 9].

Previous studies investigating the willingness of migrant populations to engage in HBV prevention exhibit distinct methodological limitations. First, the majority of research relies solely on cross-sectional, self-reported survey data, which is highly susceptible to social desirability and recall biases, often leading to an overestimation of true protection levels [10]. Second, such sociological surveys typically lack objective clinical laboratory evidence (e.g., serological immune markers) for baseline validation. Finally, behavioral studies rarely integrate micro-level psychological models with macro-level geographic information systems (GIS), thereby overlooking spatial disparities in immune protection and infection risks caused by the uneven distribution of healthcare resources.

To address these research gaps, the present study introduces a "triangulation" design that integrates social psychology, clinical biology, and spatial ecology [11], focusing on the migrant worker population in Yantai City, China. The specific objectives are to: (1) construct a robust Structural Equation Model (SEM) to quantitatively test the intention-action gap and evaluate the disruptive effects of objective structural barriers; (2) incorporate real-world seroepidemiological data to cross-validate self-reported behaviors and establish the true baseline immunity; and (3) utilize spatial heatmaps to visually map the geographic disparities in regional immunization rates. By synthesizing multi-source heterogeneous data, this study aims to look beyond superficial willingness and reveal the systemic barriers impeding the care cascade, thereby providing high-level evidence for precise public health policymaking.

## Methods

### Study design and setting

A cross-sectional, triangulated study integrating questionnaire surveys and serological testing was conducted between January and March 2025 in Yantai City, Shandong Province, China. To comprehensively assess both the subjective psychosocial determinants and the objective biological status of HBV prevention, data were collected concurrently from two distinct and comparable cohorts representing the same population.

The inclusion criteria for all participants were: (1) age 20 or older; (2) not a registered resident of Yantai; (3) currently employed in a non-agricultural sector in Yantai (e.g., manufacturing plants, construction

sites). All participants signed an informed consent form prior to enrollment, and the study protocol was reviewed and approved by the Preventive Medicine Ethics Committee of the Yantai Center for Disease Control and Prevention (No. YYLLS 2024-23).

## **Participants and sampling**

**Questionnaire Survey:** A cross-sectional survey design was adopted. In each district of Yantai City, two locations with high concentrations of migrant workers (including factories, mines, and construction sites) were selected, and participants were recruited using convenience sampling. The survey was conducted via an online questionnaire (on the Wenjuanxing platform), with the questionnaire link being sent directly by enterprise and site managers to workers who met the inclusion criteria. The questionnaire was designed to be completed anonymously, with each IP address limited to one response. Prior to the formal investigation, a pilot study involving 50 migrant workers was conducted to refine the questionnaire phrasing. The required minimum sample size was calculated as 335, based on an estimated HBV knowledge rate of 68% ( $P=0.68$ ) [12]. derived from previous literature, a 95% confidence interval ( $Z = 1.96$ ), and a margin of error of 0.05 ( $d = 0.05$ ). Considering potential non-responses, the target recruitment was set to approximately 1,000 individuals.

**Serological Testing:** Concurrently, on-site venous blood collection was conducted at comparable migrant worker sites. A trained nurse collects 5 mL of venous blood; after serum separation, the five hepatitis B markers (HBsAg, anti-HBs, HBeAg, anti-HBe, and anti-HBc) are tested using chemiluminescence (instrument: Abbott Alinity i; reagent: Abbott Hepatitis B Virus Test Kit). Result interpretation strictly follows relevant guidelines and the kit instructions: (1) Anti-HBs positivity is defined as a quantitative result  $\geq 10$  mIU/mL, indicating immune protection; (2) HBsAg positivity is defined as a quantitative result  $\geq 0.05$  IU/mL, suggesting active infection. The minimum sample size for serology was calculated as 1,067, assuming an anti-HBs positive rate of 50% ( $P = 0.50$ ) [13], with a margin of error of 0.03. Supported by a dedicated funding grant, free HBV five-panel testing was offered, which highly motivated participation. Consequently, 2,364 workers were successfully recruited, substantially exceeding the minimum requirement.

Although the questionnaire and serological cohorts did not perfectly overlap, both strictly adhered to the same inclusion criteria and geographic scope during the identical timeframe. Demographic comparisons revealed no significant differences in age and hometown distribution between the two cohorts, and only minor variations in gender (Table 1), confirming that both samples represented the target population of migrant workers in Yantai.

## **Data collection and measurements**

A structured questionnaire (provided as Supplementary Material S1) was used to collect the following information:

**Demographic characteristics:** gender, age, place of household registration (hukou), current industry sector, and monthly average income, and whether having local basic medical insurance in Yantai.

HBV-related knowledge and behavior history: awareness of hepatitis B, sources of information (television/radio, internet, community outreach, family/friends), knowledge about transmission routes and preventive measures, and self-reported history of HBV screening and vaccination.

Preventive intentions: willingness to undergo HBV screening; to receive vaccination if tested uninfected and without antibodies; to undergo diagnostic confirmation if screening suggested possible infection; and to receive treatment if diagnosed with hepatitis B. Items were rated on a four-point Likert scale (1 = very unwilling, 4 = very willing). The scales demonstrated good internal consistency, with a Cronbach's  $\alpha$  of 0.85 for the behavioral intention dimension.

Barriers to the care cascade: For participants who responded "unwilling" to any service, a multiple-choice question assessed the primary reasons, encompassing both psychosocial factors (e.g., fear of discrimination, perceived unnecessary) and objective structural constraints. In the operationalization of structural barriers for subsequent modeling, only socioeconomic and systemic impediments (i.e., time poverty, inability to afford costs, and lack of medical insurance) were included.

### **Structural Equation Modeling (SEM) variables**

To evaluate the "intention-action gap" and the disruptive effects of structural barriers, latent variables and exogenous covariates were operationalized within an adapted Health Belief Model (HBM) framework. Due to severe floor effects (positive response rates <1.2%), subjective fear indicators—including fear of testing, discrimination, and job loss—were excluded from the measurement model. Given the predominantly asymptomatic nature of chronic HBV infection, the traditional "Perceived Threat" construct was replaced by objective "HBV Knowledge" to serve as a stable proxy for cognitive appraisal.

The finalized latent constructs consisted of:

1. **Cues to Action**, measured by four binary items regarding information sources;
2. **HBV Knowledge**, comprising two indicators assessing transmission routes and preventive measures (scored 0–4);
3. **Preventive Intention**, evaluated via four Likert-type items reflecting willingness to screen, vaccinate, undergo diagnosis, and receive treatment across the care cascade;
4. **Actual Behavior**, defined by self-reported history of HBV screening and vaccination.

Three objective structural barriers—time poverty, economic constraints, and lack of medical insurance—were modeled as independent, exogenous observed covariates predicting both intention and behavior. Time poverty was defined as the inability to take time off work; economic constraints as the inability to afford out-of-pocket costs; and lack of insurance as having no localized basic medical insurance in Yantai. To account for the questionnaire's skip logic, participants who expressed willingness to utilize services were deterministically assigned a value of "0" for these barriers, as their willingness inherently indicated an absence of such impediments.

## Statistical analysis

Descriptive statistics and Chi-square tests were conducted to summarize demographic characteristics and compare serological positive rates across groups using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Spatial distribution mapping of the regional anti-HBs positive rates was generated using the *sf*, *ggplot2*, and *viridis* packages in R software (version 4.3.2).

Structural Equation Modeling (SEM) was employed to test the adapted HBM framework and evaluate the effects of structural barriers. Prior to model estimation, items measuring behavioral intention were reverse-coded so that higher scores consistently reflected stronger preventive motivation. To accommodate the categorical nature of the survey items and correct for potential non-normality, the model was estimated using the Robust Maximum Likelihood (MLR) estimator [14].

The SEM evaluated both the measurement and structural models simultaneously. Guided by Modification Indices (MI) and clinical rationale, a residual covariance was specified between diagnostic and treatment intentions to account for their shared variance within the post-screening care pathway. Model fit was assessed using robust fit indices, with acceptable fit defined as a Comparative Fit Index (CFI)  $\geq 0.90$ , Tucker-Lewis Index (TLI)  $\geq 0.90$ , Root Mean Square Error of Approximation (RMSEA)  $< 0.08$ , and Standardized Root Mean Square Residual (SRMR)  $< 0.08$  [15]. All SEM analyses were performed using the *lavaan* package (version 0.6-21) in R software (version 4.3.2), with two-tailed statistical significance defined at  $\alpha = 0.05$ .

## Results

### Characteristics of the study population

A total of 1,184 valid questionnaires were collected, yielding an effective response rate of 98.58%. As shown in Table 1, the questionnaire respondents were predominantly male (55.49%), with the majority aged between 20 and 45 years (63.77%). Regarding socioeconomic status, 63.01% reported an average monthly income below 5,000 RMB, and 90.03% lacked any form of local basic medical insurance. Occupationally, participants were primarily concentrated in manufacturing (57.26%), followed by the construction and service industries (accounting for a combined 24.32%).

The serological testing cohort included 2,364 participants. The cohort was similarly predominantly male (58.97%), with 56.26% aged between 20 and 45 years. Although industry and income data were not collected for the serological survey, no statistically significant differences were observed between the two cohorts regarding key demographic variables such as age and place of household registration ( $P > 0.05$ ), apart from a marginal difference in gender distribution ( $P = 0.047$ ). These findings indicate that both samples adequately represent the target population of internal migrant workers in Yantai and exhibit good comparability.

**Table 1. Basic characteristics of participants**

| Characteristic           | Questionnaire Survey (N=1184) | Serological Testing (N=2364) | P-value |
|--------------------------|-------------------------------|------------------------------|---------|
| Sex, n (%)               |                               |                              |         |
| Male                     | 657(55.49)                    | 1394(58.97)                  | 0.047   |
| Female                   | 527(44.51)                    | 970(41.03)                   |         |
| Age, n (%)               |                               |                              |         |
| 20-25 years              | 164(13.85)                    | 300(12.69)                   | 0.085   |
| 26-35 years              | 266(22.47)                    | 580(24.53)                   |         |
| 36-45 years              | 325(27.45)                    | 660(27.92)                   |         |
| 46-55 years              | 245(20.69)                    | 470(19.88)                   |         |
| >55 years                | 184(15.54)                    | 354(14.98)                   |         |
| Region, n (%)            |                               |                              |         |
| Same province            | 506(42.74)                    | 1050(44.42)                  | 0.099   |
| Other provinces          | 678(57.26)                    | 1314(55.58)                  |         |
| Industry, n (%)          |                               |                              |         |
| Manufacturing            | 678(57.26)                    | -                            | -       |
| Construction             | 128(10.81)                    | -                            |         |
| Service                  | 160(13.51)                    | -                            |         |
| Transportation           | 18(1.53)                      | -                            |         |
| Other                    | 200(16.89)                    | -                            |         |
| Monthly income, n (%)    |                               |                              |         |
| <3000 RMB                | 115(9.71)                     | -                            | -       |
| 3000-5000 RMB            | 631(53.30)                    | -                            |         |
| 5001-10000 RMB           | 346(29.22)                    | -                            |         |
| >10000 RMB               | 92(7.77)                      | -                            |         |
| Medical insurance, n (%) |                               |                              |         |
| No                       | 1066(90.03)                   | -                            | -       |
| Yes                      | 118(9.97)                     | -                            |         |

**Serological testing results and cross-validation**

Among the 2,364 migrant workers tested, the positive rate for protective antibodies (anti-HBs) was 51.10% (1,208/2,364), which is substantially lower than the 70% population immunity threshold recommended by the World Health Organization (WHO) (Figure 1A). The positive rate for HBsAg, indicating current active infection, was 4.23% (100/2,364).

To evaluate the reliability of the self-reported data, we cross-validated the self-reported history of HBV vaccination against the serological anti-HBs positivity rate. The questionnaire survey revealed that 44.08% (522/1,184) of respondents self-reported having "previously received the hepatitis B vaccine." This proportion was significantly lower than the actual serologically confirmed anti-HBs positive rate (51.10%) ( $\chi^2 = 15.34, P < 0.001$ ) (Figure 1B). Despite this statistical discrepancy, both metrics consistently indicated insufficient immune protection within this population.

**Spatial distribution of immune protection**

Analysis of anti-HBs positive rates in Yantai City revealed significant spatial heterogeneity ( $\chi^2 = 74.38, P < 0.001$ ), with a citywide average of 51.10% (1,208/2,364). As illustrated in Figure 2, the highest seroprevalence was observed in the Fushan industrial belt north of the city center (67.33%, 101/150). Zhifu District, an established commercial center with dense community health infrastructure, reported the second-highest rate (65.6%). Conversely, the lowest prevalence was recorded in Muping District (36.81%, 53/144), a predominantly service-based area in the eastern urban. Rates in other manufacturing-heavy districts, including Laizhou (48.8%) and Haiyang (54.2%), approximated the overall mean. Elevated immunity levels clustered in districts dominated by large-scale organized industries or comprehensive urban health networks, while lower rates were concentrated in areas reliant on dispersed, small-scale service enterprises (Table 2).

**Table 2. Distribution of anti-HBs positive rates among migrant workers by district, Yantai City**

| District            | No. tested | Anti-HBs positive n (%) | 95% CI    | Main industrial characteristics                     |
|---------------------|------------|-------------------------|-----------|-----------------------------------------------------|
| Zhifu               | 305        | 200 (65.6)              | 60.2–70.9 | Commerce, services                                  |
| Fushan              | 150        | 101 (67.3)              | 59.8–74.8 | Manufacturing (auto parts, equipment manufacturing) |
| Muping              | 144        | 53 (36.8)               | 28.9–44.7 | Services (catering, tourism, retail)                |
| Laishan             | 130        | 56 (43.1)               | 34.6–51.6 | High-tech industries                                |
| High-tech Zone      | 30         | 11 (36.7)               | 19.4–53.9 | High-tech industries                                |
| Longkou             | 240        | 120 (50.0)              | 43.7–56.3 | Manufacturing, energy                               |
| Laiyang             | 260        | 116 (44.6)              | 38.6–50.7 | Agriculture, food processing                        |
| Laizhou             | 260        | 127 (48.8)              | 42.8–54.9 | Machinery manufacturing, stone materials            |
| Penglai             | 120        | 63 (52.5)               | 43.6–61.4 | Tourism, wine                                       |
| Zhaoyuan            | 243        | 104 (42.8)              | 36.6–49.0 | Gold industry                                       |
| Qixia               | 140        | 69 (49.3)               | 41.0–57.6 | Agriculture (apples)                                |
| Haiyang             | 192        | 104 (54.2)              | 47.1–61.2 | Nuclear power, tourism                              |
| Huangbohai New Area | 150        | 84 (56.0)               | 48.1–63.9 | Manufacturing, high-tech                            |
| Total               | 2364       | 1208 (51.1%)            | 49.1–53.1 | -                                                   |

### Structural Equation Modeling Analysis

To test the underlying mechanisms driving hepatitis B protective behaviors and the effects of socioeconomic limitations, an MLR-based structural equation model (SEM) was estimated. The modified model demonstrated adequate fit to the data: Robust CFI = 0.937, Robust TLI = 0.916, Robust RMSEA = 0.061 (90% CI: 0.055-0.067), and SRMR = 0.064, confirming the appropriateness of the structural framework.

Standardized path coefficients ( $\beta$ ) and their significance levels are presented in Table 3, and the corresponding path diagram is shown in Figure 3. External Cues to Action were strongly and positively

associated with HBV knowledge ( $\beta = 0.894, P < 0.001$ ). However, HBV knowledge showed only a marginally significant positive effect on preventive intention ( $\beta = 0.192, P = 0.087$ ), suggesting that cognitive awareness alone is insufficient to generate strong preventive motivation.

The model also provided quantitative evidence for the intention-action gap. Preventive intention significantly predicted actual behavior ( $\beta = 0.655, P < 0.001$ ), confirming a functional pathway from motivation to action. Critically, however, this motivational process was substantially undermined at the intention-formation stage by objective structural barriers. Specifically, time poverty exerted the strongest negative effect on preventive intention ( $\beta = -0.563, P < 0.001$ ), followed by economic constraints ( $\beta = -0.278, P < 0.001$ ) and the lack of medical insurance ( $\beta = -0.056, P = 0.030$ ).

**Table 3. Path coefficients of the structural equation model**

| Hypothesized path                                           | Unstandardized coefficient (B) | S.E.  | Z-value | Standardized coefficient ( $\beta$ ) | P-value |
|-------------------------------------------------------------|--------------------------------|-------|---------|--------------------------------------|---------|
| HBV Knowledge $\leftarrow$ Cues to Action                   | 3.198                          | 0.160 | 20.016  | 0.894                                | < 0.001 |
| Preventive Intention $\leftarrow$ HBV Knowledge             | 0.110                          | 0.064 | 1.711   | 0.192                                | 0.087   |
| Preventive Intention $\leftarrow$ Time poverty              | -1.300                         | 0.092 | -14.190 | -0.563                               | < 0.001 |
| Preventive Intention $\leftarrow$ Economic constraints      | -0.841                         | 0.101 | -8.357  | -0.278                               | < 0.001 |
| Preventive Intention $\leftarrow$ Lack of medical insurance | -0.106                         | 0.049 | -2.166  | -0.056                               | 0.030   |
| Actual Behavior $\leftarrow$ Preventive Intention           | 0.438                          | 0.047 | 9.295   | 0.655                                | < 0.001 |

Note: The modified model demonstrated excellent fit to the data: Robust CFI = 0.937, Robust TLI = 0.916, Robust RMSEA = 0.061, and SRMR = 0.064.

## Discussion

By integrating self-reported data, serological biomarkers, and spatial analysis, this study shows that the gap between migrant workers' hepatitis B prevention intentions and their actual behaviors is driven primarily by structural barriers, not by inadequate knowledge. The structural equation model confirmed that, when external constraints are absent, preventive intention does translate into actual behavior ( $\beta = 0.655$ ). However, the formation of intention itself was substantially weakened by time poverty, economic constraints, and lack of medical insurance, with time scarcity exerting the strongest effect ( $\beta = -0.563$ ). The serological and spatial evidence reinforced this picture: only 51.10% of workers had protective anti-HBs antibodies—well below the WHO-recommended 70% threshold [5, 16]—and immune protection varied

across districts. Taken together, these findings indicate that the intention-action gap is shaped less by psychology than by socioeconomic structures that keep willingness from turning into clinic visits.

Models like the Health Belief Model assume that better knowledge and greater perceived threat lead to stronger motivation to act [6]. In our data, however, HBV knowledge showed only a marginal connection to preventive intention ( $\beta = 0.192$ ,  $P = 0.087$ ), which challenges that logic in this population [17]. In this population, external cues to action were strongly linked to knowledge acquisition ( $\beta = 0.894$ ), which meant health communication efforts succeeded in raising awareness. However, this increased awareness has not translated into correspondingly stronger health intentions. The pattern aligns with meta-analysis that changes in knowledge and attitudes are often insufficient to close the intention-behavior gap, especially in socioeconomically marginalized groups[7, 18]. The novel contribution of this study lies in its identification of specific structural factors that lead to a disconnect between knowledge and intention. The intentions reported by migrant workers do not stem from a lack of motivation or irrational health beliefs, but are constrained by the costs associated with taking action.

Among the three structural barriers, time poverty was the factor that most significantly influenced willingness to participate in prevention efforts, followed by financial constraints and lack of health insurance. This ranking reflects the realities of daily life for migrant workers in China. Most of them work in manufacturing, construction, or the service sector, where they face long working hours, strict shift schedules, and piece-rate pay[19]. Taking time off to visit a clinic for screening or vaccination often means losing income immediately, or even risking dismissal [20]. The fact that time outweighed cost does not mean cost is unimportant. It means that even when services are free—as the serological testing in this study was—the opportunity cost of time can still be too high for workers to afford [9]. This finding aligns with broader evidence that time is an underestimated social determinant of health, which can render nominally accessible services difficult to access in practice [21]. The effect of medical insurance was relatively small ( $\beta = -0.056$ ). A likely explanation is that China's basic health insurance schemes primarily cover inpatient care and offer limited reimbursement for outpatient preventive services[22]; consequently, having insurance has little effect on reducing perceived barriers to screening and vaccination [23].

Comparing self-reported vaccination history with serological anti-HBs test results provides an alternative perspective on the intention-action gap. Only 44.08% of questionnaire respondents said they had received the hepatitis B vaccine—significantly fewer than the 51.10% whose blood tests confirmed anti-HBs positivity. This discrepancy suggests that self-reporting, as the most common outcome measure in behavioral surveys, may underestimate the actual level of immune protection due to recall bias [10, 24]. There are at least two possible explanations for this: some workers may have received the vaccine through workplace vaccination campaigns or occupational health examinations but did not have it recorded in official vaccination records, leading to underreporting. Others may have acquired anti-HBs through natural infection without even realizing they had been exposed to the virus. Regardless of the scenario, both point to the same conclusion: the level of immune protection among migrant workers in Yantai is clearly insufficient. This contrast underscores a practical point—objective biomarkers hold value in behavioral research, particularly among populations where recall bias and social expectations may distort respondent reports [25].

The spatial analysis further revealed that immune protection is not evenly distributed across different regions of Yantai but is closely linked to the local industrial structure [26]. Industrial agglomeration zones such as Fushan District, dominated by large-scale manufacturing, exhibited relatively high anti-HBs positivity rates (67.33%), whereas service-oriented districts such as Muping recorded much lower rates (36.81%). This pattern plausibly reflects differential access to occupational health services[27]. Large manufacturing enterprises have standardized health management systems, pre-employment physical examinations, and routine vaccination programs covering all employees. In contrast, workers in service industries such as food service, retail, or tourism are more likely to be employed by small, scattered businesses, which are subject to weaker regulatory oversight and rarely implement organized health interventions. The pattern of immunity revealed by these data is not random. It reflects health inequalities influenced by the local economy. These findings suggest that public health interventions for migrant workers need to be adapted to each district's industrial mix and existing health infrastructure.

There are three implications for public health practice. First, interventions aimed at closing the intention-action gap must take time poverty seriously. Offering free services is necessary but not enough; immunization and screening programs need to be delivered at times and places that fit workers' schedules and locations. Workplace-based models—on-site vaccination at factories and construction sites, mobile health units during shift breaks, extended hours at community health centers—can reduce the opportunity cost of taking part [28]. Embedding hepatitis B screening and vaccination into routine occupational health examinations, and requiring employers to provide paid time off for preventive care, would further lower the time barrier [29]. Second, the geographic variation in immune protection calls for spatially targeted resource allocation. Public health authorities can use spatial heatmaps to direct outreach to underserved districts, particularly those where employment is dominated by small, dispersed service-sector businesses. Third, the limited role of health insurance suggests that simply expanding coverage may not change preventive behavior much, unless reimbursement is extended to cover outpatient preventive services such as adult vaccination. Reforming insurance schemes to reduce or eliminate out-of-pocket costs for hepatitis B screening and vaccination, alongside efforts to reduce time-related barriers, could together improve uptake.

## Strengths and limitations

This study has several strengths. The triangulation design—combining survey, serological, and spatial data—allowed findings from different sources to validate each other. Serological biomarkers served as an objective check on self-reported behavior, and the spatial analysis uncovered structural inequalities that a questionnaire-based study would have missed. In addition, bringing quantifiable structural barriers directly into the SEM framework allowed us to move from describing the intention-action gap to explaining it.

Several limitations should also be acknowledged. First, the cross-sectional design precludes causal inference; the pathways identified in the SEM represent theoretically guided associations, not confirmed causal relationships. Second, the questionnaire and serological cohorts did not perfectly overlap, so self-reported and biomarker data could not be linked at the individual level. Third, actual behavior was measured by self-reported screening and vaccination history, which is subject to recall bias. Fourth, the

study was conducted in a single city in eastern China, which limits generalizability to migrant populations elsewhere.

## Conclusions

In conclusion, this study shows that the gap between migrant workers' hepatitis B preventive intentions and their actual behavior is driven not by poor motivation or insufficient knowledge, but by structural barriers—above all, time poverty—that prevent intentions from turning into action. Reaching the WHO 2030 goal of eliminating viral hepatitis will require removing these barriers. That means delivering services at workplaces, directing resources to areas with the lowest coverage, and reforming insurance to reduce both the direct and indirect costs of prevention. For migrant workers facing high mobility, precarious employment, and limited access to care, closing the intention-action gap is not a matter of persuading individuals. It means changing the conditions in which they live and work [30].

## Declarations

**Ethics approval and consent to participate** The study protocol was reviewed and approved by the Preventive Medicine Ethics Committee of the Yantai Center for Disease Control and Prevention (No. YYLLS 2024-23). All methods were carried out in accordance with relevant guidelines and regulations. All participants signed an informed consent form prior to enrollment.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' contributions

YS performed statistical analysis and GIS mapping and drafted the manuscript. BL and NL coordinated the serological testing. PC and FH designed the study. All authors read and approved the final manuscript.

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## Figures

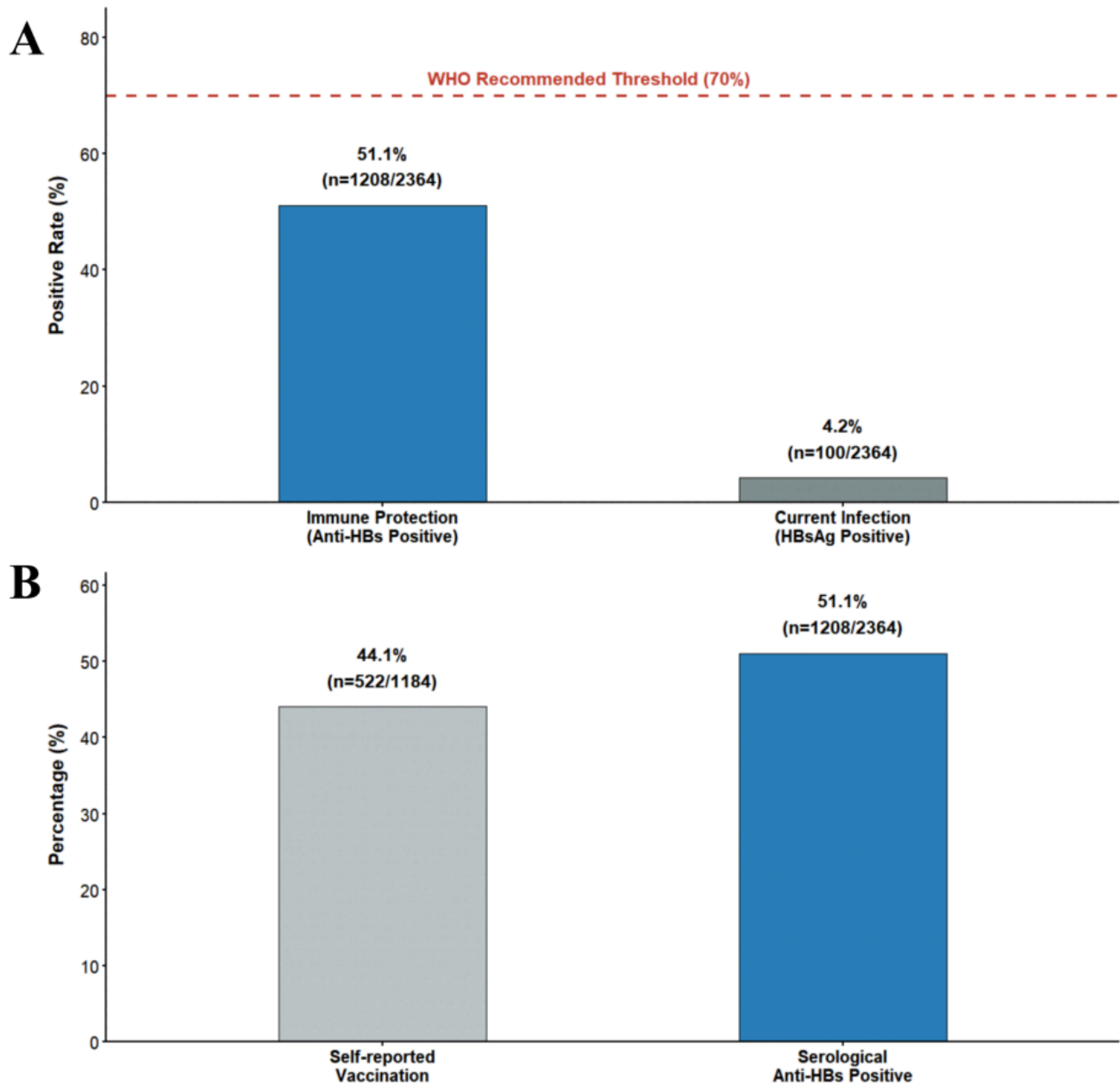


**Figure 1**

Serological markers of HBV and validation of self-reported vaccination.

(A) Prevalence of immune protection (anti-HBs positive) and current active infection (HBsAg positive) among migrant workers (N=2,364). The dashed line represents the 70% population immunity threshold recommended by the World Health Organization. (B) Cross-validation of vaccination status comparing self-reported history (N=1,184) with serologically confirmed anti-HBs positivity (N=2,364).

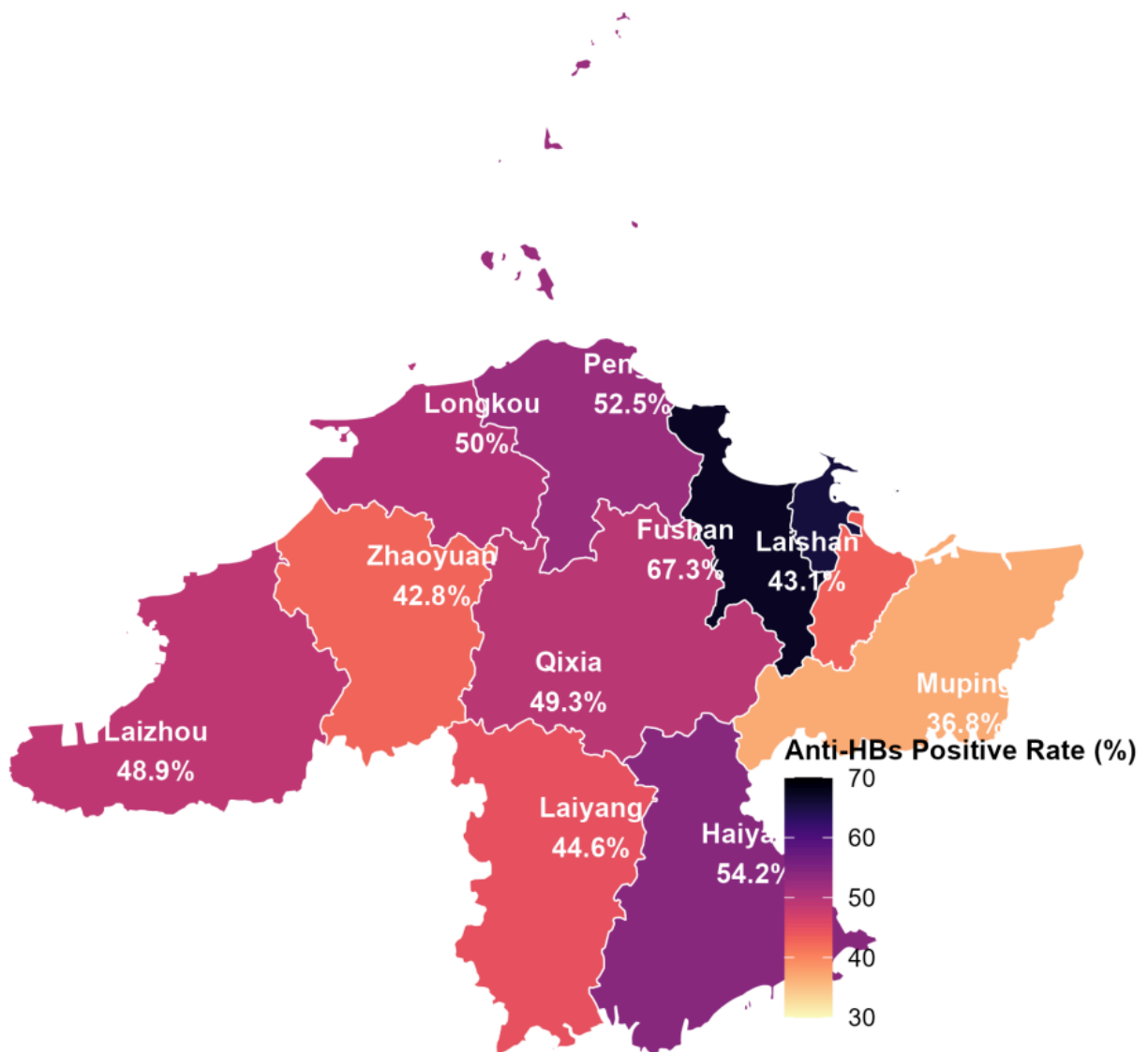


**Figure 2**

Spatial heterogeneity of HBV immune protection in Yantai City.

Spatial heatmap illustrating the variation in regional anti-HBs positive rates across the 13 districts of Yantai City. Colors represent the gradient of seroprevalence, with darker shades indicating higher levels of immune protection.

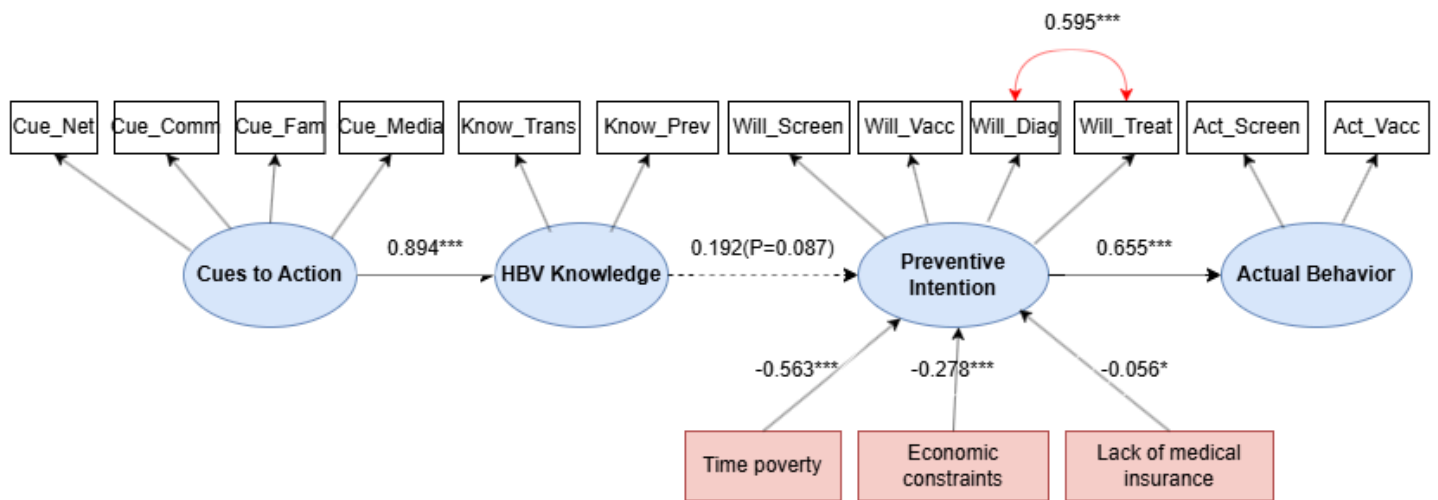


**Figure 3**

Path diagram of the structural equation model.

Standardized path coefficients ( $\beta$ ) are presented for the structural model. Solid lines indicate significant paths (\* $P < 0.05$ , \*\*\* $P < 0.001$ ), while the dashed line represents a non-significant path. Ovals denote latent constructs, and rectangles denote observed exogenous covariates (structural barriers). The red double-headed arrow indicates the residual covariance between diagnostic and treatment intentions.

## Supplementary Files

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- [SupplementaryMaterialS1.docx](#)