Scientific Reports

https://doi.org/10.1038/s41598-026-39227-7

Article in Press

Incidence and risk factors of LUTS associated with benign prostatic hyperplasia among Chinese men: findings from the CHARLS cohort

Received: 25 August 2025

Accepted: 3 February 2026

Published online: 26 February 2026

Cite this article as: Lv C., Zhao M., Meng Q. *et al.* Incidence and risk factors of LUTS associated with benign prostatic hyperplasia among Chinese men: findings from the CHARLS cohort. *Sci Rep* (2026). https://doi.org/10.1038/s41598-026-39227-7

Chao Lv, Mingyue Zhao, Qingyang Meng, Zexuan Lv, Xinze Xia, Jizhang Xing, Xiaowei Hao, Yangyang Wu, Kaikai Lv, Qing Yuan & Xu Zhang

Incidence and Risk Factors of LUTS Associated with Benign Prostatic Hyperplasia among Chinese Men: Findings from the CHARLS Cohort

Chao Lv, MD[1,2], Mingyue Zhao, MD[3], Qingyang Meng, MS[1], Zexuan Lv, MS[1,4], Xinze Xia, MS[5], Jizhang Xing, MD[2], Xiaowei Hao, MS[1], Yangyang Wu, MS[1], Kaikai Lv, MS[1], Qing Yuan, MD[1],Xu Zhang, MD[1]

[1]Senior Department of Urology, 3rd Medical Centre of PLA General Hospital, Beijing, 100039, China

[2]Department of Urology, PLA Air Force Medical Center, Beijing, 100142, China

[3]Department of Neurosurgery, PLA Air Force Medical Center, Beijing, 100142, China

[4]School of Medicine, Nankai University, Tianjin, 300071, China

[5]The Second Clinical Medical College, Shanxi Medical University, Shanxi, 030001, China

Mingyue Zhao and Qingyang Meng share the first authorship with Chao Lv.

Mingyue Zhao, Qing Yuan and Xu Zhang contributed equally to this work

Corresponding author.

Address: Senior Department of Urology, 3rd Medical Centre of PLA General Hospital, Beijing,100039, China. Tel: (86)010-66938008.

E-mail address: xzhang301@163.com;

Senior Department of Urology, 3rd Medical Centre of PLA General Hospital, Beijing 100039, China. Tel: (86)18910980422. E-mail address: qyuanmd@outlook.com；
Department of Neurosurgery, PLA Air Force Medical Center, Beijing 100142, China. Tel: (86)13671198211. E-mail address: mingyzhao@fmmu.edu.cn;

Abstract

Background: China's rapidly aging population is increasing the prevalence and economic burden of lower urinary tract symptoms associated with benign prostatic hyperplasia (LUTS-BPH). However, limited national-scale evidence exists regarding incidence, regional variation, and risk factor patterns among Chinese men.

Methods: Using data from the China Health and Retirement Longitudinal Study (CHARLS), we followed 6,713 men aged ≥ 45 years who were free of LUTS-BPH at baseline (2011–2012). LUTS-BPH onset was identified through biennial surveys (2013–2018). Age- and region-specific incidence rates were calculated, and multivariable Cox proportional-hazards models were used to identify independent risk factors.

Results: During a median follow-up of seven years (38,949 person-years), 1,175 incident LUTS-BPH cases were observed, yielding an overall incidence of 30.2 per 1,000 person-years (95% CI: 28.5–31.9). Incidence increased steadily with age until 75 years and then declined slightly. Predicted cumulative risks among 45-year-old men without LUTS-BPH were 16.7%, 30.6%, and 42.2% over 10, 20, and 30 years, respectively. Significant geographical heterogeneity was observed, with higher rates in Central and southern humid regions. Independent predictors included age, body-mass index, waist circumference, education, perceived health status, smoking, napping time, and residence region.These risk factors varied across different age groups (≤ 60, 60-75, and ≥ 75).

Conclusion: LUTS-BPH incidence in Chinese men rises with age and varies substantially by region and lifestyle. Modifiable factors such as central obesity and prolonged napping may guide early risk stratification, though causal relationships require validation in

future interventional and mechanistic studies. These findings support targeted, region-specific screening strategies for China's aging male population.

Keywords: Lower urinary tract symptoms (LUTS); benign prostatic hyperplasia (BPH); incidence; risk factors; CHARLS; obesity; geographical variation; aging population.

Introduction

China is facing a rapidly aging demographic, with nearly 30% of its population projected to be aged ≥ 60 years by 2050[1]. This demographic transition imposes increasing demands on healthcare systems managing chronic, quality-of-life–related disorders such as lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS-BPH). Traditionally, benign prostatic hyperplasia (BPH) was defined histologically by prostate enlargement; however, contemporary guidelines emphasize symptom-based diagnosis and patient-reported outcomes because they more directly reflect disease burden and treatment needs[2,3]. This paradigm shift marks a transition from anatomical classification toward function- and symptom-driven clinical management.

China's aging pace is among the fastest worldwide. National census data indicate a 3.2% annual increase in the ≥60 population between 1978 and 2020[4], while United Nations projections estimate a doubling of this demographic to 255 million by 2020, representing a growth rate of 2.8% between 2000 and 2020[5]. Such trends portend a major rise in LUTS-BPH burden, as global studies suggest that over half of elderly men experience LUTS[2], yet China still lacks longitudinal, population-based estimates of incidence.

Existing prevalence reports range from 13.1% to 22.7% across regional surveys[6,7], but true incidence rates remain unknown.

Western cohort studies report incidence rates between 3 and 45 per 1,000 person-years[8-10], but differences in genetics, diet, environmental exposures, and healthcare access limit extrapolation to Asian populations. Addressing this gap is critical to inform prevention, risk stratification, and health policy.

Using data from the China Health and Retirement Longitudinal Study (CHARLS)[11]—a nationally representative cohort with biennial follow-up—we quantified age- and region-specific incidence of LUTS-BPH and identified modifiable demographic, metabolic, and behavioral risk factors over a seven-year period. The goal was to elucidate the evolving epidemiology of LUTS-BPH in China's aging male population and to provide an empirical foundation for targeted prevention and early intervention strategies.

Materials and Methods

Study Design and Population

This longitudinal cohort study was based on data from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of adults aged 45 years and older. CHARLS implemented a computer-assisted, four-stage stratified sampling strategy to enroll participants from 450 villages or urban communities across 28 provinces during its baseline survey (2011–2012), with biennial follow-ups through 2018 (Wave 4). Details of the study design have been reported previously[11]. Population-weighted characteristics of the CHARLS cohort were consistent with the 2010 national census in age and marital structure[11].

Inclusion and Exclusion Criteria

Eligible participants were men without a previous physician diagnosis of BPH and without prostate cancer at baseline. Individuals fulfilling the operational definition of LUTS-BPH during follow-up were classified as incident cases, whereas those remaining symptom-free were defined as non-cases. Follow-up endpoints included newly diagnosed LUTS-BPH, death, loss to follow-up, or the conclusion of the 2018 wave[12].

Diagnostic criteria: The presence of ≥2 core symptoms across the following clusters:

• Voiding symptoms: straining, weak stream, or intermittency.

• Storage symptoms: frequency ≥8 times/24 hours and/or nocturia ≥2 times/night.

• Post-micturition symptoms: sensation of incomplete emptying or post-void dribbling.

Exclusion criteria: Participants were excluded if they had active urinary tract infection, neurological disorders affecting bladder function (e.g., spinal cord injury, Parkinson's disease, multiple sclerosis), history of prostate cancer or previous bladder outlet surgery, or bladder/urethral malignancy, urethral stricture, urolithiasis, or significant pelvic organ prolapse.

Data Source and Variable Definition

Data were collected through face-to-face, computer-assisted personal interviews conducted by trained fieldworkers. Datasets are publicly accessible through the CHARLS website (https://charls.charlsdata.com/pages/data/111/en.html), with variables linked by unique household or individual identifiers (IDs) (Table 1).

- Core demographic variables included age (grouped into 5-year intervals from 45–49 to ≥85 years), pulse rate, systolic and diastolic blood pressure, and geographical region, which was analyzed by both the seven major geographical divisions of China and by humidity level (wet vs. dry) according to decade-average precipitation[13]. (Table 2) Socioeconomic indicators comprised education (informal, junior, senior) and marital status (married/spouse, cohabiting/sham spouse, or unpartnered/no spouse). (Table 3)

- Health and lifestyle variables included anthropometric indices such as body mass index (BMI, categorized per Chinese standards[14]: <18.5, 18.5–24, 24–28, ≥ 28 kg/m²) and waist circumference. Self-reported health indicators covered general health perception (poor, fair, or good), chronic pain (per severity and part), smoking (yes/no), alcohol use (liquor, beer, ever-drinking status), sleep duration and nap time, social activity frequency, physical activity (MET-hours/week)[15], and depressive symptoms measured by the CES-D (Center for Epidemiologic Studies Depression) scale.
- All variables were harmonized across survey waves and coded according to clinical or population-based cutoffs.

Missing Data Handling

Multiple imputation using chained equations was applied to all study variables (including exposures and outcomes) to address missing data, generating 20 imputed datasets combined using Rubin's rules[16,17]. Sensitivity analyses were conducted to assess the robustness of imputations and are presented in the Supplementary Materials.

Statistical Framework

All covariates, including demographic, anthropometric, behavioral, and psychosocial factors, were pre-specified based on prior literature. Continuous variables such as age, blood pressure, and BMI were analyzed as both continuous and categorized measures to capture potential non-linear effects.

The incidence rate of LUTS-BPH was calculated as the number of new cases divided by total person-years at risk. Person-time was defined from baseline (2011) to the date of LUTS-BPH diagnosis, death, or the final follow-up. For descriptive visualization (Fig. 1), incidence was computed as:

$$\text{Incidence Rate} = (a + b + c) / (a + 3b + 5.5c + 7N) \times 1000‰,$$

where a, b, and c represent incident cases identified during the 2013, 2015, and 2018 waves, and N denotes non-converters. Age-specific incidence was further estimated in 5-year intervals. The cumulative incidence rate (CIR) was estimated as 1 - e^(-λT), where λ is the age-specific incidence rate (Fig. 2).

Cox proportional hazards models were used to identify independent predictors of LUTS-BPH, reporting hazard ratios (HRs) and 95% confidence intervals (CIs). The proportional hazards assumption was tested using Schoenfeld residuals, with no violations detected.

Sensitivity analyses were conducted to examine robustness under alternative assumptions regarding mortality and missing outcomes: (1) treating deceased or lost-to-follow-up participants as non-incident cases, counting full follow-up time; and (2) allocating half of their potential person-time (0.5 × person-years) to approximate uncertainty before censoring. The close agreement between complete-case, imputed, and sensitivity analyses indicated that missing data and differential follow-up had minimal impact on the robustness of the main findings.

All statistical analyses were conducted using R software (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria). A two-sided P value < 0.05 was considered statistically significant, and all confidence intervals were reported at the 95% level. All rates were expressed per 1,000 person-years and rounded to one decimal place for clarity.

Geospatial Data and Map Generation:

Provincial boundary shapefiles were obtained from the publicly accessible chinamap repository (https://github.com/GuangchuangYu/chinamap/). All maps (Figures 5–7) were generated in R version 4.2.1 using maptools, ggplot2, and plyr packages, following standard tutorials for Chinese province-level mapping.

Internal Validation and Model Assessment

Model performance was evaluated using internal validation based on bootstrap resampling with a 2:8 split-sample approach. Discriminative ability was assessed using the concordance index (C-statistic), while calibration was examined by comparing predicted versus observed event probabilities across risk deciles. The validation process aimed to assess the stability and generalizability of the multivariable Cox model within the CHARLS cohort.

Methodological Rigor

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval for all survey waves of the CHARLS was obtained from the Institutional Review Board of Peking University (IRB00001052–11015)[11]. All participants provided written informed consent prior to data collection. The CHARLS datasets used in this analysis are publicly available through its official repository[12]. Reporting of this cohort study followed the STROCSS 2021 guidelines[18].

Results

Cohort Characteristics

At baseline (2011), a total of 6,713 Chinese men were included, with a mean age of 59.3 ± 9.4 years. The average waist circumference was 84 cm, mean pulse rate 72.3 bpm, and average blood pressure 135/77 mmHg. Regarding educational attainment, 30.9% had no formal education, 53.2% had primary education, and 15.9% had secondary or higher education. Most participants were married or living with partners (87.6%), while 3.3% were cohabiting without legal marriage and 9.1% were single or unpartnered. Smoking and alcohol use were reported in 26.6% and 55.3% of participants, respectively (Tables 1-3).

During follow-up through 2018, 1,175 new cases of LUTS-BPH were identified, while 4,935 men remained event-free and 603 non-respondents were classified as non-incident (Tables 4). The total follow-up time accumulated to 38,949 person-years, including deceased participants (Table 5).

Incidence Rate Analysis

The overall incidence rate of LUTS-BPH was 30.2 per 1,000 person-years (95% CI: 28.5–31.9), consistent with the sensitivity analysis (31.1 per 1,000 person-years; 95% CI: 29.3–32.9). Age-stratified analysis revealed a steady increase in incidence from 18.3 per 1,000 person-years (ages 45–49; 95% CI: 15.5–21.5) to a peak of 43.6 per 1,000 person-years (ages 70–74; 95% CI: 36.4–51.9) (Fig. 3, Table 5). A strong linear association was observed between age and incidence (r^2 =0.91), corresponding to an increase of approximately 4.67 per 1,000 person-years per 5-year increment up to age 74. Beyond 75 years, the trend reversed (r^2 =0.89), showing a decline of 6.1 per 1,000 person-years per 5-year interval, reaching 23.2 per 1,000 person-years among men aged ≥ 85 years (95% CI: 7.5–54.1).

Cumulative Incidence of Projections

Age-specific cumulative risks of LUTS-BPH over 10-, 20-, and 30-year horizons are displayed in Fig. 4 and Table 6. For men aged 45 years at baseline, projected risks were 16.7% (10 years), 30.6% (20 years), and 42.2% (30 years). Corresponding projections for 60-year-old men were 31.5%, 53.0%, and 67.8%. The estimated lifetime cumulative risk reached approximately 73% by age 70 and plateaued thereafter.

Geographical and Environmental Variation

Marked regional heterogeneity was observed across provinces ($P < 0.05$). Hainan exhibited the highest incidence rate (69.2 per 1,000 person-years; 95% CI: 33.2–127.3), whereas Inner Mongolia had the lowest (13.2 per 1,000 person-years; 95% CI: 8.9–18.9) (Table 7, Fig. 5). Among the seven major geographic regions, Central China demonstrated the highest incidence (50.2 per 1,000 person-years; 95% CI: 42.8–58.6), while North China showed the lowest (21.1 per 1,000 person-years; 95% CI: 17.4–25.3) (Supplementary Table 1, Fig. 6). Stratification by climatic zone revealed a significantly higher incidence in humid regions compared to arid or temperate regions (31.8 vs. 26.9 per 1,000 person-years; $P < 0.05$) (Fig. 7, Supplementary Table 2).

Multivariable Cox Regression Analysis

Multivariable Cox proportional hazards modeling identified several independent predictors of incident LUTS-BPH (Fig. 8).

Anthropometric factors: Increasing age (HR = 1.03; 95% CI: 1.02–1.04), greater waist circumference (HR = 1.01; 95% CI: 1.01–1.02), and overweight status (BMI 24–28 kg/m² vs < 18.5 kg/m²; HR = 1.47; 95% CI: 1.03–2.09) were associated with higher risk.

Socioeducational factors: Compared with men without formal education, those with junior education (HR = 1.70; 95% CI: 1.42–2.04) and senior education (HR = 2.12; 95% CI: 1.70–2.65) had greater risk.

Behavioral factors: Smoking history (HR = 1.29; 95% CI: 1.08–1.54) and prolonged daytime napping (> 1 h/day; HR = 1.24; 95% CI: 1.07–1.44) were significant risk factors.

Regional factors: Residence in Central China was associated with increased risk (HR = 2.26; 95% CI: 1.55–3.29).

Protective factor: Positive self-rated health perception was inversely associated with risk (HR = 0.65; 95% CI: 0.53–0.81).

Age-stratified analyses revealed distinct risk patterns (Supplementary Figs. 1-3):

• < 60 years - chronic pain, depressive symptoms (CES-D), and residence in NW/SC/EC/CC regions;

• 60–74 years - overweight status (BMI 24–28) and Central China residence;

• ≥ 75 years - advanced age and higher education.

Model Performance and Calibration

The internally validated multivariable Cox model yielded a concordance index (C-statistic) of 0.67, reflecting modest but acceptable discriminative performance. Calibration analysis demonstrated close agreement between predicted and observed event probabilities, with no evidence of systematic over- or underestimation. Parameter estimates remained stable across bootstrap samples, supporting the model's internal reliability within this population-based cohort.

Discussion

Principal Findings

In this nationally representative cohort of Chinese men drawn from the CHARLS database, we reported, for the first time, the age-specific incidence of LUTS-BPH. Over a median follow-up of seven years, the overall incidence reached 30.2 per 1,000 person-years, with a strong age-dependent gradient peaking at 70–74 years and gradually declining thereafter, which aligns closely with rates reported in large Western cohort studies[8-10,19]. The estimated lifetime risk approached 70%, emphasizing the substantial burden of LUTS-BPH in China's aging male population.

This study extends prior cross-sectional and clinical estimates by providing longitudinal, population-based evidence of disease dynamics[6,7,9]. The observed " rise-and-fall " age trajectory is consistent with reports from Western cohorts[8,20,21] and likely reflects both biological progression and selective survival among elderly men—suggesting that risk plateaus may not indicate reduced susceptibility, but rather competing risks from comorbid aging processes.

Demographic, Metabolic, and Behavioral Determinants

Our multivariable analyses identified several independent predictors of LUTS-BPH onset. Anthropometric markers such as waist circumference and BMI emerged as consistent risk factors, in line with meta-analytic evidence linking central obesity to prostate enlargement, inflammation, and hormonal imbalance[22-27]. The positive association between higher educational attainment and risk may partly reflect diagnostic awareness, healthcare accessibility, or reporting bias, as shown in prior population-based studies[28-30].

Behavioral correlates were also notable. Smoking history was associated with increased risk, consistent with findings that nicotine exposure induces oxidative stress and impairs lower urinary tract vascularity[31,32]. Similarly, excessive napping—often associated with sedentary lifestyle patterns and disrupted circadian rhythms—was positively related to symptom incidence, reinforcing the view that lifestyle regularity is integral to urological health[33-35]. Conversely, a positive self-perception of health was associated with a lower likelihood of developing LUTS-BPH, suggesting that optimistic health cognition may buffer stress-related physiological responses[36]. In contrast, higher scores on the CES-D scale were significantly correlated with increased LUTS-BPH risk, particularly among men younger than 60 years, in line with previous population-based findings[37,38]. The dynamic association between depressive symptoms and LUTS-BPH, as noted by Charles et al., reflects a bidirectional interplay in which emotional distress may aggravate urinary dysfunction, while chronic urinary symptoms can in turn intensify psychological strain[7,39-41]. Collectively, the observed patterns reinforce that LUTS-BPH represents not only a local prostatic disorder but also a condition intertwined with systemic, psychosocial, and behavioral determinants.

Regional and Environmental Variations

Marked geographical heterogeneity was observed, with the highest incidence in Central and Southern humid regions. Environmental humidity[42-44] and dietary customs[45,46]—particularly high consumption of spicy or “warming” foods—may partially explain these patterns[25,47]. Within TCM philosophy, dampness (“shi”) is considered a pathogenic influence that obstructs qi flow, paralleling modern concepts of inflammation and metabolic imbalance[48]. Such cultural interpretations, though symbolic, offer complementary insight into population-level disparities observed in our epidemiologic data. (Fig.7)

Together, these findings illustrate that the development of LUTS-BPH in Chinese men arises from an intricate interplay among biological aging, metabolic health, lifestyle behaviors, and environmental context. Recognizing these interconnected pathways can guide more holistic prevention strategies that integrate medical, behavioral, and cultural perspectives.

Model Performance and Methodological Considerations

The discriminative performance of the multivariable model, as reflected by a C-statistic of 0.67, was modest but consistent with expectations for population-based analyses[49]. Unlike clinical prediction tools derived from specialized urological cohorts, this model was developed from a general community sample using broad demographic, metabolic, and behavioral indicators. Such exploratory frameworks are not designed for precise individual-level prediction but rather for identifying population-level risk patterns and underlying determinants. The observed level of discrimination therefore reflects the complex and multifactorial nature of LUTS-BPH in aging men. Despite its moderate C-index, the model exhibited sound calibration and stable coefficients, supporting its interpretive and epidemiological value for future hypothesis generation.

Strengths and Limitations

This study has several strengths. It represents the first longitudinal estimate of age- and region-specific LUTS-BPH incidence in a nationally representative Chinese cohort, integrating psychosocial and behavioral factors rarely assessed in previous studies. The use of multiple imputation and sensitivity analyses reduced bias from missing data, while the long follow-up strengthened temporal inference.

Nevertheless, some limitations must be acknowledged. First, the diagnosis relied on self-reported physician diagnoses and symptom-based criteria without imaging or urodynamic verification, potentially introducing misclassification[50]. Second, prostate-specific and hormonal biomarkers were unavailable, limiting biological interpretation. Third, residual confounding from unmeasured factors such as diet, genetics, or medication use cannot be excluded. Lastly, the moderate C-statistic indicates the model's exploratory rather than predictive role.

Future studies integrating longitudinal hormonal and inflammatory biomarkers, urological imaging, and multi-omics approaches will be critical to unraveling the biological pathways linking psychosocial, metabolic, and environmental determinants of LUTS-BPH.

Conclusions and Implications

In summary, this cohort study provides novel longitudinal evidence on the incidence and determinants of LUTS-BPH among Chinese men. Age, central obesity, education, smoking, depressive symptoms, and environmental humidity were independent risk factors, whereas positive health perception was protective.

These findings underscore the multifactorial and systemic nature of LUTS-BPH and highlight the need for integrative management strategies that combine lifestyle modification, mental health promotion, and early screening in high-risk populations. The results may inform both clinical counseling and population-level prevention as China's aging population continues to expand. Further validation incorporating urodynamic and biomarker data will be essential to enhance causal interpretation and predictive performance.

Funding

This work was supported by the **National Key R&D Program of China** (Grant Nos. **2023YFC3605305, 2022YFC3602900** and **2022YFC3602905**) and by the **Beijing Nova Program** (Grant No. **20220484230**).

Acknowledgments

The authors thank **Ms. Wen-Jie Liu**, Head Nurse of Urology Ward II, First Medical Center, Chinese PLA General Hospital, for her coordination of data collection and quality control. We also acknowledge all **CHARLS participants** for their sustained engagement and cooperation across survey waves. Appreciation is extended to the **CHARLS research team and field investigators** for their diligent efforts in participant follow-up, data verification, and data management that made this study possible.

Author Contributions

Conceptualization: Xu Zhang, Qing Yuan, and Mingyue Zhao.

Study design: Chao Lv, Mingyue Zhao, and Qingyang Meng.

Data acquisition: Qingyang Meng, Zexuan Lv, Xinze Xia, Xiaowei Hao, Yangyang Wu, and Kaikai Lv.

Data curation and quality control: Jizhang Xing, Qingyang Meng, and Kaikai Lv.

Formal analysis: Chao Lv and Qingyang Meng.

Methodology and statistical modeling: Chao Lv, Mingyue Zhao, and Qingyang Meng.

Visualization and figure preparation: Zexuan Lv, Xinze Xia, and Yangyang Wu.

Writing – original draft: Chao Lv and Qingyang Meng.

Writing – review & editing: Mingyue Zhao, Qing Yuan, and Xu Zhang.

Supervision: Xu Zhang and Qing Yuan.

Project administration: Xu Zhang and Qing Yuan.

References

1 United Nations Department of Economic and Social Affairs, Population Division. World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3. New York: United Nations; 2022. Accessed [March 15, 2025]. https://population.un.org/wpp/.

2 Chughtai, B. *et al.* Benign prostatic hyperplasia. *Nat Rev Dis Primers* **2**, 16031 (2016). https://doi.org:10.1038/nrdp.2016.31

3 Gratzke, C. *et al.* EAU Guidelines on the Assessment of Non-neurogenic Male Lower Urinary Tract Symptoms including Benign Prostatic Obstruction. *Eur Urol* **67**, 1099-1109 (2015). https://doi.org:10.1016/j.eururo.2014.12.038

4 Bao, J. *et al.* Current state of care for the elderly in China in the context of an aging population. *Biosci Trends* **16**, 107-118 (2022). https://doi.org:10.5582/bst.2022.01068

5 United Nations Department of Economic and Social Affairs, Population Division. World Population Prospects 2022: Custom Data Subset – Population Aged ≥60 Years, China, 2000–2020 (Median Variant). New York: United Nations; 2022. Accessed [March 15, 2025]. https://population.un.org/dataportal.

6 Xiong, Y., Zhang, Y., Li, X., Qin, F. & Yuan, J. The prevalence and associated factors of lower urinary tract symptoms suggestive of benign prostatic hyperplasia in aging males. *Aging Male* **23**, 1432-1439 (2020). https://doi.org:10.1080/13685538.2020.1781806

7 Zhang, W. *et al.* Depressive symptoms in individuals diagnosed with lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH) in middle-aged and older Chinese individuals: Results from the China Health and Retirement Longitudinal Study. *J Affect Disord* **296**, 660-666 (2022). https://doi.org:10.1016/j.jad.2021.09.045

8 Verhamme, K. M. *et al.* Incidence and prevalence of lower urinary tract symptoms suggestive of benign prostatic hyperplasia in primary care--the Triumph project. *Eur Urol* **42**, 323-328 (2002). https://doi.org:10.1016/s0302-2838(02)00354-8

9 Logie, J., Clifford, G. M. & Farmer, R. D. Incidence, prevalence and management of lower urinary tract symptoms in men in the UK. *BJU Int* **95**, 557-562 (2005). https://doi.org:10.1111/j.1464-410X.2005.05339.x

10 Platz, E. A. *et al.* Incidence and progression of lower urinary tract symptoms in a large prospective cohort of United States men. *J Urol* **188**, 496-501 (2012). https://doi.org:10.1016/j.juro.2012.03.125

11 Zhao, Y., Hu, Y., Smith, J. P., Strauss, J. & Yang, G. Cohort profile: the China Health and Retirement Longitudinal Study (CHARLS). *Int J Epidemiol* **43**, 61-68 (2014). https://doi.org:10.1093/ije/dys203

12 Zhao, Y., John Strauss, Xinxin Chen, Yafeng Wang, Jinquan Gong, Qin-qin Meng, Gewei Wang, Huali Wang. China Health and Retirement Longitudinal Study Wave 4 User's Guide. *National School of Development, Peking University* (2020). https://doi.org:http://charls.pku.edu.cn/

13 China's surface meteorological observation data refined for professional use. *National Center for Meteorological Data Science* (2005 [cited 2022-10-01]). https://doi.org:http://data.cma.cn

14 Chen, C. & Lu, F. C. The guidelines for prevention and control of overweight and obesity in Chinese adults. *Biomed Environ Sci* **17 Suppl**, 1-36 (2004). https://doi.org:https://pubmed.ncbi.nlm.nih.gov/15807475/

15 Organization, W. H. WHO Guidelines on Physical Activity and Sedentary Behaviour. World Health Organization; 2020. Accessed [April 12th, 2025]. https://www.who.int/publications/i/item/9789240015128.

16 Rubin, D. B. Multiple imputation for nonresponse in surveys. (1987). https://doi.org:10.1002/9780470316696

17 Yuan, Y. Multiple Imputation Using SAS Software. *Journal of Statistical Software* **45**, 1-25 (2011). https://doi.org:10.18637/jss.v045.i06

18 Mathew, G. *et al.* STROCSS 2021: Strengthening the reporting of cohort, cross-sectional and case-control studies in surgery. *Int J Surg* **96**, 106165 (2021). https://doi.org:10.1016/j.ijsu.2021.106165

19 Kristal, A. R. *et al.* Race/ethnicity, obesity, health related behaviors and the risk of symptomatic benign prostatic hyperplasia: results from the prostate cancer prevention trial. *J Urol* **177**, 1395-1400; quiz 1591 (2007). https://doi.org:10.1016/j.juro.2006.11.065

20 Clifford, G. M., Logie, J. & Farmer, R. D. How do symptoms indicative of BPH progress in real life practice? The UK experience. *Eur Urol* **38 Suppl 1**, 48-53 (2000). https://doi.org:10.1159/000052401

21 Logie, J. W., Clifford, G. M., Farmer, R. D. & Meesen, B. P. Lower urinary tract symptoms suggestive of benign prostatic obstruction--Triumph: the role of general practice databases. *Eur Urol* **39 Suppl 3**, 42-47 (2001). https://doi.org:10.1159/000052567

22 Passos, G. R., Ghezzi, A. C., Antunes, E., de Oliveira, M. G. & Mónica, F. Z. The Role of Periprostatic Adipose Tissue on Prostate Function in Vascular-Related Disorders. *Front Pharmacol* **12**, 626155 (2021). https://doi.org:10.3389/fphar.2021.626155

23 Alexandre, E. C. *et al.* Influence of the periprostatic adipose tissue in obesity-associated mouse urethral dysfunction and oxidative stress: Effect of resveratrol treatment. *Eur J Pharmacol* **836**, 25-33 (2018).

https://doi.org:10.1016/j.ejphar.2018.08.010
24 Klöting, N. *et al.* Insulin-sensitive obesity. *Am J Physiol Endocrinol Metab* **299**, E506-515 (2010). https://doi.org:10.1152/ajpendo.00586.2009
25 Gacci, M. *et al.* Central obesity is predictive of persistent storage lower urinary tract symptoms (LUTS) after surgery for benign prostatic enlargement: results of a multicentre prospective study. *BJU Int* **116**, 271-277 (2015). https://doi.org:10.1111/bju.13038
26 Ørsted, D. D. & Bojesen, S. E. The link between benign prostatic hyperplasia and prostate cancer. *Nat Rev Urol* **10**, 49-54 (2013). https://doi.org:10.1038/nrurol.2012.192
27 Gacci, M. *et al.* Metabolic syndrome and benign prostatic enlargement: a systematic review and meta-analysis. *BJU Int* **115**, 24-31 (2015). https://doi.org:10.1111/bju.12728
28 Ojewola, R. W., Oridota, E. S., Balogun, O. S., Ogundare, E. O. & Alabi, T. O. Lower Urinary Tract Symptoms: Prevalence, Perceptions, and Healthcare-Seeking Behavior amongst Nigerian Men. *World J Mens Health* **34**, 200-208 (2016). https://doi.org:10.5534/wjmh.2016.34.3.200
29 Väisänen, D. *et al.* Lifestyle-associated health risk indicators across a wide range of occupational groups: a cross-sectional analysis in 72,855 workers. *BMC Public Health* **20**, 1656 (2020). https://doi.org:10.1186/s12889-020-09755-6
30 Kupelian, V. *et al.* Prevalence of lower urinary tract symptoms and effect on quality of life in a racially and ethnically diverse random sample: the Boston Area Community Health (BACH) Survey. *Arch Intern Med* **166**, 2381-2387 (2006). https://doi.org:10.1001/archinte.166.21.2381
31 De Nunzio, C. *et al.* Metabolic syndrome and smoking are associated with an increased risk of nocturia in male patients with benign prostatic enlargement. *Prostate Cancer Prostatic Dis* **21**, 287-292 (2018). https://doi.org:10.1038/s41391-017-0003-z
32 Noh, J. W., Yoo, K. B., Kim, K. B., Kim, J. H. & Kwon, Y. D. Association between lower urinary tract symptoms and cigarette smoking or alcohol drinking. *Transl Androl Urol* **9**, 312-321 (2020). https://doi.org:10.21037/tau.2020.03.07
33 Fang, W. *et al.* Longer habitual afternoon napping is associated with a higher risk for impaired fasting plasma glucose and diabetes mellitus in older adults: results from the Dongfeng-Tongji cohort of retired workers. *Sleep Med* **14**, 950-954 (2013). https://doi.org:10.1016/j.sleep.2013.04.015
34 Lin, J. N. Correlates and influences of taking an afternoon nap on nocturnal sleep in Chinese elderly: A qualitative study. *Geriatr Nurs* **39**, 543-547 (2018). https://doi.org:10.1016/j.gerinurse.2018.03.002
35 Hu, Z., Tian, Y. & Hu, X. Associations between the risk of LUTS/BPH and the number and class of chronic diseases among middle-aged and elder men. *Sci Rep* **15**, 14965 (2025). https://doi.org:10.1038/s41598-025-00057-8
36 Stewart, W. F. *et al.* Patterns of health care utilization for low back pain. *J*

Pain Res **8**, 523-535 (2015). https://doi.org:10.2147/jpr.S83599

37 Rhee, S. J. *et al.* Longitudinal study of the relationship between lower urinary tract symptoms and depressive symptoms. *J Psychosom Res* **116**, 100-105 (2019). https://doi.org:10.1016/j.jpsychores.2018.11.015

38 Xie, Z., Liu, X., Hu, Z. & Dong, C. Longitudinal association between the dynamic nature of depression with lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH). *BMC Public Health* **24**, 1121 (2024). https://doi.org:10.1186/s12889-024-18618-3

39 Lung-Cheng Huang, C. *et al.* The association of healthcare seeking behavior for anxiety and depression among patients with lower urinary tract symptoms: a nationwide population-based study. *Psychiatry Res* **226**, 247-251 (2015). https://doi.org:10.1016/j.psychres.2014.12.056

40 Huang, C. L., Wu, M. P., Ho, C. H. & Wang, J. J. The bidirectional relationship between anxiety, depression, and lower urinary track symptoms: A nationwide population-based cohort study. *J Psychosom Res* **100**, 77-82 (2017). https://doi.org:10.1016/j.jpsychores.2017.07.008

41 Chung, R. Y. *et al.* Lower urinary tract symptoms (LUTS) as a risk factor for depressive symptoms in elderly men: results from a large prospective study in Southern Chinese men. *PLoS One* **8**, e76017 (2013). https://doi.org:10.1371/journal.pone.0076017

42 Yu, W. X. Integrated Chinese and Western Medicine Multidisciplinary Diagnosis and Treatment Guide for Benign Prostatic Hyperplasia (2022 Edition). *Chinese Journal of Andrology* **36**, 96-102 (2022). https://doi.org:10.3969/j.issn.1008-0848.2022.02.017

43 HUANG, Z. B. *et al.* The fundamental pathogenesis of Lingnan dampness syndrome lies in the deficiency of Yang Qi, which results in its deficiency to flourish. *Global Traditional Chinese Medicine* **14**, 1476-1479 (2021). https://doi.org:10.3969/j.issn.1674-1749.2021.08.027

44 Huang, X. F. *et al.* Correlation between TCM syndrome types and clinical symptoms of benign prostatic hyperplasia with chronic prostatitis. *Zhonghua Nan Ke Xue* **23**, 1111-1115 (2017). https://doi.org:10.13263/j.cnki.nja.2017.12.012

45 Xu, L., Zang, E., Sun, S. & Li, M. Main flavor compounds and molecular regulation mechanisms in fruits and vegetables. *Crit Rev Food Sci Nutr*, 1-21 (2022). https://doi.org:10.1080/10408398.2022.2097195

46 Zeng, Q. *et al.* Association between metabolic status and gut microbiome in obese populations. *Microb Genom* **7** (2021). https://doi.org:10.1099/mgen.0.000639

47 Yang, K. *et al.* Relationship between spicy flavor, spicy food intake frequency, and general obesity in a rural adult Chinese population: The RuralDiab study. *Nutr Metab Cardiovasc Dis* **28**, 252-261 (2018). https://doi.org:10.1016/j.numecd.2017.10.021

48 Ge, C. *et al.* A novel arthritis model induced by wind, damp, cold and heat in female rats. *Lab Anim* **54**, 433-442 (2020).

https://doi.org:10.1177/0023677219874844
49 Austin, P. C. & Steyerberg, E. W. Events per variable (EPV) and the relative performance of different strategies for estimating the out-of-sample validity of logistic regression models. *Stat Methods Med Res* **26**, 796-808 (2017). https://doi.org:10.1177/0962280214558972
50 Homma, Y. *et al.* Clinical guidelines for male lower urinary tract symptoms and benign prostatic hyperplasia. *Int J Urol* **24**, 716-729 (2017). https://doi.org:10.1111/iju.13401

Figure captions

Fig. 1. Flowchart of participant selection and incidence estimation framework.

The diagram summarizes the number of eligible male participants without LUTS-BPH at baseline (2011) and their follow-up status across the 2013, 2015, and 2018 survey waves. "a," "b," and "c" denote newly reported LUTS-BPH cases at successive follow-ups. Individuals lost to follow-up (X1–X3) were treated as non-cases in the primary analysis; a sensitivity analysis considered them as non-respondents. The incidence rate was estimated based on observed transitions in survey-reported status.

Abbreviation: IR, incidence rate.

Fig. 2. Estimated cumulative incidence of LUTS-BPH using two approximation methods.

The yellow curve illustrates a simplified linear approximation (CIR ≈ IR × T), while the blue curve represents estimates derived from an exponential model. Both curves depict cumulative risk patterns across age groups, reflecting incidence based on survey-reported onset.

Fig. 3. Age-specific incidence trends of LUTS-BPH among Chinese males.

Incidence estimates (per 1,000 person-years) are shown across 5-year age categories. Dashed lines represent 95% confidence intervals. Age-related patterns reflect event reporting from longitudinal CHARLS follow-up rather than clinical diagnostic ascertainment.

Fig. 4. Cumulative incidence risk of LUTS-BPH by age group.

Model-derived cumulative risks (%) across age intervals based on estimated incidence rates from follow-up data. These values represent estimated probabilities based on survey-reported LUTS-BPH onset.

Fig. 5. Provincial variation in estimated LUTS-BPH incidence in China.

Incidence estimates (per 1,000 person-years) are mapped by province. Hainan Province showed the highest estimated incidence, whereas Inner Mongolia exhibited the lowest. Observed variation may reflect differences in population structure, reporting patterns, healthcare access, or environmental factors.

Maps were generated using R version 4.2.1 with the maptools, plyr, and ggplot2 packages, based on publicly available shapefiles from the chinamap repository (https://github.com/GuangchuangYu/chinamap/), following the tutorial at https://felixfan.github.io/china-map/.

Fig. 6. Distribution of LUTS-BPH incidence across seven geographical regions.

Incidence estimates (per 1,000 person-years) are grouped according to standard Chinese regional divisions:

CC, Central China; **SC**, South China; **NE**, Northeast China; **NW**, Northwest China; **EC**, East China; **SW**, Southwest China; **NC**, North China.

Maps were generated using R version 4.2.1 with the maptools, plyr, and ggplot2 packages, based on publicly available shapefiles from the chinamap repository (https://github.com/GuangchuangYu/chinamap/), following the tutorial at https://felixfan.github.io/china-map/.

Fig. 7. Comparison of LUTS-BPH incidence between humid and arid regions.

Estimated incidence rates (per 1,000 person-years) are shown for regions categorized by long-term average humidity levels. Results reflect region-level environmental patterns associated with LUTS-BPH onset as reported in survey follow-up.

Maps were generated using R version 4.2.1 with the maptools, plyr, and ggplot2 packages, based on publicly available shapefiles from the chinamap repository (https://github.com/GuangchuangYu/chinamap/), following the tutorial at https://felixfan.github.io/china-map/.

Fig. 8. Multivariable Cox regression analysis of predictors of LUTS-BPH.

Hazard ratios (HRs) with 95% confidence intervals (CIs) for demographic, metabolic, behavioral, and psychosocial factors associated with incident LUTS-BPH.

Abbreviations: CI, confidence interval; HR, hazard ratio; BMI, body mass index; CESD, Center for Epidemiologic Studies Depression Scale. Regional abbreviations follow Fig. 6.

Supplementary Fig. 1. Predictors of LUTS-BPH among men

aged 45–59 years.

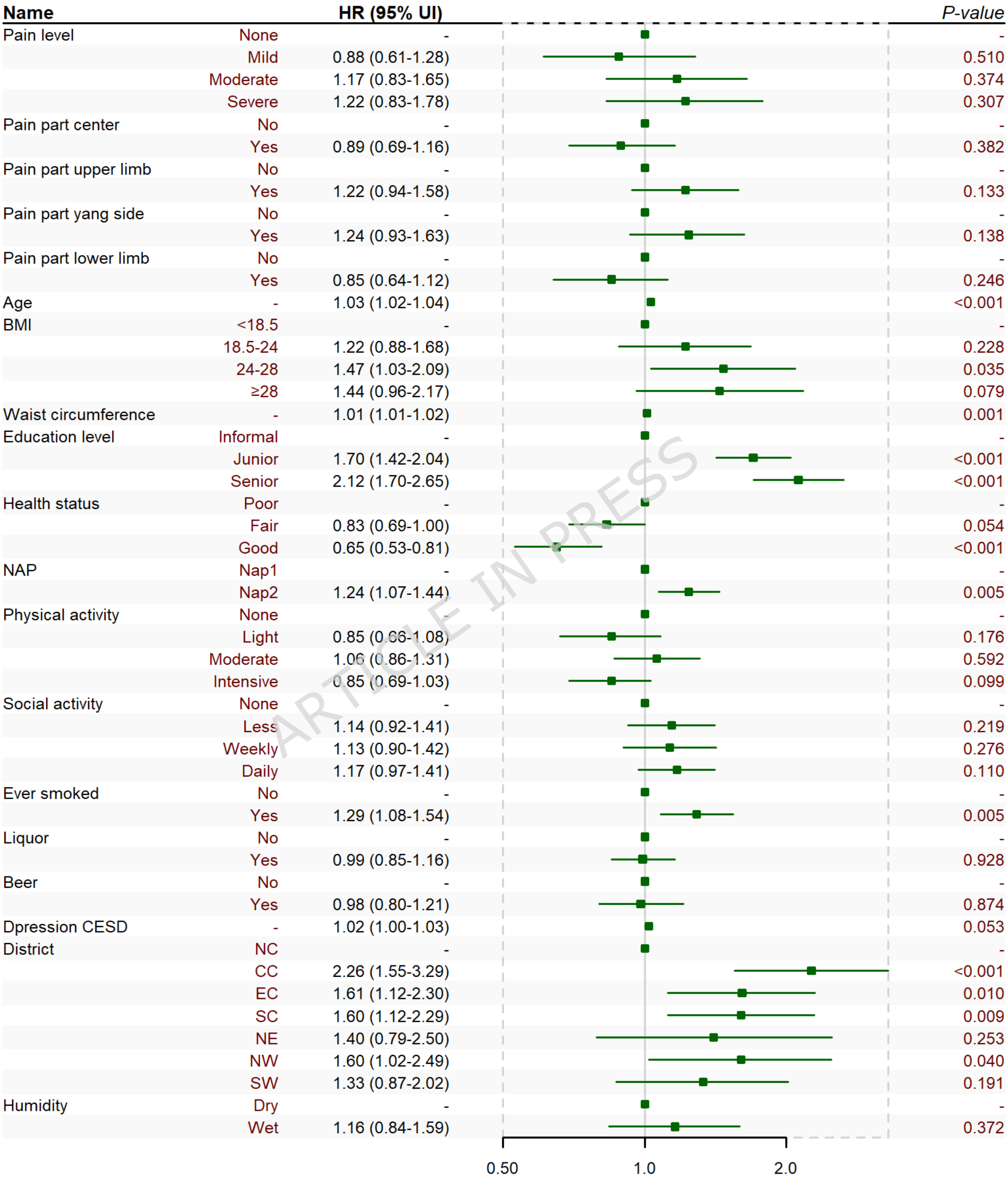
Cox regression estimates of age-specific and behavioral determinants of LUTS-BPH based on follow-up data.

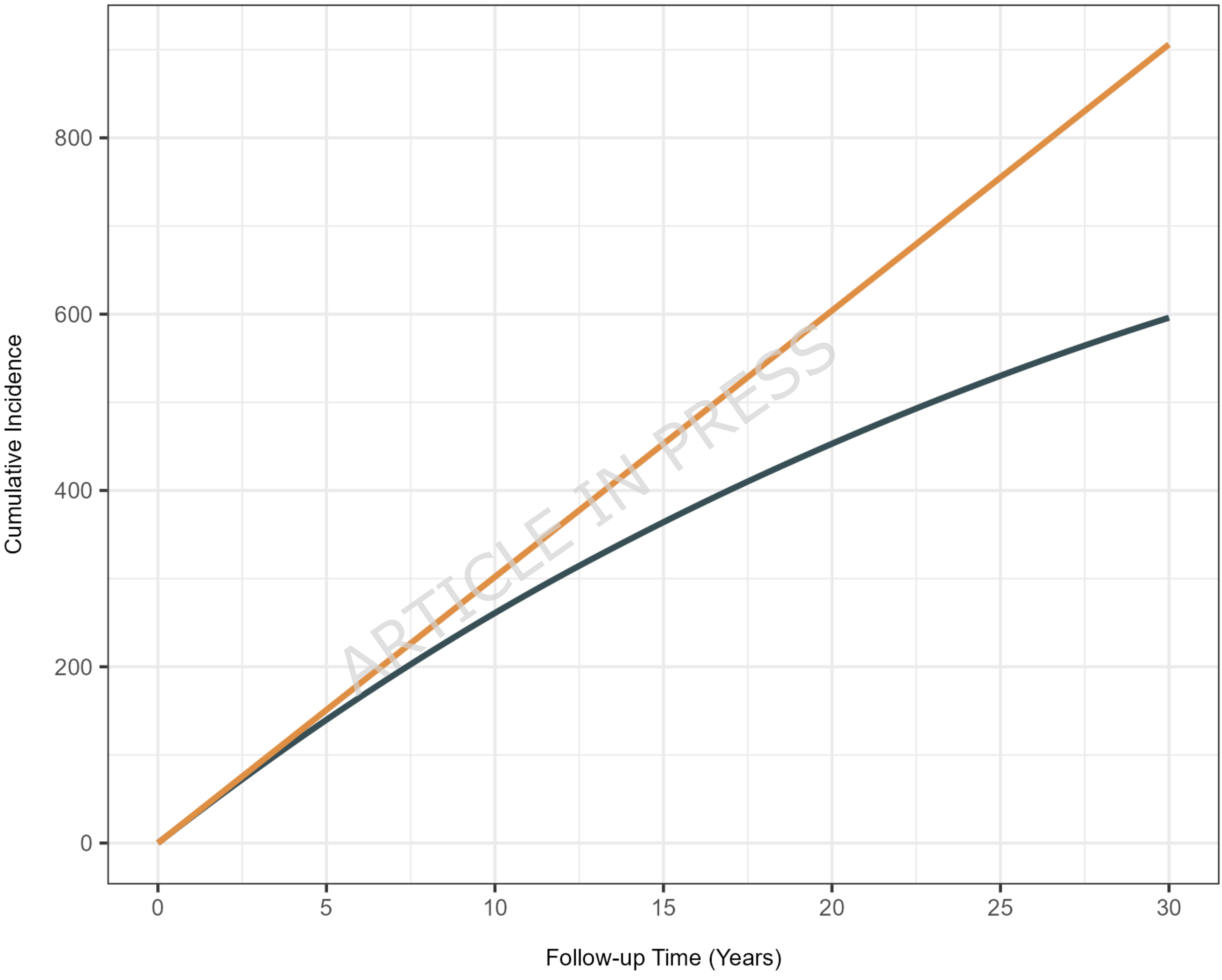
Supplementary Fig. 2. Predictors of LUTS-BPH among men aged 60–74 years.

Adjusted hazard ratios illustrating mid-to-late adulthood risk patterns.

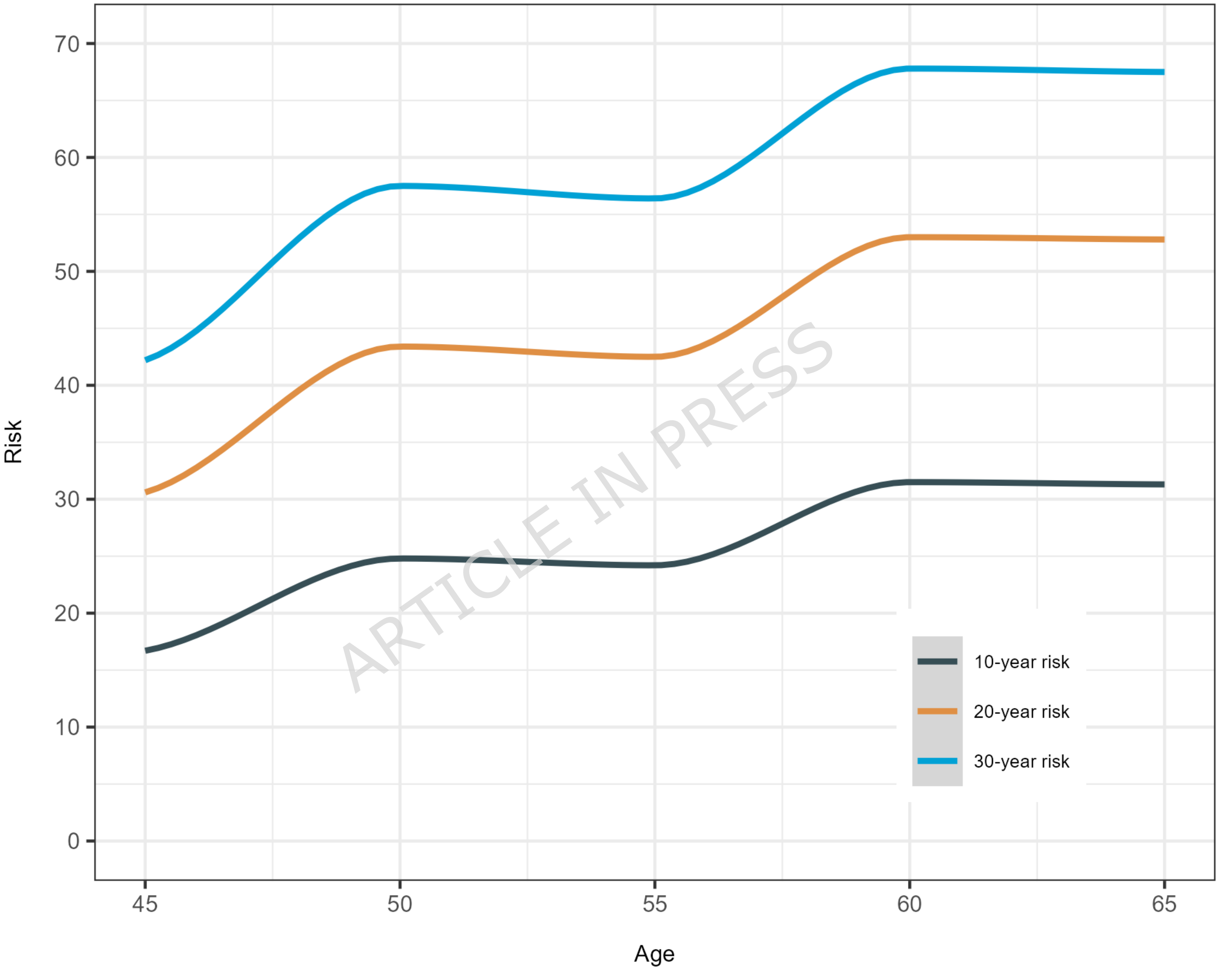
Supplementary Fig. 3. Predictors of LUTS-BPH among men aged ≥75 years.

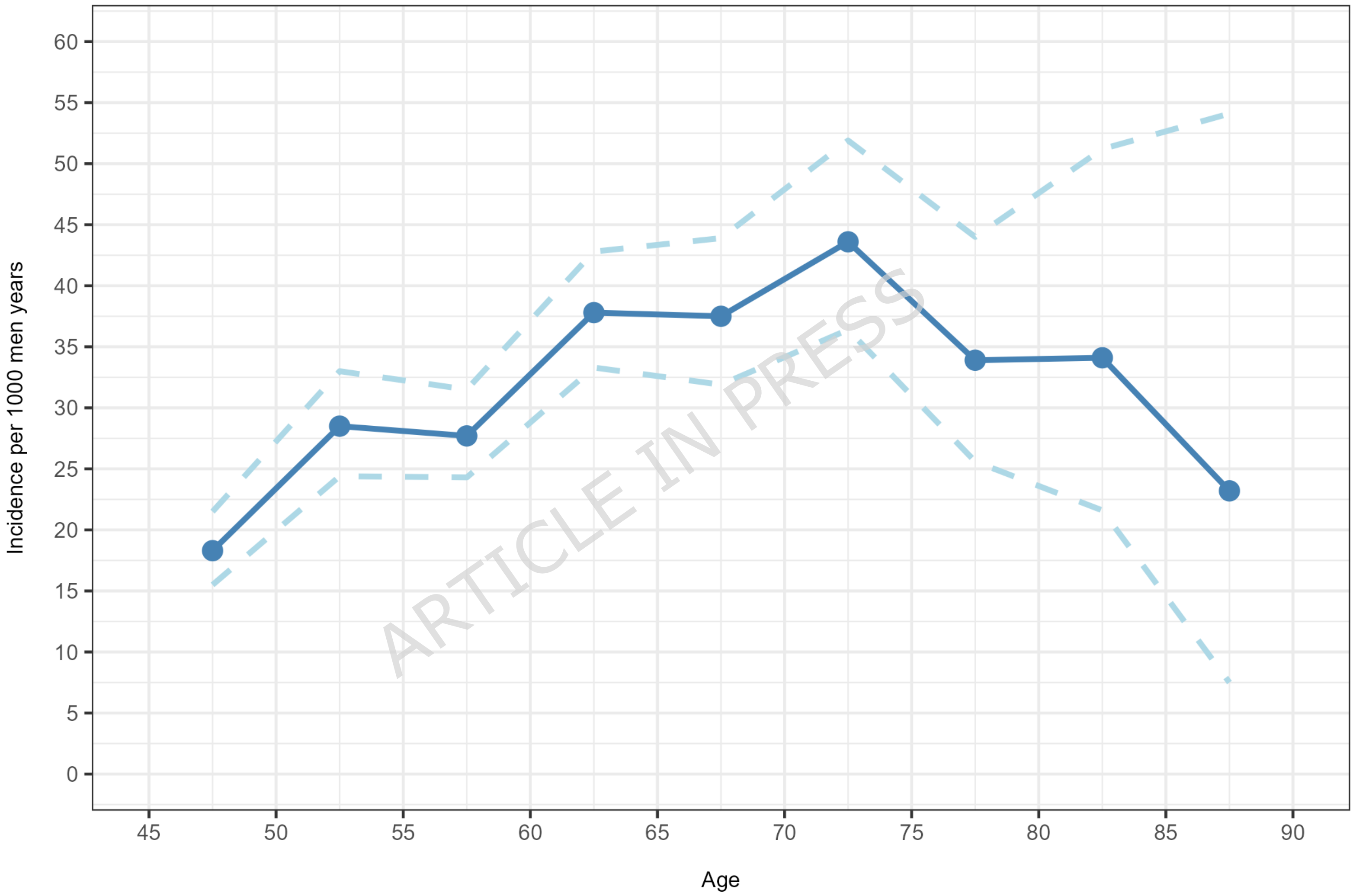
Late-life risk associations shown using age-stratified Cox regression models.

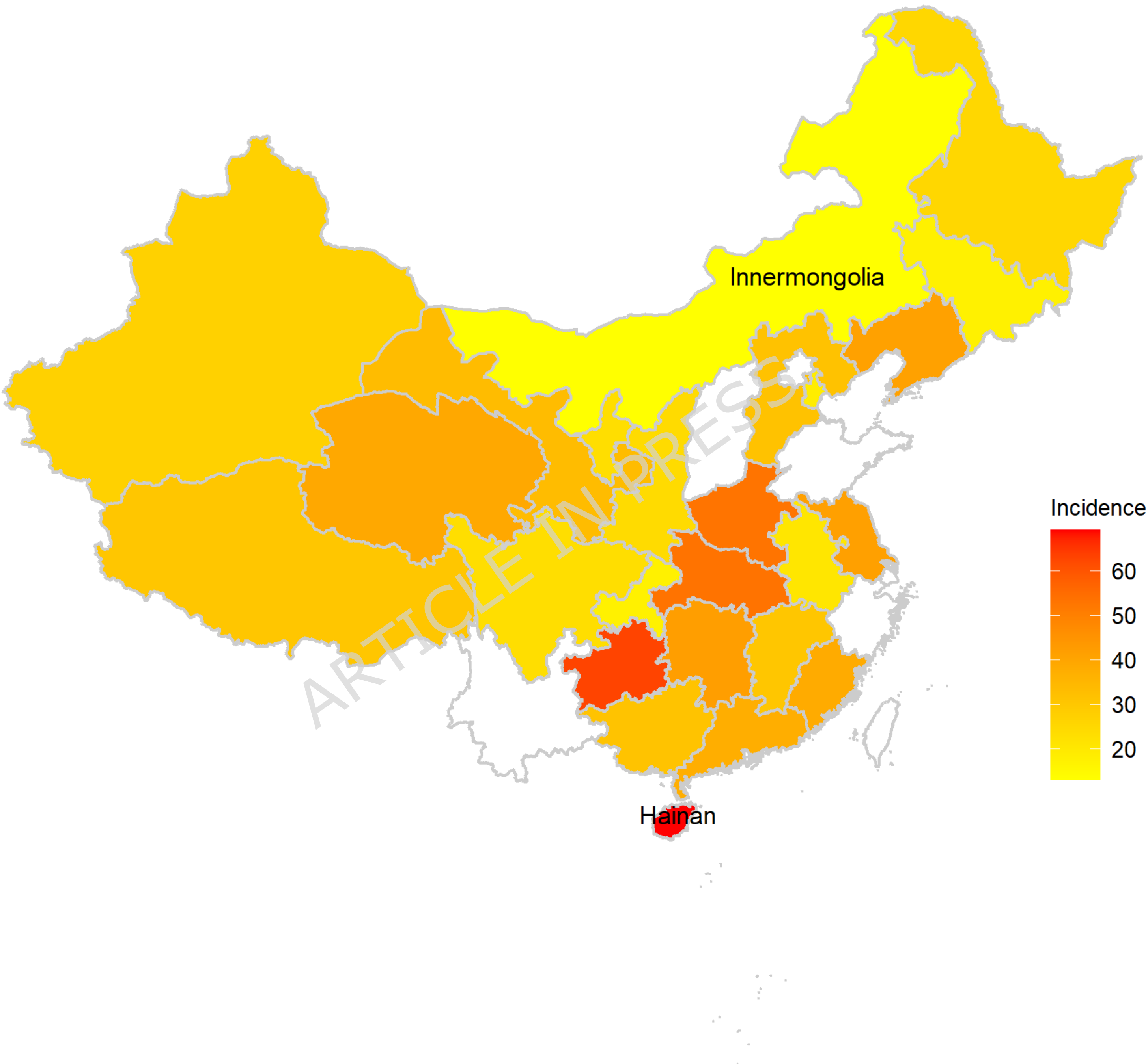

Name | HR (95% UI) | P-value
Pain level None - -
Mild 0.88 (0.61-1.28) 0.510
Moderate 1.17 (0.83-1.65) 0.374
Severe 1.22 (0.83-1.78) 0.307
Pain part center No - -
Yes 0.89 (0.69-1.16) 0.382
Pain part upper limb No - -
Yes 1.22 (0.94-1.58) 0.133
Pain part yang side No - -
Yes 1.24 (0.93-1.63) 0.138
Pain part lower limb No - -
Yes 0.85 (0.64-1.12) 0.246
Age - 1.03 (1.02-1.04) <0.001
BMI <18.5 - -
18.5-24 1.22 (0.88-1.68) 0.228
24-28 1.47 (1.03-2.09) 0.035
≥28 1.44 (0.96-2.17) 0.079
Waist circumference - 1.01 (1.01-1.02) 0.001
Education level Informal - -
Junior 1.70 (1.42-2.04) <0.001
Senior 2.12 (1.70-2.65) <0.001
Health status Poor - -
Fair 0.83 (0.69-1.00) 0.054
Good 0.65 (0.53-0.81) <0.001
NAP Nap1 - -
Nap2 1.24 (1.07-1.44) 0.005
Physical activity None - -
Light 0.85 (0.66-1.08) 0.176
Moderate 1.06 (0.86-1.31) 0.592
Intensive 0.85 (0.69-1.03) 0.099
Social activity None - -
Less 1.14 (0.92-1.41) 0.219
Weekly 1.13 (0.90-1.42) 0.276
Daily 1.17 (0.97-1.41) 0.110
Ever smoked No - -
Yes 1.29 (1.08-1.54) 0.005
Liquor No - -
Yes 0.99 (0.85-1.16) 0.928
Beer No - -
Yes 0.98 (0.80-1.21) 0.874
Dpression CESD - 1.02 (1.00-1.03) 0.053
District NC - -
CC 2.26 (1.55-3.29) <0.001
EC 1.61 (1.12-2.30) 0.010
SC 1.60 (1.12-2.29) 0.009
NE 1.40 (0.79-2.50) 0.253
NW 1.60 (1.02-2.49) 0.040
SW 1.33 (0.87-2.02) 0.191
Humidity Dry - -
Wet 1.16 (0.84-1.59) 0.372
0.50
1.0
2.0

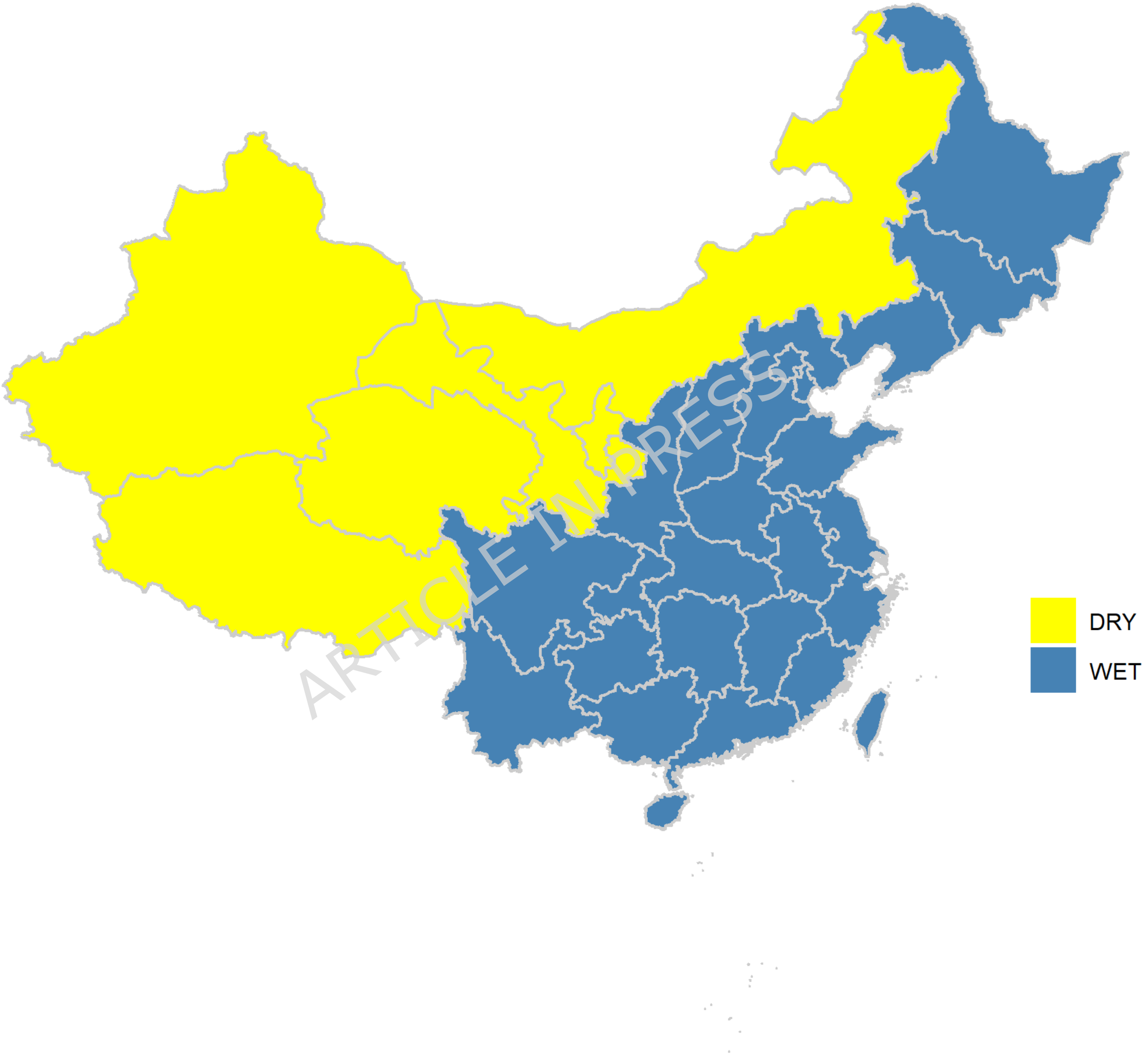


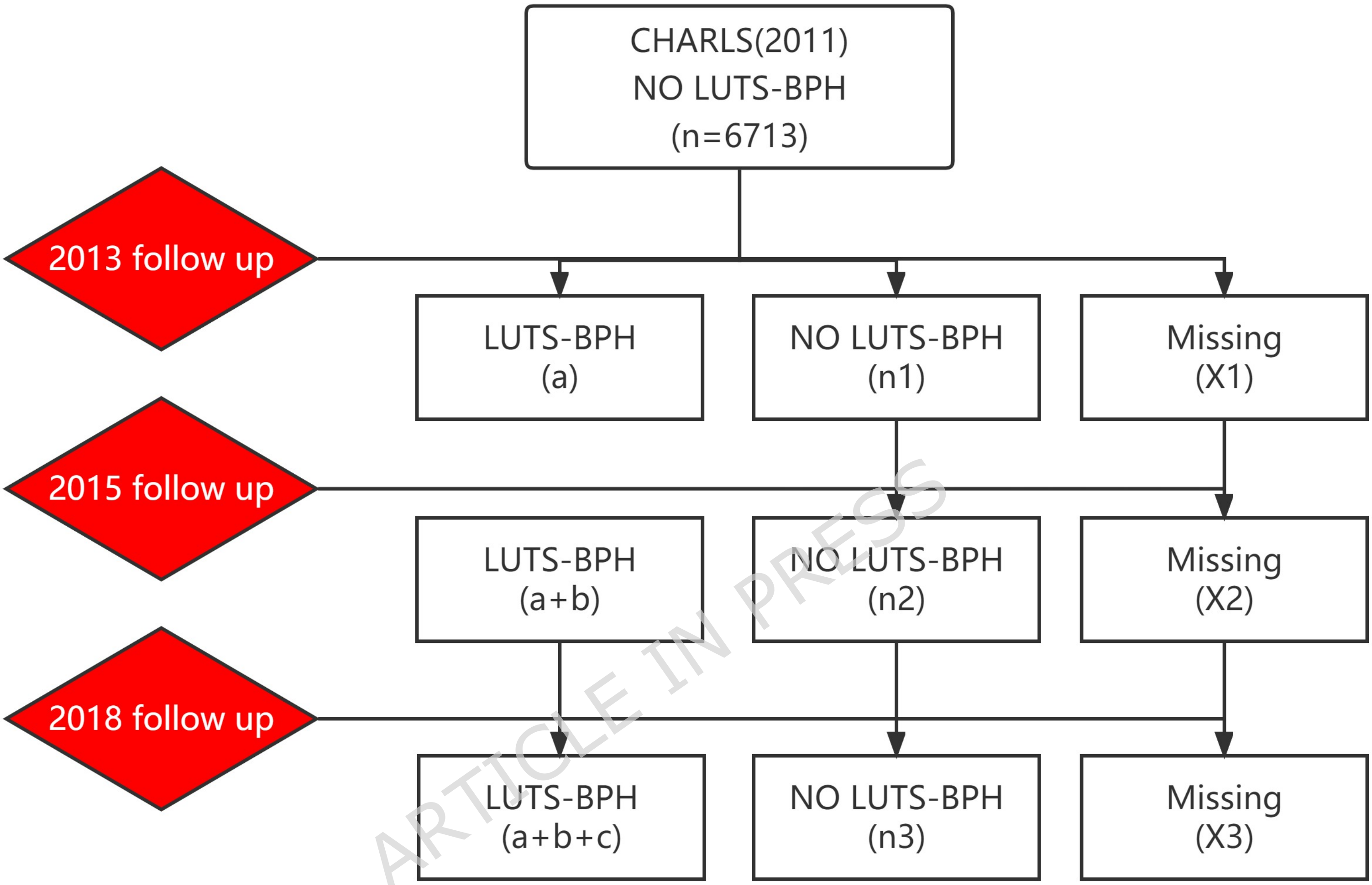
Cumulative Incidence
800
600
400
200
0
0
5
10
15
20
25
30
Follow-up Time (Years)


70
60
50
40
30
20
10
0
Risk
45
50
55
60
65
Age
10-year risk
20-year risk
30-year risk
ARTICLE IN PRESS


Incidence per 1000 men years
60
55
50
45
40
35
30
25
20
15
10
5
0
45
50
55
60
65
70
75
80
85
90
Age
ARTICLE IN PRESS


Innermongolia
Hainan
Incidence
60
50
40
30
20


DRY
WET

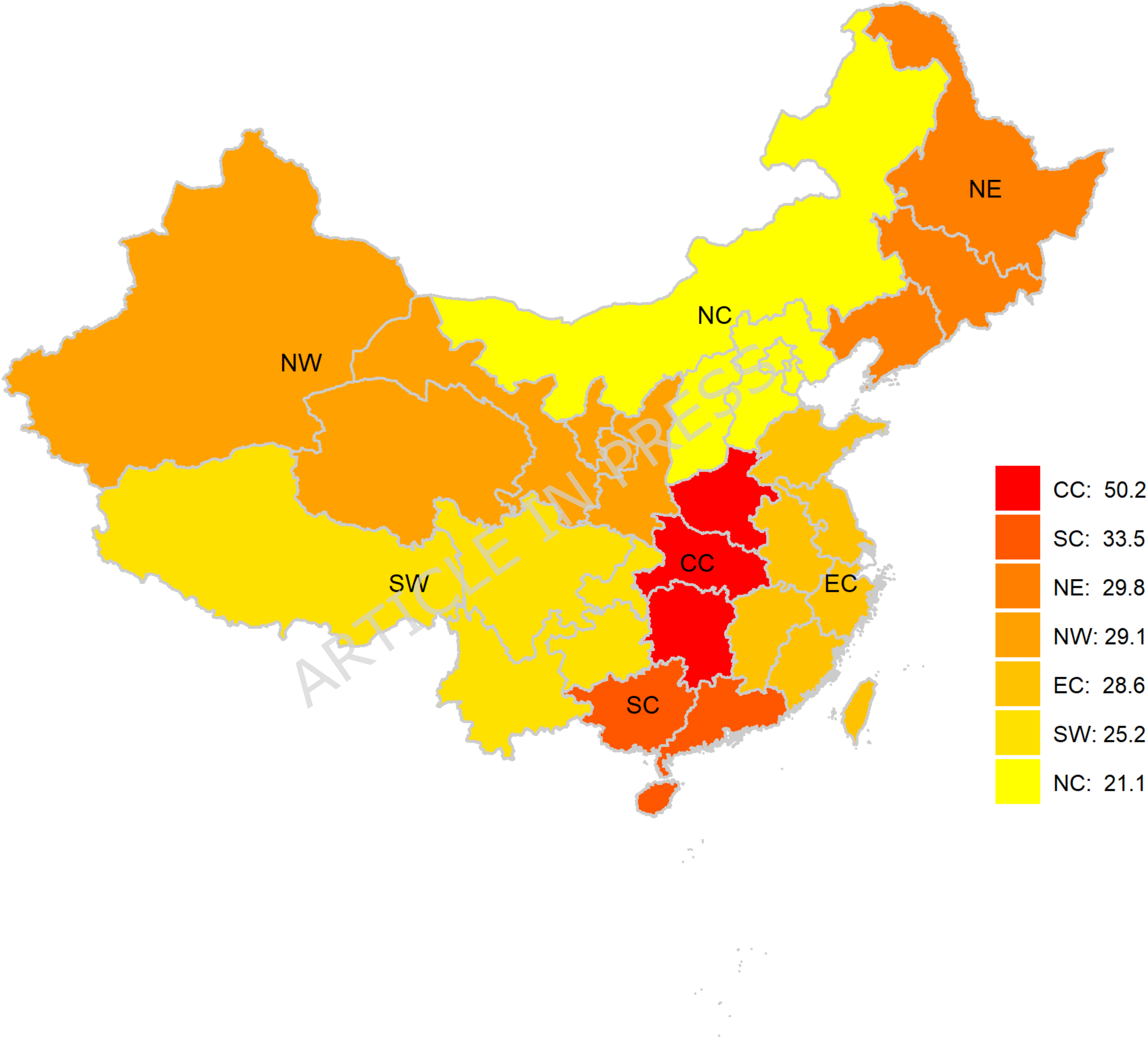


Main analysis formula

Incidence Rate=(a+b+c)/(a+3b+5.5c+7N)*1000‰ man-years N=n3+X3

Sensitivity analysis formula

Incidence Rate=(a+b+c)/(a+3b+5.5c+7N+X3*3.5)*1000‰ man-years N=n3


NE
NC
NW
CC
EC
SW
SC
CC: 50.2
SC: 33.5
NE: 29.8
NW: 29.1
EC: 28.6
SW: 25.2
NC: 21.1

Supplementary Table 2: Provinces and municipalities in CHA
categorized by geographic region and ambient humidity leve

Pronvince/municipality	Seven geographical regions	Humidity
Anhui	CE	W
Beijing	CN	W
Chongqing	SW	W
Fujian	CE	W
Gansu	NW	D
Guangdong	CS	W
Guangxi	CS	W
Guizhou	SW	W
Hainan	CS	W
He'nan	CC	W
Hebei	CN	W
Heilongjiang	NE	W
Hu'nan	CC	W
Hubei	CC	W
Inner mongolia	CN	D
Jiangsu	CE	W
Jiangxi	CE	W
Jilin	NE	W
Liaoning	NE	W
Ningxia	NW	D
Qinghai	NW	D
Shandong	CE	W
Shanghai	CE	W
Shaanxi	NW	W
Shanxi	CN	W
Sichuan	SW	W
Tianjin	CN	W
Tibet	SW	D
Xinjiang	NW	D
Yunnan	SW	W
Zhejiang	CE	W
Hongkong	CS	W
Macao	CS	W

CC: Central China, SC: South China, NE: Northeast China, N
China, EC: East China, SW: Southwest China, and NC: North

ARLS
el

NW: Northwest
China; W: wet,

Supplementary Table 3: Grouping of

	Variable content in the CHARLS
Highest level of education	
informal	(1)No formal education (illiterate); (2)Did not finish primary school but capable of reading and/or writing
junior	Sishu/home school; Elementary school; Middle school
senior	High school; vocational school; Two-/Three-Year College/Associate degree; Four-Year College/Bachelor's degree; Master's degree; Doctoral
Marital status	
spouse	Married with spouse present
sham-spouse	Married but not living with spouse temporarily for reasons such as work
no-spouse	Separated; Divorced; widowed; Never married
Self-perception of health status	
good	Da001:(1)Excellent□Da001:(2)Very good□Da001:(3)Good; DA002:(6)Very good, DA002:(7) Good
fair	Da001:(4) Fair; DA002:(8)Fair
poor	Da001:(5) Poor; DA002:(9)Poor , DA002:(10)Very poor
Degree of chronic pain	
none	DA041: (2) No
mild	DA043:(1) Mild
moderate	DA043:(2) Moderate
severe	DA043:(3) Severe
Location of pain	
center	DA042:(1)Head ,(15)Neck
upper limb	DA042:(2)Shoulder,(3)Arm,(4)Wrist,(5)Fingers
front side	DA042:(6)Chest,(7)Stomach
back side	DA042:(8)Back,(9)Waist,(10)Buttocks
lower limb	DA042:(11)Leg,(12)Knees,(13)Ankle,(14)Toes

Actual Sleep	
T1	DA049:<6h
T2	DA049:≥6h
A nap after lunch	
Nap1	DA050□≤1h
Nap2	DA050□□1h
Physical activit	
none	DA051:A(no),B(no),C(no)
light	DA051:C(yes)
moderate	DA051:B(yes)
intensive	DA051:A(yes)
Frequency of social activity in the	
none	DA056:12
less	DA057:3
week	DA057:2
daily	DA057:1
Ever smoked	
YES	DA059 (yes)
NO	DA059 (no)
Drinking alcohol	
YES	DA067:1,DA069:3 (more than once a month)
NO	DA067:2,DA067:3,DA069:1,DA069:2 (less than once a month)
Drinking liquor	
YES	DA068:1 (yes)
NO	DA068:1 (no)
Drinking beer	
YES	DA068:2 (yes)
NO	DA068:2 (no)
CESD scale for depress	DC009-DC018
BMI (kg/m^2)	Weight/Height^2

CESD: Center for Epidemiological

Supplementary Table 7: The provincial-level incidence rates of LUTS-BPH in mainland China

	Positive (n)	Negative (n)	Total	Time at risk	Incidence rate (per 1000 man-years)	95% CI (lower)	95% CI (upper)
Hainan	10	19	29	144.5	69.2	33.2	127.3
Guizhou	10	20	30	158.5	63.1	30.3	116
Hubei	35	83	118	656	53.4	37.2	74.2
Henan	91	229	320	1713.5	53.1	42.8	65.2
Hunan	36	119	155	856	42.1	29.5	58.2
Jiangsu	48	164	212	1152.5	41.6	30.7	55.2
Liaoning	14	46	60	340	41.2	22.5	69.1
Qinghai	32	115	147	812	39.4	27	55.6
Fujian	11	43	54	285.5	38.5	19.2	68.9
Guangdong	65	230	295	1735	37.5	28.9	47.8
Gansu	108	455	563	3222.5	33.5	27.5	40.5
Hebei	61	271	332	1911	31.9	24.4	41
Hongkong	96	420	516	3007.5	31.9	25.9	39
Macao	54	248	302	1705.5	31.7	23.8	41.3
Guangxi	61	270	331	1937.5	31.5	24.1	40.4
Jiangxi	41	186	227	1345	30.5	21.9	41.4
Tibet	39	180	219	1278.5	30.5	21.7	41.7
Xinjiang	98	506	604	3587	27.3	22.2	33.3
Heilongjiang	15	83	98	588.5	25.5	14.3	42
Shannxi	32	196	228	1319	24.3	16.6	34.2
Ningxia	41	248	289	1758.5	23.3	16.7	31.6
Sichuan	45	279	324	1931.5	23.3	17	31.2
Anhui	55	390	445	2638.5	20.8	15.7	27.1
Tianjin	24	191	215	1283	18.7	12	27.8
Jilin	2	18	20	113.5	17.6	2.1	63.7
Chongqing	21	184	205	1204	17.4	10.8	26.7
Innermongolia	30	345	375	2264.5	13.2	8.9	18.9

LUTS-BPH, lower urinary tract symptoms suggestive of benign prostatic hyperplasia; CI, confidence

Supplementary Table 6: Age-stratified cumulative incidence of LUTS-BPH among Chinese

Age	Risk in 10 years (%)	Risk in 20 years (%)	Risk in 30 years (%)
<50	16.7	30.6	42.2
50-54	24.8	43.4	57.5
55-59	24.2	42.5	56.4
60-64	31.5	53	67.8
65-69	31.3	52.8	67.5
70-74	35.3	58.2	73
75-79	28.8	49.2	63.8
80-84	28.9	49.4	64
>84	20.7	37.1	50.1

LUTS-BPH, lower urinary tract symptoms suggestive of benign pr

Supplementary Table 1: The structural linkage between househ

	1-2	3-4	5-6	7	8-9
household ID	XX	XX	XX	X	XX
representative	Provinc	City	County	Village	Househol
individual ID	XX	XX	XX	X	XX
representative	Provinc	City	County	Village	Househol

ID□identifiers□The household ID consisted of 9 digits, and t
consisted of 11 digits, each with a distinct representative;

old IDs and individual

10-11
ld
XX
Individual

the individual ID
X represents an

Supplementary Table 5: Age-specific incidence rates of LUTS-BPH among Chinese males

Age	Positive (n)	Negative (n)	Time at risk	Incidence rate (per 1000 man-years)	95% CI (lower)	95% CI (upper)
<50	149	1153	8140	18.3	15.5	21.5
50-54	174	830	6110	28.5	24.4	33
55-59	236	1180	8506.5	27.7	24.3	31.5
60-64	250	909	6610.5	37.8	33.3	42.8
65-69	155	585	4130	37.5	31.9	43.9
70-74	127	434	2911	43.6	36.4	51.9
75-79	56	280	1652	33.9	25.6	44
80-84	23	123	673.5	34.1	21.6	51.2
>84	5	44	215.5	23.2	7.5	54.1
Total	1175	5538	38949	30.2	28.5	31.9

LUTS-BPH, lower urinary tract symptoms suggestive of benign prostatic hyperplasia; CI, confidence

Supplementary Table 4: Baseline demographic characteristics and univariate statistical analysis

	LUTS-BPH Negative	LUTS-BPH Positive	*P*
Total	N=5538	N=1175	<0.001
Province (%)			<0.001
Anhui	390 (7.0)	[illegible] (4.7)	
Chongqing	184 (3.3)	[illegible] (1.8)	
Fujian	43 (0.8)	[illegible] (0.9)	
Gansu	455 (8.2)	[illegible] (9.2)	
Guangdong	230 (4.2)	[illegible] (5.5)	
Guangxi	270 (4.9)	[illegible] (5.2)	
Guizhou	20 (0.4)	[illegible] (0.9)	
Hainan	19 (0.3)	[illegible] (0.9)	
Hebei	271 (4.9)	[illegible] (5.2)	
Heilongjiang	83 (1.5)	[illegible] (1.3)	
Henan	229 (4.1)	[illegible] (7.7)	
Hongkong	420 (7.6)	[illegible] (8.2)	
Hubei	83 (1.5)	[illegible] (3.0)	
Hunan	119 (2.1)	[illegible] (3.1)	
Innermongolia	345 (6.2)	[illegible] (2.6)	
Jiangsu	164 (3.0)	[illegible] (4.1)	
Jiangxi	186 (3.4)	[illegible] (3.5)	
Jilin	18 (0.3)	[illegible] (0.2)	
Liaoning	46 (0.8)	[illegible] (1.2)	
Macao	248 (4.5)	[illegible] (4.6)	
Ningxia	248 (4.5)	[illegible] (3.5)	
Qinghai	115 (2.1)	[illegible] (2.7)	
Shannxi	196 (3.5)	[illegible] (2.7)	
Sichuan	279 (5.0)	[illegible] (3.8)	
Tianjin	191 (3.4)	[illegible] (2.0)	
Tibet	180 (3.3)	[illegible] (3.3)	
Xinjiang	506 (9.1)	[illegible] (8.3)	
Seven geographical regions (%)			<0.001
NC	807 (14.6)	[illegible] (9.8)	
CC	431 (7.8)	[illegible] (13.8)	
EC	783 (14.1)	[illegible] (13.2)	
SC	1187 (21.4)	[illegible] (24.3)	
NE	147 (2.7)	[illegible] (2.6)	
NW	1520 (27.4)	[illegible] (26.5)	
SW	663 (12.0)	[illegible] (9.8)	
Humidity = wet (%)	3689 (66.6)	[illegible] (70.4)	0.014
Age (years/mean (SD))	59.06 (9.64)	60.63 (8.95)	<0.001

Waist circumference [cm/mean (SD)]	83.59 (12.05)	85.98 (12.84)	<0.001
Pulse [bpm/mean (SD)]	72.29 (11.05)	[illegible] (10.66)	0.962
SBP [mmHg/mean (SD)]	134.54 (59.52)	[illegible] (65.93)	0.452
DBP [mmHg/mean (SD)]	76.51 (12.64)	[illegible] (12.13)	0.26
Education level (%)			<0.001
Informal	1793 (32.4)	[illegible] (23.8)	
Junior	2919 (52.7)	[illegible] (55.3)	
Senior	826 (14.9)	[illegible] (20.9)	
Marital status (%)			0.222
Spouse	4833 (87.3)	[illegible] (89.1)	
Sham spouse	189 (3.4)	[illegible] (2.9)	
None-spouse	516 (9.3)	[illegible] (8.0)	
Pain level (%)			<0.001
None	4218 (76.2)	[illegible] (69.6)	
Mild	379 (6.8)	[illegible] (7.4)	
Moderate	451 (8.1)	[illegible] (11.2)	
Severe	490 (8.8)	[illegible] (11.7)	
Pain (Center)=Yes (%)	535 (9.7)	[illegible] (11.7)	0.035
Pain (Upper limb)=Yes(%)	637 (11.5)	[illegible] (15.4)	<0.001
Pain (YIN side)=Yes(%)	482 (8.7)	[illegible] (10.1)	0.134
Pain (YANG side)=Yes(%)	867 (15.7)	[illegible] (20.1)	<0.001
Pain (Lower limb)=Yes(%)	778 (14.0)	[illegible] (18.8)	<0.001
Self-perception of heath status (%)			<0.001
Poor	1263 (22.8)	[illegible] (30.5)	
Fair	2660 (48.0)	[illegible] (47.7)	
Good	1615 (29.2)	[illegible] (21.8)	
Duration of sleep= T2 (%)	4146 (74.9)	[illegible] (73.3)	0.272
Nap = Nap2 (%)	2939 (53.1)	[illegible] (60.2)	<0.001
Physical activities (%)			0.003
None	3451 (62.3)	[illegible] (64.4)	
Light	507 (9.2)	[illegible] (9.4)	
Moderate	584 (10.5)	[illegible] (12.4)	
Intensive	996 (18.0)	[illegible] (13.8)	
Social activities (%)			0.011
None	2779 (50.2)	[illegible] (45.8)	
Less	828 (15.0)	[illegible] (14.3)	
Weekly	707 (12.8)	[illegible] (14.1)	
Daily	1224 (22.1)	[illegible] (25.8)	
Ever smoked= Yes (%)	1424 (25.7)	[illegible] (30.6)	0.001
Liquor= Yes (%)	1737 (31.4)	[illegible] (28.7)	0.076
Beer = Yes (%)	895 (16.2)	[illegible] (14.0)	0.078
Alcohol= Yes (%)	3076 (55.5)	[illegible] (54.2)	0.423
Depression scores of CESD (mean (SD))	8.94 (4.47)	9.53 (4.46)	<0.001

BMI (kg/m^2) (%)			<0.001
<18.5	382 (6.9)	62 (5.3)	
18.5-24	3322 (60.0)	626 (53.4)	
24-28	1399 (25.3)	339 (28.9)	
≥28	435 (7.9)	146 (12.4)	

CC: Central China, SC: South China, NE: Northeast China, NW: Northwest China, EC: East China, SW: