ORIGINAL RESEARCH ARTICLE

Changes in Behavioral Risk Factors for Diabetes in Indonesia: Evidence from National Surveys Before and After the COVID-19 (2018 and 2023)

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ABSTRACT

Background: This study assessed whether associations between key behavioral risk factors and diabetes mellitus (DM) changed between 2018 and 2023.

Methodology: A repeated cross-sectional analysis was conducted using pooled data from Riskesdas 2018 and SKI 2023, including 54,299 adults aged ≥15 years. DM was defined using fasting or 2-hour postprandial glucose. Poisson regression with robust variance estimated adjusted prevalence ratios (PRs), including interaction terms for survey year.

Results: Low physical activity remained associated with higher DM prevalence (PR = 1.11; 95% CI: 1.03-1.20), with no significant change over time. Dietary risk showed an inverse association with DM (PR = 0.79; 95% CI: 0.71-0.88), which was significantly attenuated over time (PR interaction = 1.27; 95% CI: 1.09-1.48). A similar pattern was observed for smoking (PR = 0.75; interaction PR = 1.18). Alcohol consumption became inversely associated with DM in 2023 (interaction PR = 0.55; 95% CI: 0.31-0.96), although no significant association was observed overall.

Conclusions: Low physical activity remained a consistent risk factor for diabetes in Indonesia, while other behavioral associations varied between 2018 and 2023, underscoring the need for continuous surveillance and behavior-based interventions.

Keywords: Behavior, COVID-19, Diabetes Mellitus, Indonesia, National Survey, Risk Factors

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INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disorder that affects over 537 million adults globally as of 2021, with numbers expected to rise sharply.[1] This burden is especially prominent in low- and middle-income countries, including Indonesia.[2] National data from Riskesdas 2018 and SKI 2023 indicate an increasing prevalence of DM, highlighting the need to understand contributing behavioral factors.[3,4]

Modifiable behaviors such as unhealthy diet, physical inactivity, smoking, and alcohol use play a central role in diabetes risk. The COVID-19 pandemic further disrupted lifestyle patterns and access to healthcare, potentially influencing these behavioral determinants. Evidence shows a risk of new-onset diabetes mellitus after COVID-19,[5] alongside disruptions in non-communicable disease management services.[6] These contextual changes are critical, especially considering the established link between physical activity and diabetes risk and documented shifts in physical fitness during pandemic lockdowns.[7,8] Furthermore, the Indonesian context specifically saw challenges in diabetes management and complications due to the COVID-19 lockdown.[9]

Despite growing evidence on how the pandemic affected health behaviors and diabetes prevalence separately, few studies have examined whether associations between behavioral risk factors and diabetes have changed after the COVID-19 period using nationally representative data. This study aimed to assess temporal differences in the associations between smoking, alcohol use, dietary risk, and physical activity with diabetes mellitus by comparing two national survey periods (2018 and 2023) using a pooled repeated cross-sectional model.

METHODOLOGY

Study Design and Data Sources: This repeated cross-sectional study used secondary data from the 2018 National Basic Health Survey (Riskesdas) and the 2023 Indonesia Health Survey (SKI), both conducted by the Ministry of Health. Both surveys used comparable multistage stratified cluster sampling designs and standardized data collection procedures to ensure cross-year comparability. All analyses were conducted using Stata version 14 (Stata Corp, College Station, TX, USA) with survey (svy) commands.

Sampling and Study Population: The study included respondents aged 15 years and above who had complete information on blood glucose levels and covariate information. A total of 36,094 respondents from Riskesdas 2018 and 18,205 respondents from SKI 2023 met the inclusion criteria. Survey sampling weights, clustering, and stratification were applied to produce nationally representative estimates. Survey weights were applied consistently in all descriptive and regression analyses to ensure correct population estimates and variance calculations.

Derivation of Study Sample: The derivation of the study sample from Riskesdas 2018 and SKI 2023 is presented in Figure 1. The initial total respondents comprised 1,012,290 for Riskesdas 2018 and 877,531 for SKI 2023. After excluding respondents aged less than 15 years (303,507 from Riskesdas 2018 and 239,353 from SKI 2023), the number of eligible respondents aged ≥15 years was 713,783 for Riskesdas 2018 and 638,178 for SKI 2023. A nationally representative subsample underwent blood glucose examination, totaling 37,460 respondents in Riskesdas 2018 and 19,159 in SKI 2023.

Further exclusions were applied due to missing weight, waist circumference, and blood pressure data (1,366 from Riskesdas 2018 and 954 from SKI 2023). Therefore, the final study sample included 36,094 respondents for Riskesdas 2018 and 18,205 respondents for SKI 2023. In total, 54,299 respondents were included in the final analysis.

Variables and Measurements: The outcome variable was diabetes mellitus (DM), defined solely based on laboratory blood glucose measurements. An individual was categorized as having DM if they met either or both of the following criteria:

a. Fasting blood glucose (FBG) ≥126 mg/dL, or
b. 2-hour postprandial blood glucose (2h-PBG) ≥200 mg/dL

This definition follows the criteria established by the American Diabetes Association and the World Health Organization. Random blood glucose and self-reported diagnoses were not included to minimize bias and ensure consistency. The independent variables in this study were key behavioral factors, while demographic and health-related characteristics were included as control variables. Behavioral variables consisted of smoking status (never smoked as reference vs. ever smoked), alcohol consumption (never consumed as reference vs. ever consumed in the past month), physical activity (sufficient activity as reference vs. insufficient, defined as less than 150 minutes of moderate activity per week), and dietary risk pattern (low risk as reference vs. high risk). The dietary risk variable was constructed from the frequency of consuming five high-risk food and beverage items, namely sugary foods, sweetened beverages, fatty/fried foods, preserved foods, and instant/processed foods. Respondents were classified as having a high-risk dietary pattern if they reported daily or near-daily consumption (≥1 time/day) of at least one of these items in the past month.

For the multivariate analysis, all control variables were dichotomized to improve model clarity and stability. Dichotomization was applied to harmonize variable definitions between survey years and to

improve interpretability of model estimates, although this approach may reduce variability and sensitivity compared with continuous measures. Sex was coded as male (reference) or female. Age was grouped into two categories: below 40 years (reference) and 40 years or older. Body mass index (BMI) was categorized using the Asia-Pacific criteria as either <25.0 kg/m^2 (reference) or ≥25.0 kg/m^2 (at-risk group). Waist circumference was classified as non-risk (reference) or high-risk, defined as ≥90 cm for men or ≥80 cm for women, following national guidelines. Hypertension status was defined as normotensive (reference) or hypertensive, based on systolic blood pressure ≥140 mmHg and/or diastolic ≥90 mmHg. All definitions were harmonized across both survey years to ensure consistency.

Statistical Analysis: Descriptive statistics were used to summarize respondent characteristics by survey year (2018 and 2023), providing a basic understanding of the distribution of behavioral, demographic, and health-related variables across the two time points. The primary aim of the analysis was to examine the association between behavioral risk factors and the prevalence of diabetes mellitus (DM). Multivariate Poisson regression with robust variance estimation was used to estimate adjusted prevalence ratios (PRs). Behavioral variables were included as key predictors of interest, while demographic and health status variables were included as covariates to control for potential confounding, based on theoretical frameworks and prior public health research. No variable selection based on bivariate p-values was applied to ensure consistent model specification and facilitate meaningful comparisons over time.

To assess changes over time, data from Riskesdas 2018 and SKI 2023 were pooled into a single dataset. A binary indicator for survey year (0 = 2018, 1 = 2023) was created to distinguish between the two periods. This approach allowed for the evaluation of temporal trends and the testing of interaction effects between survey year and behavioral risk factors. The model specifically controlled for demographic factors and health status indicators to isolate the independent effects and shifts of the behavioral risk factors on diabetes prevalence. To assess whether associations between behavioral risk factors and DM changed over time, interaction terms between survey year and behavioral variables were also tested. Multicollinearity was assessed using variance inflation factors (VIF), with all variables showing acceptable levels (VIF <5). Poisson regression with robust variance was selected over logistic regression because the outcome of interest is relatively common in the population. This modeling choice allows direct estimation of adjusted prevalence ratios (PRs), which are more interpretable and less biased than odds ratios in cross-sectional settings with high-prevalence outcomes.[10,11] Because both surveys are cross-sectional, the analysis was descriptive in nature, focusing on the comparison of adjusted associations across two time points rather than inference of causal or modifying effects of time.

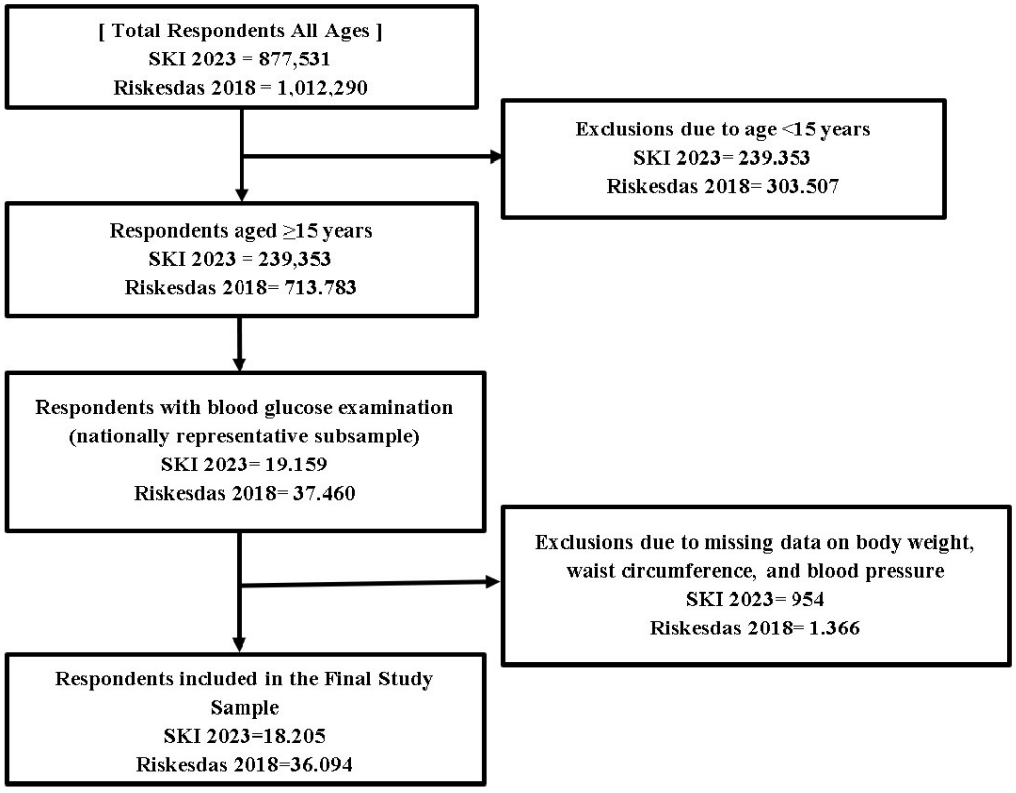

Figure 1: Flowchart of Study Sample Derivation from Indonesian National Health Surveys

Ethical Approval: Ethical approval for this research was granted by the Ethics Committee of the Faculty of Public Health, Universitas Hasanuddin, Indonesia (Approval Number: 098/UN4.14.1/TP.01.02/2025).

RESULTS

A total of 54,299 respondents were included in the analysis, consisting of 36,094 adults from Riskesdas 2018 and 18,205 from SKI 2023. The weighted prevalence of diabetes mellitus (DM) increased from 10.9% in 2018 to 11.7% in 2023.

Table 1 shows significant changes in several behavioral characteristics between survey years. The proportion of respondents who ever smoked decreased from 40.16% to 32.31% (p <0.001), while high dietary risk increased from 16.92% to 19.51% (p<0.001). Low physical activity also increased slightly (28.29% to 29.45%, p = 0.0195). Alcohol consumption remained low overall but increased marginally from 2.01% to 2.23% (p = 0.2105). Full variable distributions are available in Supplementary Table S1.

Associations Between Behavioral Factors and Diabetes: Table 2 shows adjusted prevalence ratios (PRs) based on the pooled Poisson regression model with year-interaction terms. Physical inactivity remained a stable risk factor for diabetes (PR = 1.11, 95% CI 1.03-1.20) and did not show a significant change in association across survey years.

In contrast, the associations for dietary risk, smoking, and alcohol use changed between 2018 and 2023. High dietary risk demonstrated an inverse association with diabetes (PR = 0.79, 95% CI 0.71-0.88), but the significant interaction term for 2023 (PR = 1.27, 95% CI 1.09-1.48) indicates that its association with diabetes changed in magnitude and direction. Ever smoking was associated with lower diabetes prevalence overall (PR = 0.75, 95% CI 0.68-0.83), but this association changed in 2023, as shown by the significant interaction (PR = 1.18, 95% CI 1.04-1.33). Alcohol use showed no overall association with diabetes (PR = 0.89, 95% CI 0.63-1.26), but its association also changed significantly in 2023 (PR = 0.55, 95% CI 0.31-0.96).

Interaction Effects: Figure 2 illustrates how associations changed over time. Smoking, alcohol consumption, and dietary risk showed statistically significant year-by-behavior interactions, confirming that their relationships with diabetes changed between 2018 and 2023. Physical inactivity showed minimal interaction with survey year, indicating that its association remained relatively unchanged.

Control Variables: Older age, high BMI, high-risk waist circumference, and hypertension were consistently associated with higher diabetes prevalence, with age ≥40 showing the strongest association (PR = 3.31, 95% CI 3.06-3.59). Sex was not significantly associated in the adjusted model.

Table 1: Weighted Characteristics of Respondents by Survey Year (Riskesdas 2018 and SKI 2023)

Variable	2018 (%)	2023 (%)	P Value
Diagnosed with DM			
No	89.07	88.35	0.1525
Yes	10.93	11.65	
Smoking status			
Never	59.84	67.69	<0.001
Ever	40.16	32.31	
Alcohol consumption			
No	97.99	97.77	0.2105
Yes	2.01	2.23	
Physical activity			
Adequate	71.71	70.55	0.0195
Low	28.29	29.45	
Dietary risk			
Low	83.08	80.49	<0.001
High	16.92	19.51	

Note: All percentages are weighted using complex sampling design.; P-values represent the results of survey-weighted Rao-Scott adjusted chi-square tests comparing the distribution of each variable between 2018 and 2023.; DM = Diabetes Mellitus.

Table 2: Adjusted Prevalence Ratios (PR) for Diabetes Mellitus by Behavioral Factors and Year Interaction

Variable	PR	95% CI	p-value
Survey Year			
2023 (vs 2018)	1.05	0.97 - 1.13	0.241
Smoking Status			
Ever smoked	0.75	0.68 - 0.83	<0.001
2023 × Ever smoked	1.18	1.04 - 1.33	0.009
Alcohol Consumption			
Yes	0.89	0.63 - 1.26	0.521
2023 × Yes	0.55	0.31 - 0.96	0.035
Physical Activity			
Low activity	1.11	1.03 - 1.20	0.008
2023 × Low activity	1.07	0.95 - 1.20	0.269
Dietary Risk			
High risk	0.79	0.71 - 0.88	<0.001
2023 × High risk	1.27	1.09 - 1.48	0.003
Control Variables			
Female	1.00	0.93 - 1.08	0.902
High WC	1.40	1.30 - 1.50	<0.001
Hypertension	1.57	1.49 - 1.65	<0.001
BMI at risk	1.14	1.06 - 1.22	<0.001
Age ≥ 40	3.31	3.06 - 3.59	<0.001

Note: PR = Prevalence Ratio estimated using Poisson regression with robust variance. Reference categories: 2018 (survey year), never smoked, no alcohol use, sufficient physical activity, and low dietary risk. Adjusted for sex, waist circumference, hypertension, BMI, and age group. Estimates account for complex sampling design using survey weights.
WC - waist circumference

DISCUSSION

This study examined behavioral determinants of diabetes using two nationally representative surveys conducted before and after the COVID-19 period. The increase in diabetes prevalence from 2018 to 2023 reflects the continued rise of chronic metabolic conditions in Indonesia.

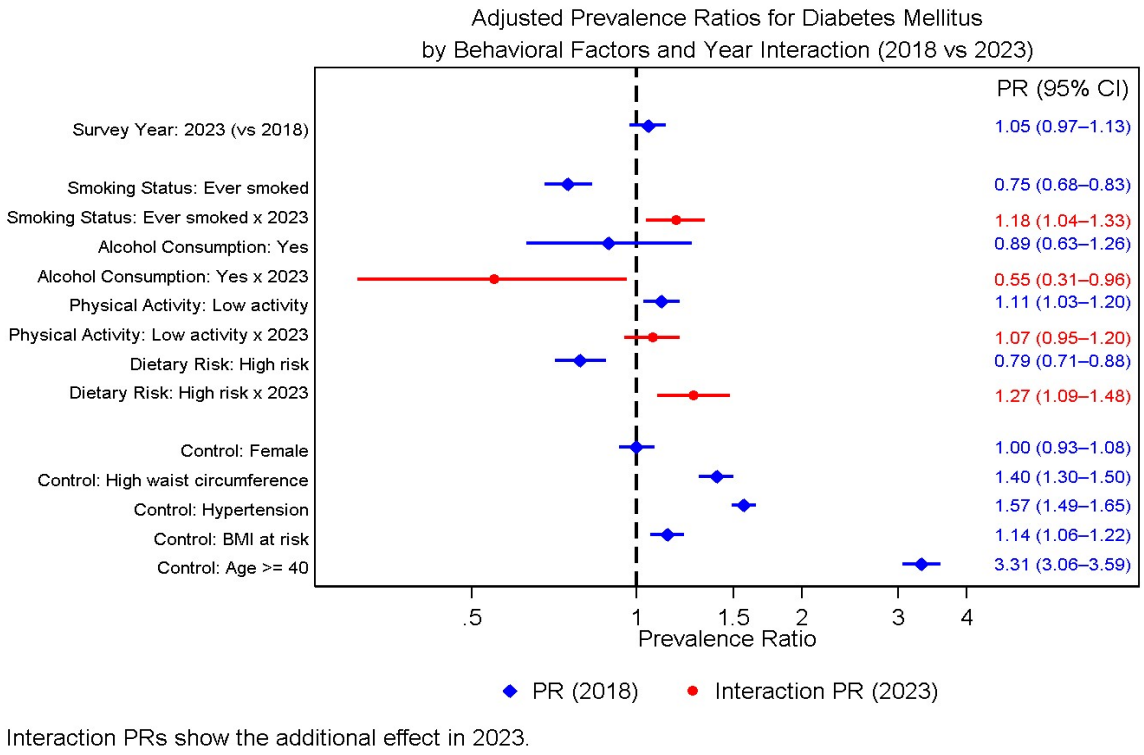

Figure 2: Comparison of Adjusted Prevalence Ratios for Diabetes Mellitus by Behavioural Factors and Year Interaction (2018 vs 2023)

Consistent with extensive global literature, our multivariate analysis consistently identified age, higher body mass index (BMI), central obesity (high risk waist circumference), and hypertension as robust independent risk factors for diabetes mellitus across both survey years. These findings are strongly supported by recent long-term cohort studies in Southeast Asia, such as the multi-ethnic cohort study in Singapore,[12] alongside data from Japan's Panasonic Cohort Study.[13] Our results highlighting the strong association of BMI are specifically consistent with comprehensive analyses focusing on low- and middle-income countries.[14] Furthermore, this consistency is corroborated by community-based cross-sectional studies that confirmed the interaction between age and these key metabolic factors.[15] This collective body of evidence resonates with the established understanding that metabolic disturbances and cardiovascular risk factors are intricately linked with the development of diabetes.

Physical inactivity showed a stable and positive association with diabetes in both survey years. Similar results have been documented in other Asian cohorts, where low physical activity is consistently linked with diabetes incidence and poor glycemic control.[16] The stability of this association despite contextual changes suggests that increasing daily movement remains a central prevention priority.

In contrast, the associations for dietary risk, smoking, and alcohol use varied across survey years. The inverse or attenuated associations observed in the pooled model are likely driven by reverse causation, in which individuals who are already living with diabetes modify their behaviors or report healthier behaviors following their diagnosis.

Behavioral adaptation following a diabetes diagnosis is a well-documented phenomenon, supported by longitudinal studies highlighting changes in health behaviors.[17,18] Furthermore, methodological factors such as survivor bias and reliance on self-reported measures may also contribute to these patterns, especially when considering the complex, dynamic nature of community behavioral changes observed in Indonesia in the post-pandemic period.[19] This need to account for behavioral changes across the lifespan underscores the importance of a life course approach to NCD prevention.[20]

Given these methodological considerations, the changing associations should be interpreted cautiously. The cross-sectional nature of both surveys limits interpretation of temporality and prevents identifying whether behavioral shifts preceded or followed diabetes onset. Future longitudinal studies are needed to clarify these pathways and capture behavioral trajectories more accurately.

From a public health perspective, the findings emphasize the ongoing relevance of physical activity promotion in diabetes prevention strategies. Given the consistent finding that low physical activity is significantly associated with DM, intervention strategies should focus on integrating movement into the daily routines of Indonesian communities.

Meanwhile, the temporal variability in other behaviors highlights the need for continued surveillance and adaptive interventions that respond to evolving lifestyle patterns, particularly in the post-pandemic context.

Strength and Limitations

This study used large, nationally representative datasets with standardized clinical glucose measurements, allowing robust comparison across two time points. The pooled analysis with interaction terms provides useful insight into temporal shifts in behavioral associations.

Despite these strengths, the study is subject to several limitations. First, the cross-sectional design inherently limits our ability to establish causal relationships or the temporality of associations between behaviors and DM. Second, behavioral variables were self-reported and may be affected by recall or social desirability bias. Third, the absence of HbA1c measurements reduces the ability to detect undiagnosed or chronic hyperglycemia. Fourth, potential differences in survey timing and operational procedures between 2018 and 2023 may introduce measurement variability. Finally, the broad categorization of dietary risk patterns, physical activity levels, and smoking/alcohol status may not fully capture the complete complexity and nuances of these behaviors or the underlying psychological, social, and environmental factors driving behavioral decisions.

Conclusion

Physical inactivity remained a consistent behavioral risk factor for diabetes in Indonesia, while the associations for smoking, dietary risk, and alcohol use varied between 2018 and 2023. These changes highlight the evolving nature of behavioral determinants and the importance of ongoing surveillance. Strengthening behavior-focused interventions, particularly those promoting physical activity, will be essential to reduce the diabetes burden in the post-pandemic period.

Individual Authors' Contributions: ES contributed to conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resource management, software handling, validation, visualization, and preparation of the original draft. **W** was involved in conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, and both original drafting and review and editing of the manuscript. **NN** contributed to conceptualization, methodology development, supervision, and review and editing of the manuscript. **HA** participated in investigation, supervision, validation, and review and editing. **DS** contributed to supervision, validation, and review and editing of the manuscript.

Availability of Data: The datasets are typically made available for public health research purposes following a formal request process. Researchers interested in accessing the original data should submit a proposal and application to the agency responsible for disseminating the data, usually the Badan Kebijakan Pembangunan Kesehatan (BKPK) within the Ministry of Health of the Republic of Indonesia. Specific details on the application process and requirements can be found on the official website of the Ministry of Health/BKPK.

Declaration of Non-use of Generative AI Tools: This article was prepared without the use of generative AI tools for content creation, analysis, or data generation. All findings and interpretations are based solely on the authors' independent work and expertise.

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