Society of Medical Education & Research

2022, Volume 2, Page No: 114-123
ISSN: 3108-4818

International Journal of Social and Psychological Aspects of Healthcare

# Impact of Age at Diabetes Diagnosis on Subsequent Hypertension, Heart Disease, Arthritis, and Other NCDs: Findings from Indonesia

**Natalie K. Foster[1]*, Oliver J. Grant[1], Rebecca L. Moore[1]**

[1]Department of Psychology and Human Development, Institute of Education, University of London, London, United Kingdom.

***E-mail** ✉ natalie.foster@gmail.com

## Abstract

This study aimed to examine how the age at which adults are diagnosed with diabetes mellitus (DM) influences their likelihood of developing various non-communicable diseases (NCDs) later on. We conducted a nationwide population-based study including 212 participants first diagnosed with DM at ages 20–39, 40–49, 50–59, or 60–69, and compared them with 17,541 participants with no history of DM, using data from the Indonesian Family Life Survey. The NCDs investigated included hypertension, lung conditions, heart diseases, arthritis, liver diseases, kidney disorders, and digestive illnesses. Poisson regression was used to calculate weighted risk ratios with 95% confidence intervals, adjusting for age, sex, urban vs. rural residence, and history of tobacco use.

Participants with DM had a higher risk of developing hypertension across all age groups compared to those without DM. Specifically, individuals diagnosed with DM between the ages of 20 and 39 had significantly higher risks of lung disease and arthritis, while those diagnosed between the ages of 20 and 49 also had increased risk for digestive disorders. Participants diagnosed with DM at ages 40–69 showed an elevated risk of liver disease, and those diagnosed at 40–59 had a higher likelihood of heart disease, compared with participants without DM. Overall, people with DM tended to develop subsequent NCDs at earlier ages than those without a DM diagnosis. These results highlight the importance of monitoring and lifestyle interventions for individuals with early- or later-onset DM, which could help prevent additional NCDs and support better public health outcomes.

**Keywords:** Diabetes diagnosis, Subsequent hypertension, Heart disease, Arthritis, Indonesia

## Introduction

Diabetes mellitus (DM) represents a persistent disorder involving prolonged elevation of blood glucose concentrations. Individuals affected by DM face an elevated probability of acquiring additional non-communicable diseases (NCDs) compared to those unaffected, attributable to variations in cellular processes, gene regulation, circulatory dynamics, and behavioural patterns [1, 2]. NCDs constitute long-lasting illnesses that cannot spread directly among individuals and typically emerge from interactions between hereditary, bodily, ecological, and habitual influences [3, 4]. On a global scale, DM stands among the primary contributors to death and impairment [5]. Age-adjusted prevalence rates for DM have risen internationally from 8.5% in 2011 to 9.8% in 2021, while in Indonesia the figures increased from 5.1% in 2011 to 10.6% in 2021 [6]. Within Indonesia, the leading microvascular issues linked to DM consist of neuropathy (17.6%), nephropathy (7.7%), and retinopathy (2.7%). In contrast, the dominant macrovascular issues include coronary artery disease and cerebrovascular disease (both 5.4%), succeeded by heart failure (5.0%) and peripheral artery disease (0.5%) [5]. Accordingly, clarifying the connections between DM and later-arising NCDs

**Access this article online** https://smerpub.com/

**Received:** 26 January 2022; **Accepted:** 11 March 2022



**How to cite this article:** Foster NK, Grant OJ, Moore RL. Impact of Age at Diabetes Diagnosis on Subsequent Hypertension, Heart Disease, Arthritis, and Other NCDs: Findings from Indonesia. Int J Soc Psychol Asp Healthc. 2022;2:114-23. https://doi.org/10.51847/4AH6uwNPAc

remains crucial for enhancing monitoring strategies in patients with DM.

As far as we are aware, earlier investigations into links between DM and other NCDs have not distinguished between early- and later-onset forms across varying adult age brackets while simultaneously assessing several NCD categories within one cohort. To bridge this evidentiary shortfall concerning the manner in which DM onset at diverse adult ages relates to subsequent NCD development probabilities, we drew upon information from an extensive national Indonesian survey. This enabled us to contrast initial occurrence probabilities for multiple later NCDs among persons initially identified with DM at ages 20–39, 40–49, 50–59, or 60–69 years against those lacking any DM record. Additionally, we examined whether persons with DM received diagnoses of later NCDs earlier than their counterparts without DM. The temporal ordering evident in our results may aid primary healthcare monitoring and encourage healthful behavioural adjustments among patients with both early- and later-onset DM, thereby assisting in NCD prevention.

## Materials and Methods

*Study design and participants*

A comprehensive population-level investigation across Indonesia was carried out, encompassing 212 adults with prior DM and 17,541 without such a background, based on data from the fifth iteration of the RAND Indonesian Family Life Survey (IFLS-5). Prior publications have detailed the approach and framework of IFLS-5 [7]. This cross-sectional survey took place from late 2014 through early 2015, involving 16,204 households and 50,148 persons across 13 provinces; following application of weights, the sample reflected approximately 83% of the national population [7]. Oversampling targeted urban residences and non-Java provinces, thus requiring weighted computations to yield nationally representative figures [7].

The analysis contrasted risks of initial subsequent NCD detection in individuals whose DM was first identified at 20–39, 40–49, 50–59, or 60–69 years versus those never diagnosed with DM. Reported ages at diagnosis established chronological precedence of DM over later NCDs, while age at survey completion confirmed eligibility for new NCD diagnoses. Specifically, for the 20–39 years DM onset comparison with non-DM cases, only respondents aged 40 or above were retained, and any NCD of interest diagnosed prior to age 40 was removed; for 40–49 years onset, inclusion required age 50 or older with exclusion of pre-50 NCDs; for 50–59 years onset, age 60 or older and exclusion before 60; and for 60–69 years onset, age 70 or older with exclusion before 70. Cases with DM detected at 20–39 years were categorised as early-onset DM.

*Ethical approval*

Data from the IFLS are accessible to the public. The study received approval from the institutional review boards at Gadjah Mada University in Indonesia and the RAND Corporation in the United States. All individuals involved gave written informed consent before any data were gathered [7].

*Measurements of variables*

Information for IFLS-5 was gathered through Computer-Assisted Personal Interviewing (CAPI). The investigation relied on participant-reported initial diagnoses made by physicians for DM as well as for later NCDs, which encompassed hypertension, pulmonary disorders, cardiac conditions, arthritis, hepatic disorders, renal disorders, and gastrointestinal disorders. A condition was confirmed if respondents answered “Yes” to “Has a doctor, paramedic, nurse, or midwife ever informed you that you have [disease name]?” and specified “Doctor” when asked “Who made the diagnosis of [disease name]?”. The pulmonary disorders category incorporated asthma along with other non-malignant respiratory issues. Cardiac conditions, as outlined in the survey, covered myocardial infarction, coronary heart disease, angina, or additional cardiac issues. Renal disorders were restricted to non-cancerous kidney conditions in the survey. Gastrointestinal disorders referred to non-malignant stomach or other digestive tract problems. Age at initial diagnosis for each condition was derived from responses to “When were you first diagnosed with [disease name]?”.

Covariates incorporated into the multivariable regression included age, sex, residence type (urban/rural), and prior tobacco exposure, all recorded at the time of survey completion. Participant age and sex were verified via CAPI. Residence classification followed the predefined IFLS urbanicity categories by province. History of tobacco exposure was assessed through the query “Have you ever chewed tobacco, used a pipe, smoked hand-rolled cigarettes, or smoked manufactured cigarettes or cigars?”.

*Statistical analysis*

Descriptive comparisons in **Table 1** employed weighted chi-squared tests for categorical data and weighted t-tests for continuous data. To derive risk ratios (RR) and corresponding 95% confidence intervals (CI) presented in **Table 2**, weighted Poisson regression was applied, treating DM status as the exposure and each subsequent NCD as the outcome. Mean ages at NCD diagnosis in **Table 3** were contrasted between groups with and without DM using weighted t-tests. All computations incorporated IFLS-5 cross-sectional household weights, without adjustments for attrition. Consequently, the weighted results are intended to reflect the population across the 13 surveyed provinces as of 2014 [7]. Missing values were handled through complete-case analysis. The adjusted weighted Poisson models controlled for age at survey (treated continuously), sex (male/female), household location (urban/rural), and tobacco exposure (ever/never). Analyses were performed using STATA 15.1 (StataCorp, TX), while figures were created with GraphPad Prism 9. Statistical significance was set at $P < 0.05$.

**Table 1.** Characteristics of participants with and without a history of diabetes mellitus (DM)

| **Age at DM Diagnosis** | **60–69 years** | | **50–59 years** | | **40–49 years** | | **20–39 years** | |
|---|---|---|---|---|---|---|---|---|
| | **DM** | **No DM History** | **DM** | **No DM History** | **DM** | **No DM History** | **DM** | **No DM History** |
| **Sample size (N)** | 20 | 2,245 | 65 | 5,268 | 83 | 10,458 | 44 | 17,541 |
| **Age at survey (Weighted mean ± SD)** | 72.8 ± 3.00 | 76.8 ± 6.12 | 63.1 ± 3.40 | 69.0 ± 7.90 | 55.7 ± 4.85 | 61.3 ± 9.46 | 54.1 ± 11.21 | 48.3 ± 8.87 |
| **P-value** | 0.003 | | <0.001 | | <0.001 | | <0.001 | |
| **Sex, n (%)** | | | | | | | | |
| Male | 12 (64.2) | 941 (42.1) | 38 (61.6) | 2,383 (46.5) | 38 (44.9) | 4,789 (48.2) | 19 (41.6) | 8,374 (48.8) |
| Female | 8 (35.8) | 1,304 (57.9) | 27 (38.4) | 2,886 (53.5) | 45 (55.1) | 5,669 (51.8) | 25 (58.4) | 9,167 (51.2) |
| **P-value** | 0.060 | | 0.019 | | 0.241 | | 0.375 | |
| **Residence, n (%)** | | | | | | | | |
| Rural | 0 (0) | 1,113 (44.2) | 14 (22.9) | 2,397 (48.3) | 22 (30.3) | 4,559 (49.8) | 7 (20.1) | 7,354 (48.8) |
| Urban | 20 (100) | 1,132 (55.8) | 51 (77.1) | 2,871 (51.7) | 61 (69.7) | 5,859 (50.2) | 37 (79.9) | 10,187 (51.2) |
| **P-value** | <0.001 | | <0.001 | | 0.002 | | 0.001 | |
| **Tobacco use, n (%)** | | | | | | | | |
| Ever | 8 (48.8) | 787 (35.4) | 26 (38.9) | 1,692 (32.7) | 31 (46.7) | 3,304 (32.9) | 16 (34.7) | 5,710 (33.2) |
| Never | 12 (51.2) | 1,458 (64.6) | 39 (61.1) | 3,576 (67.3) | 52 (53.3) | 7,154 (67.1) | 28 (65.3) | 11,831 (66.8) |
| **P-value** | 0.173 | | 0.303 | | 0.016 | | 0.849 | |
| **Non-communicable diseases, n (%)** | | | | | | | | |
| Hypertension | 12 (58.7) | 560 (24.5) | 31 (47.1) | 1,203 (22.1) | 39 (42) | 2,160 (20.7) | 14 (34.7) | 3,050 (16.8) |
| Lung diseases | 3 (15) | 121 (5.2) | 3 (5.5) | 242 (4.5) | 2 (1.5) | 435 (4.1) | 5 (13.2) | 645 (3.6) |
| Heart diseases | 1 (3.3) | 66 (2.7) | 10 (17.3) | 170 (3.1) | 10 (11.8) | 289 (2.6) | 2 (3.8) | 411 (2.3) |
| Arthritis | 2 (10.0) | 263 (10.3) | 9 (13.1) | 556 (9.5) | 10 (8.7) | 1,029 (9.1) | 8 (20.1) | 1,381 (7.3) |
| Liver diseases | 1 (7.1) | 9 (0.3) | 6 (10.5) | 32 (0.6) | 3 (3.3) | 63 (0.6) | 1 (2.3) | 130 (0.7) |
| Kidney diseases | 1 (6.0) | 24 (0.9) | 2 (3.8) | 63 (1.1) | 6 (7.8) | 152 (1.4) | 1 (2.3) | 287 (1.6) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Digestive diseases | 2 (11) | 178 (7.7) | 8 (11.5) | 447 (8.4) | 19 (22.2) | 887 (8.5) | 9 (22.6) | 1,641 (9.5) |
| **P-values** | Hypertension 0.001; Lung 0.260; Heart 0.867; Arthritis 0.500; Liver <0.001; Kidney 0.034; Digestive 0.620 | | Hypertension <0.001; Lung 0.746; Heart <0.001; Arthritis 0.354; Liver <0.001; Kidney 0.055; Digestive 0.378 | | Hypertension <0.001; Lung 0.168; Heart <0.001; Arthritis 0.900; Liver 0.002; Kidney <0.001; Digestive <0.001 | | Hypertension 0.004; Lung 0.003; Heart 0.481; Arthritis 0.003; Liver 0.255; Kidney 0.734; Digestive 0.009 | |

Data are presented as unweighted sample sizes, weighted percentages, and weighted P-values. Weighted t-tests and chi-squared tests were applied to calculate P-values for continuous and categorical variables, respectively.
NCDs: Non-communicable diseases

**Table 2.** Connections between diabetes mellitus (DM) onset in the age ranges of 20–39, 40–49, 50–59, or 60–69 years and later-onset non-communicable diseases

| **Condition** | **Crude RR (95% CI) by Age at DM Diagnosis** | | | |
|---|---|---|---|---|
| | 60–69 years | 50–59 years | 40–49 years | 20–39 years |
| **Hypertension** | | | | |
| Crude | 2.39 (1.60–3.59)*** | 2.13 (1.62–2.80)*** | 2.08 (1.58–3.29)*** | 2.06 (1.30–3.24)** |
| Adjusteda | 2.14 (1.35–3.39)** | 2.27 (1.71–3.01)*** | 2.12 (1.64–2.75)*** | 2.12 (1.31–3.43)** |
| **Lung disorders** | | | | |
| Crude | 1.93 (0.62–5.99) | 1.22 (0.37–4.01) | 0.38 (0.08–1.62) | 3.68 (1.52–8.89)** |
| Adjusteda | 1.57 (0.46–5.35) | 1.25 (0.36–4.29) | 0.36 (0.08–1.56) | 3.74 (1.55–9.00)** |
| **Cardiovascular disease** | | | | |
| Crude | 1.18 (0.16–8.48) | 5.74 (3.17–10.39)*** | 4.51 (2.35–8.65)*** | 1.68 (0.39–7.23) |
| Adjusteda | 0.70 (0.09–5.23) | 4.62 (2.44–8.72)*** | 4.30 (2.22–8.31)*** | 1.66 (0.39–7.12) |
| **Arthritis** | | | | |
| Crude | 1.55 (0.44–5.38) | 1.37 (0.70–2.66) | 0.95 (0.46–1.96) | 2.76 (1.41–5.38)** |
| Adjusteda | 1.50 (0.42–5.31) | 1.52 (0.79–2.93) | 0.97 (0.47–2.01) | 3.16 (1.62–6.14)** |
| **Liver disorders** | | | | |
| Crude | 19.42 (2.63–142.9)** | 16.69 (7.01–39.75)*** | 5.07 (1.57–16.35)** | 2.96 (0.42–20.84) |
| Adjusteda | 8.90 (1.12–70.66)* | 10.94 (4.38–27.31)*** | 3.68 (1.08–12.50)* | 2.38 (0.33–16.88) |
| **Kidney disorders** | | | | |
| Crude | 6.50 (0.92–45.6) | 3.61 (0.90–14.46) | 5.69 (2.38–13.56)*** | 1.39 (0.19–9.80) |
| Adjusteda | 2.25 (0.26–19.08) | 2.27 (0.59–8.62) | 4.35 (1.80–10.53)** | 1.21 (0.17–8.39) |
| **Digestive disorders** | | | | |
| Crude | 1.43 (0.35–5.90) | 1.37 (0.68–2.75) | 2.59 (1.66–4.04)*** | 2.37 (1.27–4.42)** |
| Adjusteda | 1.15 (0.27–4.82) | 1.26 (0.63–2.53) | 2.32 (1.47–3.64)*** | 1.94 (1.03–3.64)* |

aThe multivariable weighted Poisson regression included controls for age (as a continuous variable), sex (male/female), residence type (rural/urban), and smoking status (ever/never). RR: risk ratio, CI: confidence interval
*P < 0.05
**P < 0.01
***P < 0.001

**Table 3.** Diagnosis age for non-communicable diseases (NCDs) in persons with versus without prior diabetes mellitus (DM)

| Age at DM Diagnosis | 60–69 years | | 50–59 years | | 40–49 years | | 20–39 years | |
|---|---|---|---|---|---|---|---|---|
| | DM | No DM History | DM | No DM History | DM | No DM History | DM | No DM History |
| **Age at NCD Onset (Weighted mean, years)** | | | | | | | | |
| Hypertension | 72.2 | 76.8 | 62.7 | 69.7 | 55.4 | 62.6 | 50.1 | 57.1 |
| **P-value** | <0.001 | | <0.001 | | <0.001 | | <0.001 | |
| Lung disorders | 73.9 | 76.9 | 60.7 | 69.9 | 53.1 | 62.6 | 52.2 | 56.1 |
| **P-value** | 0.007 | | <0.001 | | 0.001 | | 0.196 | |
| Cardiovascular disease | 74.0 | 76.5 | 64.6 | 68.6 | 56.4 | 62.8 | 50.5 | 57.1 |
| **P-value** | 0.002 | | 0.003 | | 0.001 | | 0.477 | |
| Arthritis | 72.0 | 76.8 | 63.3 | 69.6 | 56.8 | 62.0 | 49.7 | 57.3 |
| **P-value** | <0.001 | | <0.001 | | <0.001 | | 0.033 | |
| Liver disorders | 70.0 | 76.5 | 62.8 | 66.1 | 55.2 | 60.5 | 44.0 | 52.3 |
| **P-value** | 0.023 | | 0.082 | | 0.073 | | <0.001 | |
| Kidney disorders | 70.0 | 75.7 | 61.0 | 67.9 | 55.6 | 60.1 | 44.0 | 52.3 |
| **P-value** | 0.001 | | <0.001 | | 0.008 | | <0.001 | |
| Digestive disorders | 72.0 | 77.2 | 64.0 | 68.6 | 56.5 | 61.2 | 49.9 | 53.1 |
| **P-value** | <0.001 | | 0.005 | | <0.001 | | 0.195 | |

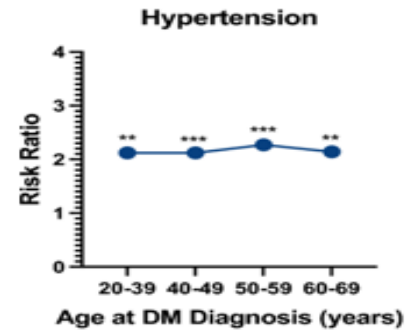
## Results and Discussion

*Profile of the study cohorts*

**Table 1** outlines the demographic and clinical profiles of individuals stratified by DM status. Persons with initial DM diagnosis between 20–49 years were predominantly women, in contrast to the non-DM group, whereas those diagnosed between 50–69 years were predominantly men compared to non-DM participants. Urban dwelling and past smoking were more prevalent among those with DM than in the non-DM group. In the 20–39 years onset category, the leading later NCDs included hypertension (34.7%), digestive disorders (22.6%), and arthritis (20.1%). For the 40–49 years group, hypertension (42.0%), digestive disorders (22.2%), and cardiac conditions (11.8%) predominated. Among those with onset at 50–59 years, hypertension (47.1%), cardiac conditions (17.3%), and arthritis (13.1%) were most prominent. In the 60–69 years onset group, hypertension (58.7%), pulmonary conditions (15.0%), and digestive disorders (11.0%) were the primary later NCDs.

*Links between DM onset and later NCDs*

**Table 2** details both unadjusted and multivariable associations between DM first detected at 20–39, 40–49, 50–59, or 60–69 years and subsequent NCD development. Findings from crude and adjusted analyses aligned closely. In general, DM cases exhibited a greater likelihood of developing later NCDs than non-DM individuals. Elevated hypertension risk was consistently significant across every DM onset age category versus the non-DM reference. Notably heightened risks for pulmonary conditions and arthritis emerged in the 20–39 years onset group compared to non-DM participants, whereas digestive disorders showed particularly strong elevation for onset up to 49 years. Conversely, DM onset from age 40 onward was associated with substantially greater risks for hepatic and renal conditions relative to non-DM cases. Cardiac conditions displayed a markedly increased risk specifically for onset between 40 and 59 years against the non-DM group. **Figure 1** depicts the multivariable risk ratios from **Table 2** via line plots.

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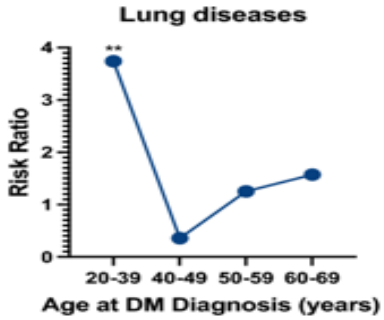


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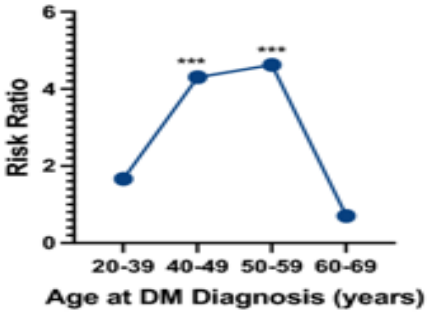


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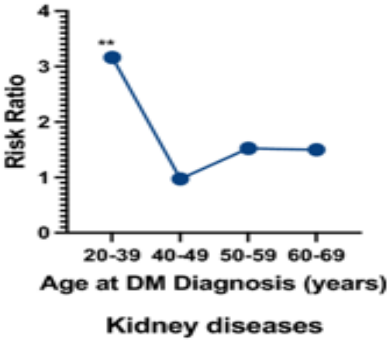


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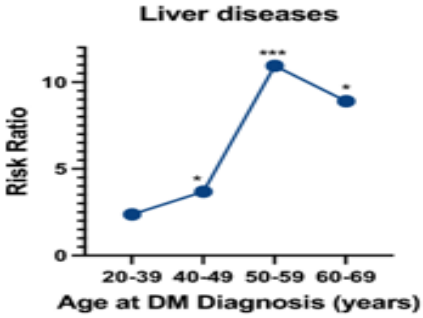


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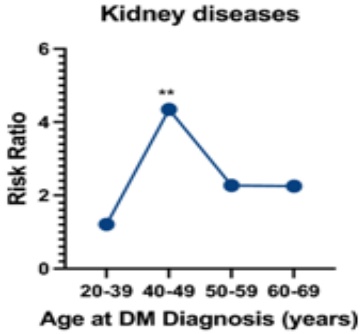


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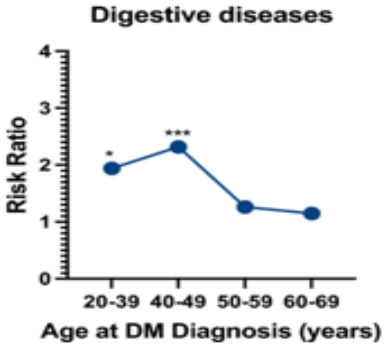


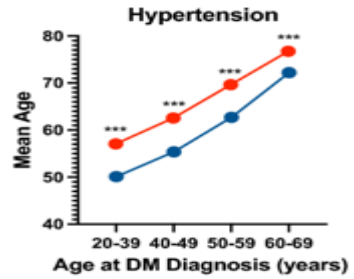

g)

**Figure 1.** Multivariable connections between diabetes mellitus (DM) first detected at 20–39, 40–49, 50–59, and 60–69 years and subsequent non-communicable diseases. Weighted Poisson regression was employed. Controls in the adjusted analysis covered age (continuous), sex (male/female), residence type (rural/urban), and smoking status (ever/never). *P < 0.05, **P < 0.01, ***P < 0.001

*Average diagnosis age for NCDs*

**Table 3** together with Fig. 2 illustrate comparative mean ages of NCD onset between groups with and without prior DM. Broadly, DM cases experienced NCD diagnoses at substantially earlier ages than non-DM individuals, with numerous comparisons reaching statistical significance. Age differences for NCD onset

ranged from 3.2 to 8.3 years earlier in the 20–39 years DM group versus non-DM. Corresponding ranges were 4.5 to 9.5 years for the 40–49 years group, 3.3 to 9.2 years for the 50–59 years onset, and 2.5 to 6.5 years earlier for the 60–69 years DM category relative to those without DM.

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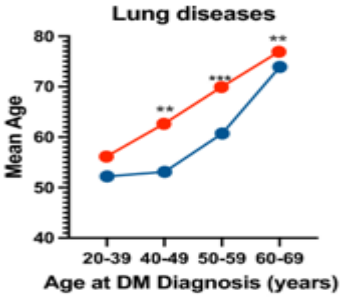


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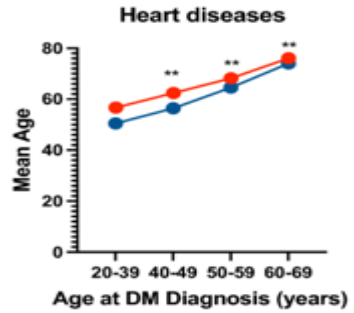


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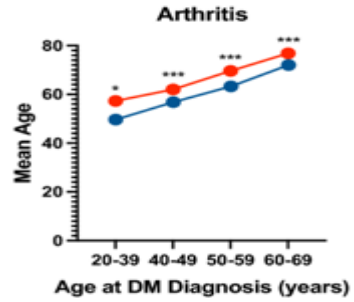


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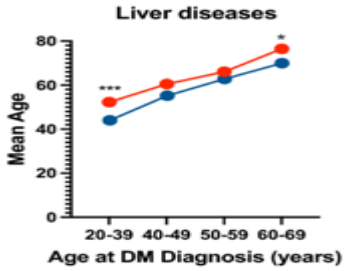


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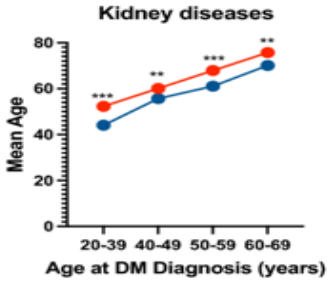


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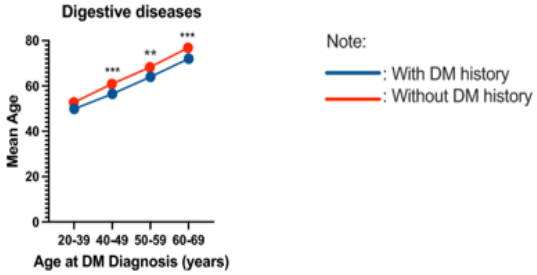


g)

**Figure 2.** Onset age for non-communicable diseases (NCDs) stratified by diabetes mellitus (DM) history, presence or absence. Weighted t-tests formed the basis of comparisons. *P < 0.05, **P < 0.01, ***P < 0.001

This study analyzed data from a nationwide Indonesian cohort to explore how diabetes mellitus (DM), diagnosed at different stages of adulthood, influences the development of non-communicable diseases (NCDs). We observed that adults with DM tend to experience subsequent NCDs at younger ages than individuals without a DM history. These findings provide insight for targeted health monitoring and preventive strategies for both early- and later-onset DM, potentially reducing the risk of additional NCDs.

*Hypertension*

Across all age groups, participants with DM showed a notably higher likelihood of developing hypertension compared to those without DM. This suggests that blood pressure monitoring should be prioritized for individuals

with both early- and later-onset DM. Previous evidence indicates a reciprocal relationship between DM and hypertension [8]. In the UK, approximately 70% of people with diabetes also have hypertension, which is almost double the prevalence seen in non-diabetic populations [9]. By age 45, around 40% of type 2 diabetes patients have hypertension, increasing to 60% by age 75 [9]. Mechanistically, DM may increase hypertension risk through vascular remodeling and dysfunction driven by chronic oxidative stress, inflammation, and fibrosis [10].

*Heart disease*

Individuals diagnosed with DM at ages 40–49 or 50–59 experienced a higher risk of heart disease than those without DM. While the link between DM and cardiovascular disease is well-established, few studies have explored how age at DM onset affects this risk. A study in Taiwan found that type 2 DM patients diagnosed before 60 years had higher mortality and more complications, both macrovascular and microvascular, than those diagnosed at 60 or older [11]. In our analysis, the mean age at onset of heart disease was lower for participants with DM regardless of age at diabetes diagnosis. Other research has also reported that individuals with DM experience myocardial infarction, stroke, or death at younger ages than those without DM [12]. These findings underscore the need for intensified cardiovascular surveillance in adults diagnosed with DM before age 60.

*Liver and kidney disease*

For DM diagnosed at age 40 or older, the risks of liver and kidney diseases were especially elevated. Liver disease prevalence is higher in type 2 DM patients, particularly in younger and middle-aged adults, according to studies in Asia [13, 14]. However, those studies often did not stratify participants by age at DM diagnosis or establish the temporal sequence [13, 14]. Regarding kidney disease, chronic kidney conditions are common among older type 2 DM patients in South Korea [15]. Conversely, Australian studies indicate that earlier-onset type 2 DM is linked to a greater risk of end-stage kidney disease, likely due to longer disease duration [16]. Research from Singapore reported that 53% of type 2 DM patients have kidney disease [17], and a Dutch study showed that renal microvascular dysfunction occurs nearly four times more often in individuals with type 2 DM than in non-diabetic counterparts [18].

*Lung disease*

Participants with early-onset DM (20–39 years) were more likely to develop lung diseases compared to non-DM individuals. Previous studies have connected DM to asthma [19] and other pulmonary conditions, such as pulmonary hypertension, potentially due to microvascular and macrovascular damage affecting lung vasculature [19]. DM has also been linked to chronic obstructive pulmonary disease and idiopathic pulmonary fibrosis [19]. Additional research is necessary to confirm the relationship between early-onset DM and pulmonary disorders identified in our study.

*Arthritis risk*

In our cohort, individuals diagnosed with early-onset DM (20–39 years) exhibited a notably increased likelihood of developing arthritis compared with participants without a history of DM. Previous meta-analyses indicate that rheumatoid arthritis is linked with a heightened risk of developing DM [20]. Additionally, both clinical observations and experimental studies suggest that DM may exacerbate the onset and severity of osteoarthritis [21]. Evidence from systematic reviews further demonstrates that DM elevates the risk of osteoarthritis, while osteoarthritis is also associated with increased DM risk [22]. To better understand this relationship, future studies should provide detailed information on specific arthritis subtypes and explore causality.

*Digestive disease risk*

Our results indicated that adults diagnosed with DM before age 50 were at greater risk of developing digestive disorders compared with individuals without DM. A population-based study in Australia similarly reported a higher prevalence of gastrointestinal symptoms among people with type 1 or type 2 DM relative to those without DM [23]. Prior cross-sectional research has linked these gastrointestinal symptoms to inadequate glycemic control; however, temporality was not established [23, 24]. Possible mechanisms include diabetic autonomic neuropathy, which can impair gastrointestinal motility [25], and the gastrointestinal effects of anti-hyperglycemic medications such as metformin [26].

*Strengths and limitations*

A major strength of our analysis is the use of a nationally representative dataset containing age-at-diagnosis information, which allowed us to establish temporal relationships between DM and subsequent NCDs and to

compare risks among individuals diagnosed at different adult ages. Nonetheless, several limitations exist. By relying on physician-diagnosed cases, undiagnosed individuals, and those unable to participate were excluded. For instance, in 2013, the Indonesian Ministry of Health reported a 6.9% DM prevalence based on blood glucose testing, whereas only 2.1% was captured through self-report [27]. The dataset lacked information on DM type, duration, and severity; however, as type 2 DM constitutes over 90% of cases [28, 29], findings likely apply mainly to this group. Furthermore, the survey only provided general NCD categories, limiting the granularity of analyses. Finally, while our results are useful for monitoring purposes, causal inference between DM and NCDs is constrained due to potential unmeasured confounders.

## Conclusion

This study enhances understanding of the risks of subsequent NCDs among adults diagnosed with DM at various ages, offering guidance for primary care and preventive interventions. Hypertension was the most frequently observed NCD in both DM and non-DM groups, yet DM patients faced a significantly higher risk. Individuals with early-onset DM (20–39 years) also exhibited elevated risks for arthritis, digestive diseases, and lung diseases. Longitudinal cohort studies are needed to clarify how age at DM onset affects the development of subsequent NCDs. Future research should further explore these relationships by DM type and severity and examine the biological mechanisms that underlie age-specific NCD risk in DM patients.

**Acknowledgments:** None

**Conflict of Interest:** None

**Financial Support:** None

**Ethics Statement:** None

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