DISSERTATION FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Indicators for Diabetes Mellitus in Primary Care

By Dr. Undraa Jargalsaikhan

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Abbreviations

95% CI	95% confidence interval
ACR	albumin:creatinine ratio
ACE	angiotensin converting enzyme
ACDMI	adjusted composite diabetes mellitus indicator
ARB	angiotensin II receptor blockers
BMI	body mass index
CDMI	composite diabetes mellitus indicator
DM	diabetes mellitus
EUBIROD	European Best Information through Regional Outcomes in Diabetes
ED	erectile dysfunction
GD	gestational diabetes
GMP	general medical practice
GP	general practitioner
HCSO	Hungarian Central Statistical Office
ISR	indirectly standardized ratio
IDF	International Diabetes Federation
NHIF	National Health Insurance Fund
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
MPIG	Minimum Practice Income Guarantee
nISR	normalized empirical Bayes-adjusted indirectly standardized ratio
P4P	pay for performance
QOF	Quality and Outcomes Framework
rHD	relative housing density
rRP	relative Roma proportion
SD	standard deviation
SES	socioeconomic status
srEDU	standardized relative education
srEMP	standardized relative employment
β	standardized linear regression coefficient

Introduction

Public health importance of diabetes mellitus

The global burden of diabetes mellitus (**DM**) has grown significantly in the last few decades. The rising burden is often attributed to a combination of aging populations, urbanization, sedentary lifestyles, and diets that include more processed foods. The International Diabetes Federation (**IDF**) reported that in 2022, over 800 million adults had DM, a fourfold increase from 1990 [1].

Although, the risk factors of DM are well known, and many of those are preventable, the recent time trend of prevalence is a steady increase in the overwhelming majority of the countries. The organized efforts to utilize available knowledge in order to reduce DM prevalence have been effective in only a few countries (Spain, France, Denmark) [2]. Recent estimates suggest, this number is expected to increase to approximately 1.3 billion by 2050, with the greatest rises in populations in North Africa and the Middle East, where prevalence could be as high as 16.8% [3].

The nationally representative H-UNCOVER study, published in 2024, concluded that about 12.0% of women and 11.9% of men aged 20–79 in Hungary have DM. Of these, undiagnosed diabetes had a prevalence of 2.2% in women and 2.8% in men. Men in their forties had the highest odds for being undiagnosed. In contrast, undiagnosed DM versus diagnosed DM prevalence was similar for women aged 40 and older [4].

However, the burden of DM is greater than an increase in prevalence numbers. DM is a significant contributor of global morbidity and premature mortality culminating in detrimental complications like cardiovascular diseases, chronic kidney failure, and peripheral neuropathy [5]. More recently, DM is associated with a number of additional serious complications including cancers, liver disease, declines in cognitive function, mental health disorders, and increased susceptibility to infections [6],[7],[8],[9]. Such widespread ramifications reinforce the multisystem nature of the disease and its lasting impact on individuals and health systems. The IDF estimates worldwide diabetes healthcare costs will reach USD 1.015 trillion by 2024 an overall increase of 338% transmitted over 17 years. It is estimated that there are currently 537 million adults aged 20–79 with diabetes (12% of total global health spending); and the average diabetes annual cost (per person) is USD 1,760 (with significant regional variances based on relatively divergent healthcare build and access) [3].

Hungary belongs to the majority of the countries with high and increasing DM prevalence [4]. DM is a significant public health challenge within Hungary, not only for its effects on morbidity and mortality but because of the significant economic costs. The cost of diabetes care was more than 0.65 percent of the Gross Domestic Product in 2008, and approximately 13 percent of the overall healthcare spending of the National Health Insurance Fund (**NHIF**) [10]. The average yearly costs of care for each diabetic patient, depending on age, treatment, and complications, varied from 136,700 HUF to 715,300 HUF [10].The recent estimates of DM prevalence in Hungary based on the database of the NHIF was 9.1% in 2021, representing 661,400 people suffering from this disease [11]. According to the IDF Diabetes Atlas, the prevalence of DM in 2024 was 10.1% among adults aged 20-79 years. The corresponding cost per person with DM was $1,396.7 (497,200 HUF). The financial burden for the country was $1,068,496,147.1 (380 billion HUF) [3].

Role of primary health care in controlling diabetes mellitus

In response to the global health crisis caused by DM, the United Nations identified DM with the inclusion in Sustainable Development Goal 3, which aims to prevent one-third of premature death from non-communicable disease by 2030 [12]. The accompanying DM management is identified as an important tracer to track progress of health systems performance and progress toward universal health coverage. In response to DM, World Health Organizations (**WHO**) has focused to diabetes in its Global Action Plan for the Prevention and Control of non-communicable disease by naming DM one out of three focused diseases [13] . WHO also launched the Global Diabetes Compact in 2024 as a comprehensive initiative to increase result and to expand equitable access to prevention, diagnosis, and treatment services for those living with DM [14]. Furthermore, the Lancet

Commission on Diabetes have highlighted the requirement for more granular and disaggregated data to support health system planning and policy-development [15].

While there have been significant improvements in diagnostics, therapeutics, and models of care, there are still major gaps across the DM control continuum [16]. Large parts of the global population remain undiagnosed or poorly treated, resulting in avoidable complications, premature mortality, and excessive healthcare costs. These gaps will not be overcome without coordinated, multi-faceted systemic approaches beyond clinical management. It will require an audacious public health approach in prevention, early detection, and equitable access to high-quality affordable care that focuses on supporting people with DM and delivering coordinated clinical care [17], [18].

Strengthening primary care will be an essential part of any DM response. Primary care is the first entry point for most people when they engage the health system; it is fundamental to managing chronic conditions in the community. Primary care provides person-centered continuity, accessibility, and care that is well-suited to DM chronic longitudinal needs [19]. In addition to providing screening and diagnosis, primary care provides monitoring, education, and coordination for the continual care of the person with DM, and is the backbone of delivering DM care [20]. However, the complexity of DM management is on the rise. Currently, care must involve individualized treatment plans that address not only glycemic control, but blood pressure, lipids, obesity, and other cardiovascular risks, in tandem with psychosocial and behavioral support [21],[22],[23],[24],[25].

The increasing number of pharmacologic therapies and developing clinical guidelines adds further complexity. In many environments—particularly resource-challenged environments—general practitioners (**GP**s) have challenges that act as barriers to staying current with best practice, which was associated with clinical inertia and suboptimal outcomes [26],[27]. Patients also face challenges in managing DM. They may struggle with adherence to complex medication regimens, feelings of behavioral change, and just completing the daily emotional labor of living with a chronic condition. Even more so, social determinants of health are often ignored in patient outcomes—demands of life and social conditions (e.g., income inequality, food insecurity, health literacy, and housing) dramatically affect DM-related outcomes and cycle through inequities in care [28],[29],[30]. That said, the literature confirms that when resourced and supported adequately, primary care can provide high-quality DM care. Evidence-informed, patient-centered interventions that are built within integrated care models have demonstrated improvements in glycemic control and reductions in complications, as well as quality of life [21],[22]. Additionally, comprehensive management of other comorbid risk factors such as hypertension and dyslipidemia with early intensification of therapy is shown to reduce overall cardiovascular events and DM mortality [23].

As DM increasingly challenges health systems and exacerbates the burden imposed on them, we must rethink the paradigm in which they engage chronic disease management. Providing care coordination that strengthens primary care capacity must be paramount. This includes investment in workforce development, clinical training, decision-support systems, and care coordination capacity [5]. In addition, systems need to adopt a cross-sectoral approach that targets social determinants and helps to empower patients through culturally informed education and community-based services. We should expect health systems to respond to the global diabetes crisis and improve long-term health outcomes only by adopting an inclusive, equity-focused, and integrated approach [31].

Monitoring the care of diabetes mellitus

While clinical guidelines are essential for standardizing care, their presence alone does not guarantee improved quality. Evidence shows that guidelines lead to better outcomes only when their implementation is regularly evaluated. To support the evaluation and improvement of DM care, several quality indicator frameworks have been developed in many countries. For example, the UK's Quality and Outcomes Framework (**QOF**) have proposed systems-level indicators to monitor and benchmark diabetes care [32],[33].

National Health Services (**NHS**) indicators are important tools for enhancing healthcare quality. They concentrate on both outcomes and evidence-based processes that are known to improve patient care. NHS indicators are developed through a systematic and transparent approach, ensuring high-quality, effective, and person-centered healthcare [34]. The choice of NHS indicator development is important for a number of key reasons:

- Quality Improvement: NHS indicators are used for quality improvement by identifying where care gaps exist, and driving strategies for invention
- Accountability: NHS indicators can facilitate benchmarking and comparative performance, thereby providing clarity of action through a transparent approach throughout the system
- Planning and Prioritization: NHS indicators can also drive local and national planning and prioritization strategies by highlighting priority areas of improvement
- Upholding Robust Evidence: Developed by specialists, and carefully piloted, an NHS indicator is developed based on clinical evidence, practical relevance and policy requirements
- Flexible applications across settings: NHS indicators can be used within single practices and whole systems, to monitor performance, dashboards and quality improvement schemes

NHS indicators are a key part of the quality improvement in healthcare systems. NHS indicators are developed through a robust system led by evidence and support improved outcomes, enable consistency alongside assisting healthcare services to monitor the care they provide and how they can improve. The following indicators are used in auditing the primary DM care in England [35],[36],[37]:

1. **IND81** - This indicator measures the proportion of participants with DM that have had in the past fifteen months, an annual **foot check and risk classification**. Foot issues are a considerable concern for people with diabetes, mainly from either nerve damage or poor blood flow. Regular foot examinations will detect problems relating to low sensation, poor circulation, deformities, ulcers that put people at risk for serious issues. Risk classification for diabetes participants (e.g. low risk, increased risk, high risk, ulcerated) will ensure that those participants at higher risk for foot problems, will receive adequate intervention, and care. This indicator looks at how

successful a general practice is to screening and managing the foot health of patients with diabetes through regular assessment and testing.

2. **IND88-** The proportion of newly diagnosed DM patients who participated in an **education program** within 9 months. Effective DM management starts when someone gets diagnosed. This indicator ensures that individuals are referred to structured education program within nine months of diagnosis to help them have the skills and confidence to maintain self-management on a daily basis. Structured education will help improve understanding, create long-term changes in lifestyle, and reduce risk of complications. Prompt referral promotes better health at diagnosis, and empowers the patient to take control of their diabetes management from the outset.
3. **IND89** - The percentage of DM patients whose **diet was assessed** by a competent professional in 15 months. It measures outcomes that reflect the quality of care or processes linked by evidence to improved outcomes. DM is a lifelong disease that requires daily self-management by individuals living with the condition. A significant aspect of effective self-management is having the knowledge, skills, and confidence to make choices (especially regarding diet) to manage their blood glucose levels and prevent long-term complications. This indicator facilitates regular diets reviews with an appropriately trained professional, such as a registered dietitian or trained health professional, at least every 15 months. The reviews provide opportunities for the individual with diabetes to receive personalized advice, motivation, and practical support to improve diet and overall self-management. Regular, personalized dietary reviews facilitate this individualized management of diabetes by providing proactive, personalized guidance. Proactive management promotes better health outcomes, empowers people living with diabetes to self-manage their diabetes care and limit the risk exposure of long-term complications.
4. **IND100** - The GP **register** of all DM patients aged 17 or over, which specifies the type of DM. This qualitative indicator shows whether the GMP has or has not DM register. For a general practice to be effective in management of DM, it is essential

that it establishes and maintains a register of all patients 17 years and older (aged 17 and over) with DM. The effective register allows the practice to systematically provide care for the patients and to manage them by the type of DM they have been diagnosed with. The register may also support a recall system for regular follow-up with its patients and it serves as a mechanism for auditing the quality of care provided to people living with diabetes. This indicator is crucial for evaluating a practice's performance in managing diabetes and for ensuring that people living with DM receive appropriate ongoing care.

5. **IND105** - The ratio of male DM patients who was **asked about erectile dysfunction** (**ED**) in 15 months. ED is common, and an under-recognized complication of DM autonomic neuropathy relating to prolonged hyperglycemia. This indicator seek to assure that men on the DM register have at least been asked about ED in a 15-month period, encouraging dialogue with patients about a complication which can significantly influence people's emotional health, relationships and quality of life, using the assessment to raise awareness for meaningful discussion. ED is rarely life-threatening but can be distressing for men and their families; assessment has relevance as part of holistic, person-centered diabetes care. This indicator is also guided by the National Institute for Health and Care Excellence **(NICE)** guidelines and highlights consideration for complications beyond physical health, as part of a holistic approach to chronic disease management including psychosocial implications. Ultimately, this indicator seeks to promote better awareness, recognition, communication and management of a difficult (but relevant) complication of diabetes, aimed at improving overall quality of life and patient satisfaction.

6. **IND106** (Counseling for Indicator on Erectile Dysfunction) - This indicator supports the provision of holistic, person-centered care, through the process of ensuring that male patients with diabetes who have a recorded diagnosis of **ED on their medical record will receive appropriate counseling**, assessment of contributory factors, and

a discussion of treatment options within 15 months. Secondly, as there is a strong relationship between long-term hyper-glycaemia and ED as well as autonomic neuropathy, this indicator supports clinical engagement with a common complication of diabetes that is often not given priority. This indicator is important for promoting sensitive, supportive dialogue to help practices talk about a condition that can have significant impacts on emotional wellbeing, intimate relationships, and quality of life. Additionally, it supports the NICE recommendations to consider diabetes management holistically by considering both physical health and psychosocial aspects of care. This indicator also represents an important step in embedding the assessment and support for ED as part of routine diabetes management, in order to decrease stigma around the condition and for practice to ensure individuals affected are offered appropriate interventions to improve their health and consequently quality of life.

7. **IND111 -** The ratio of DM patients whose **albumin: creatinine ratio** (**ACR**) was tested in 15 months. This indicator emphasizes the early identification and monitoring of kidney complications in people with diabetes; it requires them to have at least one albumin: creatinine ratio test every 15 months. The completion of ACR testing is an important process measure supporting the timely recognition of moderate increases in albuminuria and diabetic nephropathy, both early markers for chronic kidney disease. When renal impairment is detected at an early stage, the clinician may be able to undertake interventions to delay progression to end-stage renal disease, while lessening cardiovascular risks. The indicator is consistent with NICE guidelines and reflects evidence-based practice within the framework of using the ACR, because ACR has greater sensitivity than protein to creatinine ratio, and is the preferred method for detecting and quantifying proteinuria in diabetes. In summary, this indicator provides a reflection of chronic disease management quality within the primary care setting, and supports better long-term outcomes by creating proactive care, guideline concordance, and screening.

8. **IND116**-This indicator looks at the percentage of females with DM aged 17 – 44 years who received tailored information and **advice about pregnancy**, conception or contraception in the last twelve months. DM during pregnancy can increase risks for the woman and the baby; miscarriage, preterm labor, congenital defects are all serious consequences of the mother's controlled blood glucose levels prior and during pregnancy. Through personalized advice, the mother will hopefully plan the pregnancy thus reducing risk and improve the pregnancy outcomes. This indicator helps promote general practice in helping that they are providing women with DM with the information needed for reproductive health and overall, improved maternal and fetal health.
9. **IND120** -The "Diabetes: Annual GMP Checks" indicator (percentage of DM patients participated in general check in a year) aims to ensure that general practices provide comprehensive and holistic care to those patients living with DM. Auditing the annularity of **certain checks** indicates whether key or essential health checks have been carried out annually, including BMI, blood pressure, HbA1c, cholesterol, foot assessment, kidney function. Determining whether these checks have been undertaken in the last year aims to monitor the quality of diabetes management and consequently improve quality of care. One of the goals is to improve patient outcomes through regular assessment of key health factors to limit or prevent issues leading to heart disease or kidney failure or limb loss, ultimately reducing long-term health risks to people living with diabetes.
10. **IND134** Angiotensin converting enzyme **(ACE)** inhibitor or angiotensin receptor blocker indicator (**ARB**s) **-** This indicator encourages evidence-based management of diabetic kidney disease by determining the percentage of patients with DM and documented nephropathy or microalbuminuria who are currently treated with **either ACE** inhibitors **or ARB**s. These agents are the foundation of management for diabetic kidney disease and are fully endorsed in NICE guideline for slowing kidney disease, regardless of blood pressure. This indicator promotes the routine prescribing

of ACE-inhibitors, or ARBs much more uniformly in this group of at-risk patients, and promotes early intervention to prevent long-term complications such as end-stage renal failure and cardiovascular morbidity, and to encourage practices to identify and treat proteinuria in persons with DM and uniformly treat eligible patients with reno-protective therapy. Overall, this indicator will align with national guidance to improve renal outcomes and patient quality of life in patients with DM, and help promote the embedding of preventative, proactive kidney care into everyday general practice.

11. **IND135** - The indicator shows the percentage of DM patients who are **below or equal to HbA1c level** of 64 mmol/mol (8.0%) in the previous 12 months. It is a pragmatic indicator for the control of blood sugar level in DM, aimed at reducing the risk of serious long-term complications of DM including heart disease, kidney failure, and importantly severe nerve problems. This indicator does not aim to reduce HbA1c to below or equal to 58 mmol/mol or even 64mmol/mol, not all patients will achieve that target but offers a middle ground where there is some indication of management of glycaemia. It also focuses our attention on those DM patients that achieve moderate control, and aids the organization and management of diabetes care in primary care to be more individualized and safe. This indicator is useful as it encourages practices to enhance overall glycemic management in a wide range of patient groups rather than focusing on strict targets that patients may find difficult to achieve. It has the potential to drive population-level improvement in DM-related health outcomes.
12. **IND136 -** This indicator is measuring the proportion of DM patients on the practice register who have an **HbA1c level equal to, or less** than, 75 mmol/mol in the previous 12 months. This measure is important because good blood glucose control is paramount to preventing complications from DM. It is worth noting that the target of 75 mmol/mol represent a compromise between appropriate glucose control and exposure to possible adverse events from excessively strict targets. This is a useful

measure to assist practices in effective blood glucose control for the entire cohort of diabetes patients, while realizing that individual patients may require somewhat alternative approaches.

13. **IND137-** The ratio of DM patients, who participated in **retinal screening** in the previous 12 months**.** Individuals diagnosed with DM are at an increased risk of developing diabetic retinopathy, which is a progressive eye disease that can eventually cause loss of vision if not detected and treated. Regular retinal screening is important for the early detection of sight-threatening diabetic retinopathy, which typically has no symptoms in its early stages. There is consistent evidence that retinal screening is effective at identifying retinal disease that has not previously been recognized. The focus of this indicator is to support regular engagement in annual retinal screening to reduce the incidence of preventable blindness in people with diabetes and to ensure they are aware of the offer of screening when they are invited for screening. Participation in screening is vital for population screening programs to succeed and effectively reduce vision impairment and blindness in diabetes. The NHS Diabetic Eye Screening Program is endorsed by the UK National Screening Committee and is aimed at ensuring that patients with diabetes and eligible for screening services are offered an annual preventative screening. Directly, GPs do not do the screening, but can help to ensure that their patients are aware of the screening service and referred to service, and facilitated to access this service. This indicator can help to track and promote the uptake of annual screening and help general practices with improving population health outcomes and preventing worsening complications of diabetic retinopathy.

14. **IND160 -** The indicator defines the percentage of DM patients who have received a **foot sensation test** using a 10g monofilament in 12 months. Foot complications in DM patients, especially neuropathy, are common and result in serious consequences such as ulceration. Foot test sensation using monofilament assess sensory neuropathy which is a significant risk factor leading to ulceration. Regular yearly foot checks,

including the foot sensation test, will help identify early and reduce the risk of complications in patients with diabetes. This indicator overall quantifies how well general practices are screening and managing the foot health for patients with diabetes.

15. **IND163** - The proportion of DM patients who was **vaccinated against influenza** in the preceding 1 August to 31 March. This indicator supports practices to increase the rates of influenza vaccines in eligible DM patients, who may be at higher risk of flu related morbidity and serious complications. Measuring vaccination rates in a defined seasonal period of time can promote encouraged screening with timely and targeted preventive health care. Improving recording, exception reporting, and promotion of patient participation will improve rates of vaccines and reduce avoidable adverse morbidity in this vulnerable population.
16. **IND165** - The ratio of DM patients, whose **HbA1c** was 58 mmol/mol or less in the previous 12 months. The indicator encourages better glycemic control in all people with DM, to reduce their future risk of serious complications including cardiovascular disease, kidney failure and eye problems. By adopting HbA1c ≤58 mmol/mol as a target, the indicator encourages general practice to manage DM proactively and personalize management, while keeping safety as a primary concern. It offers an important trade-off between achievable rates and clinical benefit.
17. **IND170** - This qualitative indicator (GMP has or has not register for non-diabetic hyperglycemia) supports practices to maintain an up-to-date **register of patients with non-diabetic hyperglycemia**. By keeping and maintaining a structured register for these patients, general practices can improve support for risk assessment, access to timely lifestyle interventions, and ability for monitoring opportunities to prevent the progression of these patients to Type 2 DM, which is important to their health. This initial step toward a publicly available register will allow practices to improve population health management and earlier preventive care.

18. **IND171 -** The indicator measures the proportion of patients' newly diagnosed non-diabetic hyperglycemia who are referred to the NHS Diabetes Prevention Program for an **intensive lifestyle intervention**. As individuals with non-diabetic hyperglycemia are at increased risk of type 2 DM, timely referral to a structured intervention involving diet, physical activity and weight is appropriate. The aim of the indicator is to ensure that at risk patients receive appropriate lifestyle intervention to minimize the likelihood of developing diabetes, which will help to improve long-term population health outcomes and reduce the demands on the NHS in the future.
19. **IND172** – It is the proportion of people with non-diabetic hyperglycemia who have had an **HbA1c or a fasting plasma glucose test** in the past 12 months. Non-diabetic hyperglycemia shows there is an increased risk of developing Type 2 DM. Routine testing can provide the opportunity to identify individuals with elevated glucose levels who may have developed DM so that they can be treated before they develop significant complications. The aim of this indicator is to ensure that individuals who are at high risk of developing Type 2 DM have appropriate testing so that DM can be prevented and complications mitigated. By monitoring these patients and offering timely interventions, GPs should be able to help to improve health outcomes for people with non-diabetic hyperglycemia.
20. **IND173 -** This indicator supports **annual HbA1c testing** beyond 12 months of diagnosis for women with a previous diagnosis of gestational diabetes (**GD**), which would allow for follow-up assessment and monitoring of long-term population health risk. As the progression to Type 2 diabetes is more prevalent in women with a history of GD, routine testing would identify those with HbA1c levels above normal and if necessary, further intervention. Repeated testing and recording, incorporating follow up into coding, can help identify patients at high risk and prompt follow up for better outcomes and eliminate avoidable complications in this patient cohort at risk.
21. **IND179 -** The ratio of DM patients without moderate or severe frailty, whose **HbA1c** was 58 mmol/mol or less in the previous 12 months. This indicator facilitates optimal

blood sugar management in the non-frail DM populations, reducing future complications such as heart disease, kidney damage, or vision loss. In looking to achieve an HbA1c of 58 mmol/mol or lower, the indicator indicates tighter glycemic targets for those less likely to experience the risk of harm and receive benefit from intensive treatment options—further promoting safe person-centered, outcome-focused diabetes care.

22. **IND180-** The proportion of DM patients whose last **HbA1c** was 75 mmol/mol or less in the previous 12 months. Different people with DM require different intensities of management. This indicator allows to adopt a person-centered framework using the categories of mild, moderate, or severe frailty, the group with moderate or severe frailty may be at greater risk for harm than from benefit if aggressive glucose lowering occurs. Maintaining HbA1c at or below 75 mmol/mol prevents future complications brought on by under-and overtreatment, reduces risk from hypo glycaemia, and improves quality of life for frail patients to receive safer, more appropriate, and responsive individual care.
23. **IND181** (Cardiovascular Risk Assessment Indicator) – Ratio of patients aged 25 and 84 years with type 2 DM, not taking a **statin**, whose cardiovascular disease risk was assessed in 3 years. This indicator is fundamental in improving early identification and prevention of cardiovascular disease in people with type 2 DM who are not currently taking a statin, and who are not experiencing moderate or severe frailty. By facilitating routine, and formal, cardiovascular risk assessment, including the use of risk estimators, the indicator fosters personalized patient-centered care, which can facilitate timely and more appropriate intervention. It meets national priorities for quality improvement, and addresses potential gaps in care by targeting individuals who may be under-assessed or under-treated. By incorporating personalization in care adjustments, the approach remains flexible to clinical appropriateness. With a sufficiently sized eligible population spread across general practices, this indicator would be useful across frameworks e.g. QOF and provide a key indicator for

determining progress in terms of prevention of cardiovascular events and optimizing long-term outcomes for those living with type 2 DM.

24. **IND221 -** This indicator monitors the percentage of patients with hypertension or DM and **a BMI of 27.5 kg/m^2 or greater** (or 30 kg/m^2) who have been referred to a weight management program within 90 days of their BMI being recorded. Proper weight management can result in great benefit when managing portion of hypertension or diabetes for patients, regarding their overall health, risk of disease complications and by just plain following those principles above it reminds the general practices to allow their reasonably eligible patients to be referred to a selected subset of weight management services, including both digital and non-digital settings and providing more timely interventions to mitigate other risks before any complicating medical conditions take effect. Overall whole person care will be improved of the contribution of obesity in the management of a healthier weight will support the best possible outcomes for people living with hypertension or diabetes.

25. **IND249 -** This indicator records the percentage of patients with DM, aged 79 years and under, without moderate or severe frailty, whose most recent **blood pressure** (in the last 12 months) measures appropriately low in relation to clinical target: <135/85 mmHg for home or ambulatory blood pressure monitoring, <140/90 mmHg for clinic blood pressure measurement. This measure is establishes evidence of an association between the effective management of blood pressure and improved cardiovascular and renal outcomes for diabetic patients, and therefore, and effective indicator of quality of care and preventive health intervention.

26. **IND274 -** This indicator shows the ratio of individuals, with type 2 DM, with moderate or severe frailty, who have a recorded cardiovascular **risk score** equal or greater than 10%, who are also on lipid-lowering therapy. It reflects quality of care using a clinically important intervention that has a robust evidence base to help reduce cardiovascular risk in this high-risk group.

27. **IND275** - This measure is the percentage of patients with DM aged 40 years and older, without a prior history of cardiovascular disease, and not with moderate or severe frailty that are on a **lipid lowering therapy**. It excludes type II DM patients with a cardiovascular disease risk score less than 10% over the last three years. As an indicator, this metric is a measure of clinical care quality, and effectual treatment in accordance with evidence on effective care practices, that are related to better outcomes.
28. **IND276** - This indicator captures the ratio of individuals with DM and a history of cardiovascular disease, excluding hemorrhagic stroke, on **lipid-lowering therapy**. It should be used to measure care quality and effectiveness, as it supports the use of interventions that have been clinically shown to lower cardiovascular risk.
29. **IND277** - This indicator pertains to the ratio of individuals who have type 1 DM, age greater than 40 years, without a history of hemorrhagic stroke, who are on **lipid-lowering therapy**. It is supposed to be used to examine care processes and patient outcomes that have been clinically shown to reduce cardiovascular risk and improve patient health.

Using this indicator set, QOF and the National Institute for Health and Care Excellence (NICE) in the UK introduced a pay-for-performance (**P4P**) model that incentivizes primary care providers to meet predefined DM care targets. While this system has led to better adherence to care processes, evidence suggests limited impact on long-term patient outcomes [38],[35],[39]. Moreover, concerns have been raised about the potential neglect of non-incentivized conditions.

Several countries have established national diabetes registries, including Sweden, Germany, Australia, Norway, Denmark, and the USA. For instance, Australia's National Diabetes Services Scheme not only facilitates subsidized access to essential DM services but also supports nationwide quality monitoring. The Australian National Diabetes Audit emphasizes both process and outcome measures to ensure continuous quality improvement [40],[41].

Germany's Robert Koch Institute has developed an evidence-based registry system that integrates routine monitoring, patient education, and lifestyle interventions. Unlike more fragmented frameworks, this model prioritizes long-term outcomes and coordinated, inter-professional care, demonstrating effectiveness in reducing complications and hospital admissions [42].

Across Europe, several initiatives—such as EUBIROD, EUCID, and DIABCARE-Q-Net—have aimed to harmonize diabetes care metrics. These programs often focus on key indicators like HbA1c levels, lipid profiles, and complication rates. However, implementation varies significantly between countries, limiting comparability and effectiveness [43],[44],[45]. The EUCID project sought to establish a consistent set of indicators for diabetes care across Europe, creating a unified framework for assessing clinical performance [44]. Similarly, EUBIROD connects diabetes registries from multiple countries to evaluate epidemiological trends and care quality, though inconsistent data collection remains a barrier to accurate comparison[46]. DIABQCARE expanded on these efforts by incorporating a comprehensive evaluation model that includes process, outcome, and patient-reported indicators. This initiative also highlighted the potential of digital health solutions and real-world data to enhance monitoring and drive improvements in diabetes care [47]. The OECD Diabetes Care Indicators focus on standardized metrics such as hospitalization rates for uncontrolled diabetes, enabling international comparisons. However, these indicators often lack the contextual sensitivity needed to reflect country-specific healthcare realities [48].

Research on diabetes quality indicators has yielded mixed conclusions. A systematic review by Carlos et al. (2025) demonstrated that performance monitoring enables primary care providers to assess and maintain care [49]. Abdel-Rahman et al. (2024) performed a longitudinal study that established a connection between the improvement of diabetes quality indicators and the reduced overall mortality rates [50].

Despite their intended benefits, performance indicators present notable challenges, particularly the issue of data manipulation. To preserve high-performance ratings, some healthcare providers selectively avoid treating high-risk patients, thereby deepening health disparities. Moreover, the burden of excessive documentation has grown, forcing physicians to devote more time to administrative work at the expense of direct patient care [51].

Patient-centered outcome measures are generally defined as self-efficacy, behavioral change, and patient satisfaction; evaluated as valid tools for measuring quality of care. However, implementation has been limited due to data collection issues and reimbursement systems that continue to give preference to clinical metrics over more holistic assessments of patients [52].

Monitoring the care of diabetes mellitus in Hungary

In contrast, Hungary's NHIF predominantly uses a limited pay-for-performance incentives. While it monitors some aspects of care quality, there is still a notable lack of patient-centered and outcome-based indicators. Currently, DM care quality is evaluated by only two indicators: HbA1c testing frequency in a year, and the ophthalmologic examination frequency in a year among treated DM patients. Such minimal approaches do not capture the complexity of managing DM and thus allows the failure of quality improvement efforts [53]. To improve primary healthcare quality, Hungary adopted a P4P model in 2009 under the NHIF. This initiative was intended to drive GPs toward better patient care, particularly in managing chronic conditions like DM, hypertension, and chronic pulmonary disease. This system (updated many times in the past 16 years) provides GPs with monthly feedback reports [54]. Thus far, the standard of primary care and DM management still falls behind many other EU countries, exposing an ongoing gap in the quality of care. It indicates that the timely monitoring and feedback regarding DM care may not be adequate to substantiate any significant improvements. Hungary on the other hand is making impressive dealings concerning DM care through various P4P mechanisms but there is still a need for more well-rounded and less skewed strategies [55],[56],[57]. The continuing expansion of P4P schemes is still being researched for their implementation and exposure effects.

Composite indicators

Composite indicators can be used as tools in health quality assessment, since indicators from an indicator set can be melded into integrated measures based on quality and safety perspectives. Sizing the broader balance obtained from many individual indicators allows for the comparison of results amongst the healthcare states and the identification of which state is better or worse than each other in the performance of care delivery [58],[59].

An important advantage of composite indicators is their ability to summarize complex information into an intuitive overall metric. This has made performance benchmarking simple and accessible for healthcare providers, policymakers, and patients, facilitating straightforward decision-making. By incorporating multiple individual indicators into a composite measure, it enhances statistical robustness by increasing the number of observations, leading to more stable and meaningful results [60],[61].

Moreover, while composite measures possess great potential, they are beset with some challenges, which need to be worked out thoughtfully. Determining the selection, weighting, and aggregation of the various individual indicators represents some of the major decisions of constructing composite measures.

Divergence in methodology could bring about considerably different outcomes, leading to possible inconsistencies in the ranking of providers and evaluations of care performance. Consequently, composites may blur important differences that exist in the underlying data and reveal a façade of quality, which may obscure an area's deficiencies or merits.

For experimental composite indicators to gain credibility and acceptance as dependable tools, a systematic approach needs to be utilized, consisting of a perfectly vetted theoretical framework and an unambiguous selection of component measures.

Validating that the measures correctly represent what they are supposed to underlie the assessment is an important step that must be undertaken in the composite indicator development. Methodological transparency is essential for covert credibility. Some examples include the Composite Rating for Overall Hospital Quality and the Patient Safety and Adverse Events Composite, which combines aspects of multiple quality dimensions like mortality, patient safety, readmission rates, and patient satisfaction [62],[63].

Composite indicators are still in contention as to the role and rating of healthcare providers. Some critics claim that choices regarding methods: data standardization, weighting assignments, and the way hypotheses are handled make it easier to introduce confounding and distortion into the research. To respond to these complaints, researchers call for other methodologies to be observable, reinforced, and flexible in the design of composite measures.

Using composite indicators correctly and perfectly is helpful to the stakeholders in health sector for health quality improvement [64]. The purpose of composite indicators will be achieved to the extent that they define the purpose, provide a methodology, and explain how the information will be interpreted and used in improving the decision-making and policy development processes in the healthcare industry [60],[65].

Determinants of the quality indicators

Diabetes-related health outcomes are influenced by both individual and community-level socioeconomic factors. While personal attributes such as education and household deprivation are well-established risk factors, spatial inequalities also play a significant role in shaping DM prevalence and outcomes. These spatial disparities reflect broader structural issues, including unequal access to healthcare and support for self-management [66],[67].

In Hungary, regional patterns of deprivation are linked to DM outcomes. Current research often focuses narrowly on individual-level of SES indicators [68],[69]. Incorporating spatial deprivation measures and adapting tools like the Carr–Hill formula to reflect patients' needs offers a more comprehensive approach to addressing socioeconomic disparities in primary care and improving equity in diabetes management [70].

As of 2020, every GMP in the UK is funded by core funding through the Carr-Hill formula instead of Minimum Practice Income Guarantee (**MPIG**). GMPs are also transitioning (albeit more slowly) to this universal approach. MPIG was first introduced in 2004 when the new GP contract was signed, to protect practices from being disadvantaged if they could not receive as much funding under the Carr-Hill formula. It essentially provided a "correction factor" which guaranteed minimum core funding to practices, derived from their base historic income[71],[72]. However, MPIG was meant only to be a transitional measure. The gradual phase-out began in 2014, and continued until 2021, with the “correction factor” decreasing by one-seventh each year. Any available funding reinstated through the release of MPIG would be put back into the core contract for all practices. So, in effect, slightly over half of practices benefited from that funding, as the other half lost funding. After 2020, all GMPs receive equal weighted funding per patient along with funding determined by the Carr-Hill formula with no adjustment from MPIG. The Carr-Hill formula determines the allocation of funding based on the workload created by the NHS, by the population of patients registered with a practice, and it allocates funding based on the following two categories of information:

1) Drivers of Workload
    a) Patient Age and Gender: different groups require different levels of care.
    b) Additional Needs, based on health surveys and rates of illness and mortality.
    c) Turnover in the list: new patients generally increase clinical workload.
2) Uncontrollable Costs
    a) Staffing Market Forces Factor: makes adjustments for variations in costs associated with staff when considering regional differences in staff costs.
    b) - Rurality: makes adjustments in consideration of the difficulty of servicing distanced and/or isolated populations.

Each driver generates an individual index for each practice - and individually indexed against a national average - which we aggregate to calculate each practice's weighted practice population, which we update regularly, and determines a practice's funding entitlement [73],[74].

Effective management of DM within primary care involves a complete strategy that considers clinical indicators, performance indicators, processes of care, composite indicators, and P4P as a value-based care model. These approaches from providers will improve patient-level indicators, reduce complications, and enhance quality improvement across care dimensions.

In Hungary, the extent of socioeconomic deprivation has a decisive effect on diabetes care. Some improvements were noted in glycemic control, lipid levels, and obesity, while blood pressure control could be better. Target achievement rates for glycosylated HbA1c (61.66%), low density lipoprotein cholesterol (53.48%), and blood pressure (54.00%) are below the acceptable target rates, particularly in less educated people and socioeconomically deprived populations [55].

Despite equitable levels of care process delivery, deprived, and particularly less educated patients, are at greater risk of complications than more affluent patients treated by the same primary healthcare professionals, and also receive more intensive therapies such as insulin. The effect of socioeconomic status on service use often outweighed that of patient attitude; service use was highly variable (18% to 97.9%) [56].

Crude expressions of GP performance indicators in Hungary do not capture the inequalities in health care delivery by variables including age, education, geographic location, and settlement type. With this in mind, it is essential to adjust performance indicators for deprivation in order to achieve fairness, and to provide meaningful feedback that could help to improve primary healthcare. In poorly performing primary health care systems like Hungary's, personalizing indicators to consider equity in terms of deprivation is crucial to achieve improved outcomes in the long term and to develop successful financial incentives [56],[55],[75],[76]

The P4P system embodies a strategic move away from traditional healthcare payment methods by aligning provider payments with measurable outcomes regarding care quality, efficiency, and accountability. Its most important significance is how it alters the incentives paid to providers and has implications that go well beyond reimbursement, explicitly shifting the focus from volume to value realigning provider accountability for patient outcomes [77]. P4P has can potentially real improvements in chronic disease management, patient follow-up, preventative services, and health system responsiveness. While there is evidence of positive impacts (e.g., greater adherence to clinical guidelines, better continuity of care, and in some areas, lower mortality), its effects will be moderated by context and have not been consistently modelled methodologically across multiple healthcare contexts [32],[33]. The variation in design, performance incentives and measures, and the diversity of health system structural factors limit any kind of universal application and cross-comparability of results. Nevertheless, the significance of P4P stems from its ability to:

- Align provider behavior with policy priorities related to quality and safety.
- Bring accountability to the service delivery of healthcare.
- Foster cost-effective care, through accountability for performance.
- Encourage reform that can be system-wide, particularly in settings with less coherent and developing health systems.

Going forward it is important to conduct more rigorous and context-sensitive evaluations to understand how P4P models can be framed, designed, and implemented in a way that takes into account local context (such as deprivation of the provided population and is likely to have the highest health gains for patients particularly in low- and middle-income countries, where health financing is a clearly defined public policy problem [78],[79].

Objectives

The aims of this study were: (1) to broaden the NHIF's diabetes care indicator set for assessing DM care quality at the GMP level in Hungary; (2) to explore the associations between these indicators and the structural characteristics of GMPs; (3) to broaden the NHIF's DM care indicator set by developing a composite diabetes management indicator (**CDMI**) for GMPs across Hungary, with a focus on adult populations; (4) to assess the relationship between the CDMI and GMP-specific structural characteristics, with the goal of constructing an adjusted CDMI that neutralizes the impact of GP-independent factors; (5) to formulate recommendations for advancing monitoring systems and designing structured intervention programs; and (6) to propose recommendations for improving the existing P4P scheme.

Methods

Settings

A secondary analysis of a large national dataset obtained from the NHIF was performed as part of a primary care development pilot program from 2012 to 2017 [76],[77]. The identifications of patients diagnosed with DM used the operational definition used by the NHIF which required at least four redemptions of diabetes medications (Anatomical Therapeutic Chemical code: A10) prescribed within a 12-month period.

The cross-sectional analysis encompassed all GMPs in Hungary (n = 4,784) that provided care either solely for adults or for both adults and children, covering the period from April 2017 to March 2018.

Patient demographic and structural characteristics of GMPs used in indicator calculations were extracted from the NHIF's integrated information system. The NHIF reported diabetes care data disaggregated by sex and age (in five-year age bands from 18–19 up to 90+ years). Socioeconomic status (SES) data were obtained from the Hungarian Central Statistical Office (HCSO), derived from the most recent national census conducted in 2011. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for reporting observational cross-sectional studies [78].

Explanatory variables

The structural features of GMPs were described by the following categories: Patient List Size: Practices were categorized according to their patient list size into the following five categories: ≤800, 801-1200, 1201-1600, 1601-2000, and ≥2001 patients. GP Vacancy Status: GMPs were differentiated according to their staffing status, i.e. managed by a temporary substitute GP with limited availability or contracted GPs with full availability, balanced against the age of contracted GPs (<65 years vs. ≥65 years). Residence Type: The practice type was identified as urban or rural. Practice Type: The practice was identified as adult only and mixed (serving adult and child populations). County: The geographic location of GMPs were identified by the county where the practice operates.

SES indicators associated with GMPs were derived from the 2011 Hungarian Census and adapted using established UK-based indicators of deprivation (i.e., Carstairs, Townsend) scores [80],[81]. The following SES variables were used:

- Education: The education level was defined as the total number of years of schooling of adults aged 7 years and older in each settlement of the defined administrative units. The expected years of schooling was obtained from the national census based on age and sex. The standardized relative education (srEDU) score was derived from the ratio of observed to expected years of schooling for each area.
- Employment: The employment rate of residents aged 15 years and older was calculated for each settlement. The employment rate was then standardized for age and sex using national employment statistics to derive the standardized relative employment ratio (srEMP).
- Housing Density: A crowding measure was calculated by dividing the number of people by the number of rooms for the residential units within each area. The relative housing density (rHD) was based on the local crowding measure as a proportion of the national average.
- Roma Ethnicity: The relative Roma population (rRP) was defined as the ratio of self-reported Roma residents to the proportion of Roma residents nationally.

For GMPs providing more than one settlements, the SES indicators were weighted based on the residential distribution of patients belonged to the GMP. The resulting GMP-level SES indicators were binned into tertiles for use in later analyses.

Outcome variables: DM care quality indicators

Our DM care quality evaluation relied basically on EUBIROD process indicators [46],[79]. But, due to the incomplete or missing registration of some variables (i.e. microalbuminuria, blood pressure and foot examination) in the NHIF, not all the EUBIROD indicators on DM care quality could be used for the evaluation. The seven indicators assessed were the percentage of DM patients who were tested for hemoglobin A1c, serum creatinine, and serum lipid status, who underwent ophthalmologic examination, and who received influenza vaccine in a year; and prevalence of DM in the 40−54 and 55−69 years age strata. (**Table 1**)

Table 1. Definitions of the quality of DM care indicators.

	Indicator name	**Target group**	**Indicator definition**
Process indicators	Hemoglobin A1c testing	Primary health care patients with DM	Proportion of diabetics who were involved in hemoglobin A1c testing (at least once in previous 12 months)
	Ophthalmological examination	Primary health care patients with DM	Proportion of diabetics who participated in an ophthalmological examination (at least once in previous 12 months)
	Serum creatinine check	Primary health care patients with DM	Proportion of diabetic patients who participated in a serum creatinine determination (at least once in previous 12 months)
	Influenza vaccination	Primary health care patients with DM under 65 years old	Proportion of people under 65 years of age who were vaccinated against influenza in diabetic patients
	Lipid status checking	Primary health care patients with DM	Proportion of diabetics who participated in a serum lipid status test (at least once in previous 12 months)
Prevalence indicators	DM patients aged 40–54 years	40–54-years-old primary health care patients with DM	Proportion of diabetic patients, aged 40–54 years, who redeemed a diabetic medicine at least 4 times in the previous 12 months
	DM patients aged 55–69 years	55–69-years-old primary health care patient with DM	Proportion of diabetic patients, aged 55–69 years, who redeemed a diabetic medicine at least 4 times in the previous 12 months

In recognition of the impact of patients' sociodemographic characteristics on diabetes care equity care [56] and to inform the indirect standardization of diabetes care indicators, we determined some indicators would indirectly by the patients' age, sex and eligibility for exemption certificates. Age was categorized as follows: 18-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 70-74, 75-79, 80-84, 85-89, and ≥90 years. An exemption certificate is issued by local municipalities and provides patients with medications free of charge due to chronic illness or low socioeconomic status, it was used as a source of social disadvantage. The standardization was performed based on national reference values for each demographic stratum and weighted based on the same demographic structure of each GMP's patient population. From this standardization exercise, we calculated the expected number of cases for each indicator in each practice by age, gender and exemption certificate eligibility. Then using the expected number of cases per indicator as a reference point, we calculated ISRs as relative performance indicators across GMPs.

Composite Outcome Variable

A **CDMI** was developed utilizing five key process indicators, including: (1) the proportion of DM patients who underwent hemoglobin A1c (HbA1c) testing, (2) the proportion of DM patients who received an ophthalmological examination, (3) the proportion of DM patients who underwent serum creatinine measurement, (4) the proportion of DM patients who had their serum lipid status measured, and (5) the proportion of DM patients under 65 years of age who received an influenza vaccination within the previous 12 months [79],[43], [82] ,[83].

To address the challenge of low observed case numbers in the statistical analysis, the ISRs were adjusted using empirical Bayes methods [84]. The empirical Bayes-adjusted ISRs were subsequently normalized using a two-step Box–Cox transformation [85],[86] to get normalized empirical Bayes adjusted indirectly standardized ratios (**nISR**s).

Factor analysis (using principal component analysis with PROMAX rotation), was performed with nISRs to help uncover latent structures behind the indicators. The number of factors retained was identified based on eigenvalues with a cutoff of greater than or equal to one. Factor analysis suggested a single factor (Kaiser–Meyer–Olkin measure of sampling adequacy: 0.727; Bartlett's test of sphericity p value < 0.001) structure, with the factor loadings (**Table 2**).

The resulted factors with normal distribution were used as CDMIs. These parameters showed the standardized DM care quality indicator across the GMPs.

Table 2. DM quality care indicators and the factor identified in the principal component analysis.

Indicators	Factor Loading
HbA1c testing	0.932
Ophthalmological examination	0.259
Serum creatinine check	0.812
Influenza vaccination	0.023
Lipid status checking	0.932

Statistical Analysis

To investigate the relationships between GMP characteristics and transformed DM care indicators (nISRs or CDMIs), multivariable linear regression models were used. Results of the regression analysis were reported using standardized regression coefficients (**β**) and associated 95% confidence intervals (**95% CI**) to evaluate strength of the association and significance, respectively.

In the case of CDMI analysis, next, we used the nonstandardzed regression coefficients from the model to remove the effects of each explanatory variable from the CDMI and get adjusted overall quality indicator of DM care (**ACDMI**). Then, we compared distributions of the CDMI and ACDMI. The extreme scores were determined by 2.5 and 97.5 percentiles of indicators. Extreme overall quality indicator values were grouped and defined as follows:

- $LowCDMI_{nonstructural}$: extremely low CDMI and ACDMI scores, where the low CDMI score was not explained by the structural characteristics in the regression model (i.e.: the cause of poor DM care quality reflects nonstructural factors);
- $LowCDMI_{structural}$: extremely low CDMI but not extremely low ACDMI, where the low CDMI score could be explained by the structural factors analyzed in the regression model (i.e.: the cause of poor DM care quality reflected structural factors);
- $HighCDMI_{nonstructural}$: GMPs with extremely high CDMI and ACDMI, where the high rating could not be accounted for structural factors (indicating good DM care quality due to nonstructural factors);
- $HighCDMI_{structural}$: GMPs with extremely high CDMI and ACDMI, where high rating was accounted for structural factors assessed in the regression model (indicating good DM care quality due to structural factors);
- $HighACDMI_{nonstructural}$: GMPs with non-extreme CDMI but extremely high ACDMI, where the high adjusted score was not accounted for structural factors (indicating good DM care quality due to nonstructural factors);
- $LowACDMI_{nonstructural}$: GMPs with non-extreme CDMI but extremely low ACDMI, where the low adjusted score could not be accounted for structural factors (indicating poor DM care quality due to nonstructural factors).

Analysis of data was conducted using a statistical analysis software statistics (version 18.0, SPSS Inc., Chicago, IL, USA).

Results

Descriptive Statistics

The evaluation included data from and 4,784 general medical practices (GMPs) and 516,052 patients diagnosed with DM. The average age of the DM patient community was 65.73 years (±12.37), and the male: female ratio was 1.11. Exemption certificates (indicating socioeconomic disadvantage and or chronic illness) were held by 8.34% of the DM patients (n = 43,064). The average number of completed school years, for anyone aged seven years and older, was 10.7. The employment rate for those aged 15 and over was 46.44%, and the average household crowding index was 1.08, describing the average number of persons per room. In terms of ethnicity, 3.10% self-identified as Roma. Most GMPs were rural (66.3%), and 3.70% of practices had no contracted full-time GP. For patient list sizes, the most predominant was 1,201 to 1,600 patients (32.0%). Most GPs, 77.89%, were aged under 65 (**Table 3**).

Table 3. Characteristics of the investigated GMPs and patients with DM.

Structural characteristics of the GMPs	Categories	GMP		DM patients	
		N	Percentage	N	Percentage
Settlement type	Rural	3172	66.30%	365,381	70.80%
	Urban	1612	33.70%	150,671	29.20%
GMP list size	<800	153	3.00%	7207	1.40%
	801–1200	655	14.00%	45,335	8.78%
	1201–1600	1522	32.00%	142,544	27.62%
	1601–2000	1504	31.00%	178,537	34.60%
	>2000	950	20.00%	142,429	27.60%
GP vacancy	Filled	4608	96.30%	503,713	97.60%
	Vacant	176	3.70%	12,339	2.40%
GMP type	Adult	3317	69.00%	385,372	74.68%
	Mixed	1467	31.00%	130,680	25.32%
Age of GP (years)	<65	1019	22.11%	103,895	20.12%
	≥65	3589	77.89%	399,818	77.48%
County	Baranya	207	4.33%	21,458	4.15%

Structural characteristics of the GMPs	Categories	GMP		DM patients	
		N	Percentage	N	Percentage
	Bács-Kiskun	256	5.35%	27,720	5.37%
	Békés	187	3.91%	19,939	3.86%
	Borsod-Abaúj-Zemplén	370	7.73%	35,345	6.85%
	Csongrád-Csanád	204	4.26%	18,907	3.66%
	Fejér	194	4.06%	22,576	4.37%
	Győr-Moson-Sopron	202	4.22%	23,251	4.51%
	Hajdú-Bihar	242	5.06%	25,993	5.04%
	Heves	160	3.34%	16,616	3.22%
	Komárom-Esztergom	141	2.95%	16,105	3.12%
	Nógrád	109	2.28%	10,537	2.04%
	Pest	466	9.74%	61,273	11.87%
	Somogy	172	3.60%	18,934	3.67%
	Szabolcs-Szatmár-Bereg	265	5.54%	28,431	5.50%
	Jász-Nagykun-Szolnok	192	4.01%	21,118	4.10%
	Tolna	119	2.49%	14,144	2.74%
	Vas	133	2.78%	14,551	2.82%
	Veszprém	164	3.43%	18,889	3.66%
	Zala	141	2.95%	14,868	2.90%
	Budapest	860	17.98%	85,397	16.55%
Total		4784	100%	516,052	100%

The prevalence of DM was 3.33% among adults aged 40–54 years (67,942 DM patients/2,042,573 adults) and 12.65% among those aged 55–69 years (225,816 DM patients/1,785,514 adults). In 2018, 58.64% of DM patients used each of the studied 5 services properly. Among these, 86.18% underwent serum creatinine testing, while only 12.89% received an influenza vaccination. HbA1c testing, ophthalmological examinations, and serum lipid status assessments were conducted in 78.05%, 38.03%, and 78.05% of patients, respectively. Detailed descriptive statistics are provided in **Table 4**. The distribution of nISRs is illustrated in histograms of **Figures 1a–g**. Bivariate analyses revealed that each process indicator was significantly lower in GMPs with GPs aged 65 years or older. Additionally, an inverse relationship was observed between the process indicators and GMP list size. Similar associations were found for lower levels of education and rural practice locations, with the exception of influenza vaccination rates. Furthermore, the prevalence of DM was lower among patients residing in urban areas, with higher education levels, employment, and less crowded households (**Table 5**).

Table 4. Patient characteristics, received DM care, and crude indicators in 2018 Hungarian GMPs.

	HemoglobinA1c Testing		**Ophthalmological Examination**		**Prevalence of DM Patients Aged 40–54**		**Prevalence of DM Patients Aged 55–69**		**Serum Creatinine Determination**		**Influenza Vaccination**		**Lipid Status Testing**	
	Received Care 32.907	**Target Group 39.155**	**Received Care 18.559**	**Target Group 39.155**	**Received Care 6.837**	**Target Group 160.22**	**Received Care 19.455**	**Target Group 132.26**	**Received Care 35.065**	**Target Group 39.155**	**Received Care 4.815**	**Target Group 18.552**	**Received Care 32.907**	**Target Group 39.155**
18–19 years	375	424	133	424					377	424	21	424	375	424
20–24 years	1708	2021	597	2021					1737	2021	81	2021	1708	2021
25–29 years	2283	2839	839	2839					2394	2839	132	2839	2283	2839
30–34 years	3139	4018	1170	4018					3373	4018	210	4018	3139	4018
35–39 years	5461	6968	2001	6968					5846	6968	424	6968	5461	6968
40–44 years	11,033	13,969	4279	13,969	13,969	794,746			11,726	13,969	928	13,970	11,142	13,969
45–49 years	17,044	21,343	6716	21,343	21,343	664,755			18,065	21,343	1614	21,342	17,231	21,343
50–54 years	26,119	32,630	10,758	32,630	32,630	583,072			27,723	32,630	3092	32,630	26,119	32,630
55–59 years	39,932	49,370	17,400	49,370			49,370	548,390	42,727	49,370	6187	49,370	39,933	49,370
60–64 years	67,835	84,683	31,705	84,683			84,683	667,123	73,341	84,683	15,442	84,682	67,835	84,683
65–69 years	73,687	91,763	38,054	91,763			91,763	570,001	80,409	91,763			73,687	91,763
70–74 years	64,054	80,775	35,188	80,775					71,236	80,775			64,054	80,775
75–79 years	48,889	64,265	27,069	64,265					55,853	64,265			48,889	64,265
80–84 years	27,292	38,619	14,054	38,619					32,471	38,619			27,292	38,619
85–89 years	11,213	17,455	5210	17,455					17,437	22,365			13,932	22,365
>90 years	2719	4910	1105	4910										
female	210,188	271,463	106,910	271,463	27,419	1,018,978	108,533	977,814	234,150	271,463	12,544	97,176	210,189	271,463
male	192,595	244,589	89,368	244,589	40,523	1,023,595	117,283	807,700	210,565	244,589	15,587	121,088	192,595	244,589
exemption certificate (+)	369,225	472,988	179,898	472,988	60,763	2,001,258	205,813	1,705,497	406,802	472,988	23,914	194,946	369,226	472,988
exemption certificate (−)	33,558	43,064	16,380	43,064	7179	41,315	20,003	80,017	37,913	43,064	4217	23,318	33,558	43,064
total	402,783	516,052	196,278	516,052	67,942	2,042,573	225,816	1,785,514	444,715	516,052	28,131	218,264	402,784	516,052
crude indicator	78.05%		38.03%		3.33%		12.65%		86.18%		12.89%		78.05%	

Figure 1. Distribution of the GMP-specific outcome indicators prepared for linear regression analysis with the fitted normal distribution curve: (**a**) DM prevalence in 40–54-year-old patients, (**b**) DM prevalence in 55–69-year-old patients, (**c**) serum creatinine testing, (**d**) ophthalmological examination, (**e**) hemoglobin A1c testing, (**f**) influenza vaccination, and (**g**) lipid status testing. (**SD**: standard deviation)

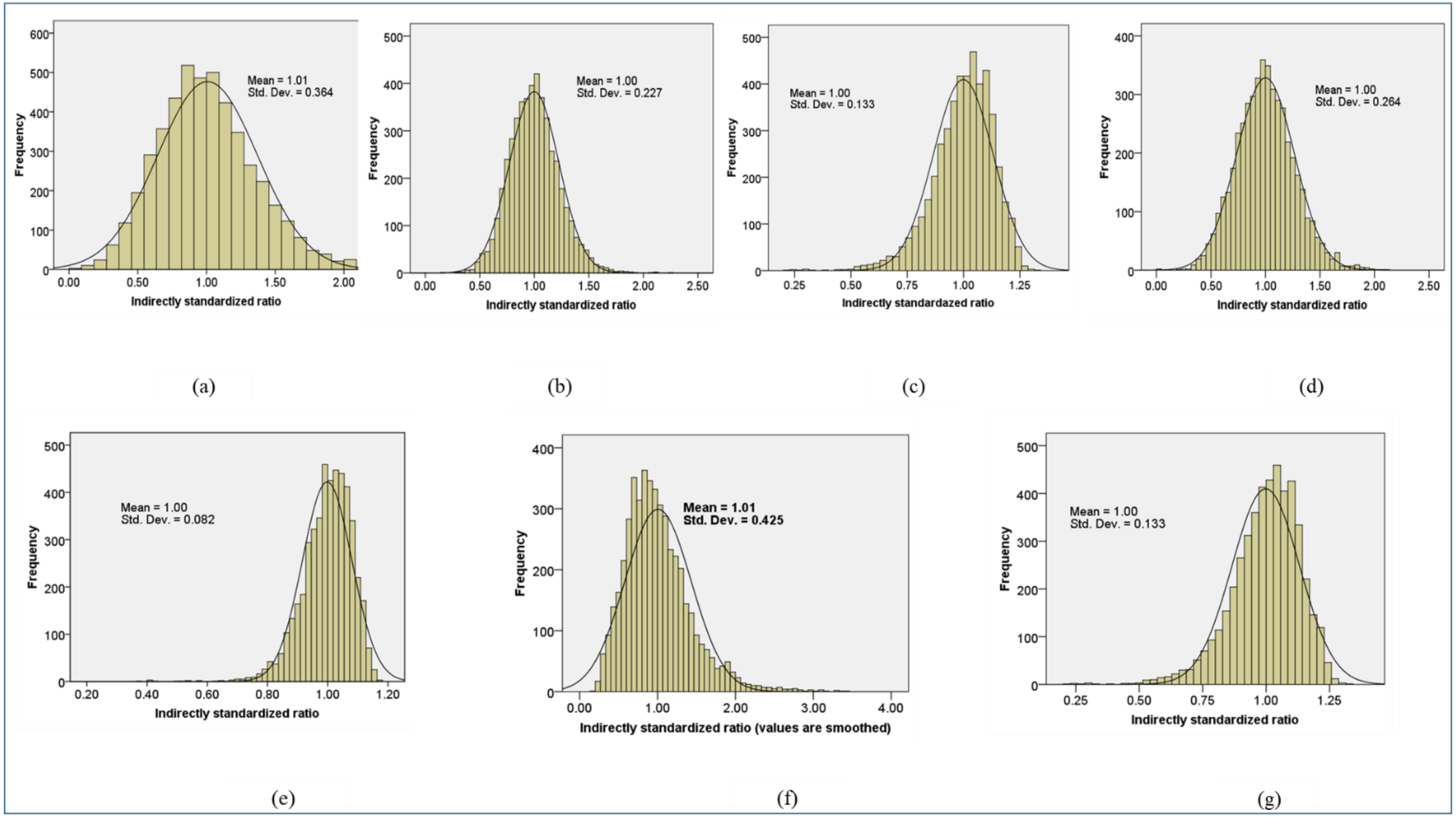


Table 5. The association between the structural characteristics and socioeconomic status indicators of GMPs and the standardized DM indicators and their corresponding 95% confidence interval by bivariate linear regression analyses*.

	HemoglobinA1c Testing	Ophthalmological Examination	Serum Lipid Status Checking	Serum Creatinine Determination	Influenza Vaccination	Prevalence of DM Aged 40–54	Prevalence of DM Aged 55–69
GMP type (adult/mixed)	0.020 [0.006;0.034]	0.010 [−0.016;0.036]	0.020 [0.006;0.034]	0.015 [0.006;0.024]	−0.052 [−0.099;−0.006]	−0.019 [−0.057;0.018]	0.011 [−0.013;0.035]
Settlement type (urban/rural)	0.017 [0.003;0.03]	0.027 [0.001;0.052]	0.017 [0.003;0.030]	0.013 [0.005;0.022]	−0.006 [−0.052;0.040]	−0.045 [−0.082;−0.007]	−0.034 [−0.058;−0.011]
GP (vacancy/age < 65)	0 [−0.021;0.021]	0.018 [−0.020;0.057]	0 [−0.021;0.021]	0.006 [−0.007;0.019]	−0.119 [−0.188;−0.051]	0.023 [−0.033;0.079]	−0.001 [−0.036;0.034]
GP (age ≥ 65X/age < 65)	−0.027 [−0.036;−0.018]	−0.016 [−0.033;0]	−0.027 [−0.036;−0.018]	−0.017 [−0.023;−0.012]	−0.033 [−0.062;−0.003]	−0.032 [−0.056;−0.008]	−0.028 [−0.043;−0.013]
List size (≤800/1201–1600)	−0.007 [−0.029;0.016]	−0.055 [−0.097;−0.014]	−0.006 [−0.029;0.016]	−0.003 [−0.017;0.010]	0.023 [−0.051;0.096]	−0.036 [−0.096;0.024]	−0.022 [−0.06;0.015]
List size (801–1200/1201–1600)	−0.007 [−0.019;0.004]	−0.001 [−0.022;0.021]	−0.007 [−0.019;0.004]	−0.004 [−0.011;0.003]	0.004 [−0.035;0.043]	−0.022 [−0.054;0.009]	−0.010 [−0.030;0.010]
List size (1601–2000/1201–1600)	−0.005 [−0.014;0.004]	−0.018 [−0.035;−0.001]	−0.005 [−0.014;0.004]	0 [−0.006;0.005]	−0.015 [−0.045;0.015]	0.011 [−0.013;0.036]	0.008 [−0.008;0.023]
List size (>2000/1201–1600)	−0.023 [−0.033;−0.012]	−0.021 [−0.041;−0.001]	−0.023 [−0.033;−0.012]	−0.011 [−0.018;−0.004]	−0.043 [−0.078;−0.007]	0.003 [−0.026;0.032]	0.004 [−0.015;0.022]
Level of education (low/medium)	−0.030 [−0.043;−0.018]	−0.056 [−0.080;−0.032]	−0.031 [−0.043;−0.018]	−0.018 [−0.026;−0.010]	−0.004 [−0.046;0.038]	0.037 [0.003;0.072]	0.009 [−0.013;0.030]
Level of education (high/medium)	0.013 [0.001;0.026]	0.020 [−0.004;0.044]	0.013 [0.001;0.026]	0.006 [−0.002;0.014]	0.035 [−0.008;0.078]	−0.136 [−0.171;−0.101]	−0.067 [−0.088;−0.045]
Employment ratio (low/medium)	−0.005 [−0.018;0.008]	−0.010 [−0.034;0.014]	−0.005 [−0.018;0.008]	−0.002 [−0.011;0.006]	0.050 [0.007;0.094]	0.039 [0.004;0.075]	0.029 [0.007;0.051]
Employment ratio (high/medium)	0.001 [−0.013;0.014]	0.016 [−0.009;0.042]	0.001 [−0.013;0.014]	−0.004 [−0.012;0.004]	0.008 [−0.037;0.053]	−0.052 [−0.088;−0.015]	−0.053 [−0.076;−0.03]
Housing density (low/medium)	0.012 [−0.001;0.024]	−0.048 [−0.072;−0.025]	0.012 [−0.001;0.024]	0.003 [−0.004;0.011]	0 [−0.042;0.041]	−0.044 [−0.078;−0.010]	−0.024 [−0.045;−0.003]
Housing density (high/medium)	−0.002 [−0.013;0.009]	−0.021 [−0.041;−0.001]	−0.002 [−0.013;0.009]	−0.002 [−0.009;0.004]	0 [−0.036;0.036]	0.037 [0.008;0.066]	0.023 [0.004;0.041]
Proportion Roma (low/medium)	−0.003 [−0.016;0.009]	0.008 [−0.015;0.031]	−0.003 [−0.016;0.009]	0.003 [−0.005;0.01]	0.047 [0.006;0.087]	−0.031 [−0.065;0.002]	0.007 [−0.014;0.028]
Proportion Roma (high/medium)	−0.004 [−0.017;0.009]	−0.013 [−0.037;0.012]	−0.004 [−0.017;0.009]	0.002 [−0.006;0.011]	−0.028 [−0.071;0.016]	0.013 [−0.023;0.048]	0.019 [−0.004;0.041]
Baranya/Budapest	0.046 [0.020;0.073]	−0.068 [−0.117;−0.018]	0.046 [0.020;0.073]	0.027 [0.011;0.044]	0.091 [0.003;0.178]	−0.040 [−0.111;0.032]	−0.014 [−0.059;0.031]
Bács-Kiskun/Budapest	0.051 [0.025;0.077]	−0.184 [−0.233;−0.135]	0.051 [0.025;0.077]	0.026 [0.010;0.042]	0.002 [−0.085;0.088]	−0.070 [−0.140;0]	−0.079 [−0.123;−0.035]
Békés/Budapest	0.004 [−0.025;0.034]	−0.204 [−0.259;−0.148]	0.005 [−0.025;0.034]	−0.010 [−0.028;0.008]	−0.097 [−0.195;0.001]	−0.080 [−0.160;0]	−0.067 [−0.117;−0.017]
Borsod-Abaúj-Zemplén/Budapest	0.026 [0;0.052]	−0.119 [−0.168;−0.071]	0.026 [0;0.052]	−0.015 [−0.031;0.002]	−0.058 [−0.145;0.029]	−0.131 [−0.201;−0.060]	−0.149 [−0.193;−0.104]
Csongrád/Budapest	0.044 [0.015;0.072]	−0.067 [−0.121;−0.013]	0.044 [0.015;0.073]	0.012 [−0.006;0.03]	−0.058 [−0.154;0.038]	−0.154 [−0.231;−0.076]	−0.152 [−0.201;−0.103]
Fejér/Budapest	0.016 [−0.012;0.043]	−0.139 [−0.191;−0.087]	0.016 [−0.012;0.044]	−0.001 [−0.018;0.017]	−0.052 [−0.144;0.040]	−0.043 [−0.117;0.032]	−0.040 [−0.087;0.007]
Győr-Moson-Sopron/Budapest	0.024 [−0.003;0.05]	−0.319 [−0.370;−0.269]	0.024 [−0.003;0.051]	−0.011 [−0.028;0.005]	−0.188 [−0.278;−0.099]	−0.023 [−0.096;0.05]	0.015 [−0.031;0.061]
Hajdú-Bihar/Budapest	0.07 [0.042;0.098]	−0.025 [−0.078;0.028]	0.070 [0.042;0.098]	0.018 [0;0.035]	−0.123 [−0.217;−0.029]	−0.084 [−0.160;−0.007]	−0.095 [−0.143;−0.047]
Heves/Budapest	−0.010 [−0.038;0.018]	−0.362 [−0.414;−0.309]	−0.010 [−0.038;0.018]	−0.023 [−0.041;−0.006]	−0.026 [−0.119;0.067]	−0.094 [−0.169;−0.018]	−0.097 [−0.144;−0.049]
Komárom-Esztergom/Budapest	−0.052 [−0.081;−0.023]	−0.273 [−0.327;−0.219]	−0.052 [−0.080;−0.023]	−0.035 [−0.053;−0.017]	−0.051 [−0.147;0.045]	−0.144 [−0.222;−0.066]	−0.043 [−0.092;0.006]

	HemoglobinA1c Testing	**Ophthalmological Examination**	**Serum Lipid Status Checking**	**Serum Creatinine Determination**	**Influenza Vaccination**	**Prevalence of DM Aged 40–54**	**Prevalence of DM Aged 55–69**
Nógrád/Budapest	−0.069 [−0.103;−0.036]	−0.265 [−0.328;−0.203]	−0.069 [−0.103;−0.036]	−0.031 [−0.051;−0.010]	−0.003 [−0.114;0.108]	−0.205 [−0.296;−0.115]	−0.183 [−0.240;−0.126]
Pest/Budapest	−0.003 [−0.026;0.021]	−0.156 [−0.201;−0.112]	−0.002 [−0.026;0.021]	−0.009 [−0.024;0.006]	−0.065 [−0.144;0.014]	−0.045 [−0.11;0.019]	0.003 [−0.037;0.043]
Somogy/Budapest	−0.003 [−0.031;0.025]	−0.203 [−0.255;−0.150]	−0.003 [−0.031;0.026]	−0.012 [−0.03;0.005]	0.188 [0.095;0.282]	0.018 [−0.059;0.094]	0.014 [−0.034;0.062]
Szabolcs-Szatmár-Bereg/Budapest	0.064 [0.037;0.091]	−0.155 [−0.206;−0.105]	0.064 [0.037;0.091]	0.031 [0.014;0.047]	−0.093 [−0.182;−0.003]	−0.090 [−0.163;−0.017]	−0.083 [−0.129;−0.037]
Jász-Nagykun-Szolnok/Budapest	0.030 [0.002;0.058]	−0.254 [−0.306;−0.203]	0.031 [0.003;0.058]	−0.008 [−0.025;0.010]	−0.113 [−0.205;−0.021]	−0.046 [−0.121;0.029]	−0.073 [−0.120;−0.026]
Tolna/Budapest	−0.055 [−0.085;−0.025]	−0.164 [−0.220;−0.107]	−0.054 [−0.084;−0.024]	0.025 [0.006;0.044]	0.148 [0.048;0.248]	0.037 [−0.045;0.118]	0.043 [−0.008;0.094]
Vas/Budapest	0.068 [0.039;0.097]	−0.122 [−0.176;−0.067]	0.068 [0.039;0.098]	0.036 [0.018;0.054]	−0.136 [−0.233;−0.039]	−0.032 [−0.111;0.047]	0.008 [−0.041;0.057]
Veszprém/Budapest	0 [−0.028;0.027]	−0.168 [−0.220;−0.116]	0 [−0.028;0.028]	−0.001 [−0.018;0.017]	0.004 [−0.089;0.096]	−0.107 [−0.183;−0.032]	−0.062 [−0.110;−0.015]
Zala/Budapest	0.015 [−0.013;0.043]	−0.167 [−0.219;−0.114]	0.015 [−0.012;0.043]	0.009 [−0.009;0.026]	0.110 [0.017;0.202]	−0.144 [−0.219;−0.069]	−0.094 [−0.142;−0.047]

* Linear regression coefficients with their 95% confidence intervals. Significant results bolded.

Linear Regression Modeling for DM process indicators

Regression analyses demonstrated that both patient- and practice-level characteristics uniquely shaped the diabetes care indicators (**Table 6**).

Among these characteristics, educational attainment was consistently the strongest determinant across all process indicators, with lower levels of educational attainment significantly associated with lower rates of HbA1c testing (β = −0.108, 95% CI: −0.153 to −0.063), ophthalmological exam (β = −0.100, 95% CI: −0.142 to −0.057), serum creatinine (β = −0.103, 95% CI: −0.148 to −0.058), and serum lipids testing (β = −0.108, 95% CI: −0.153 to −0.063). Educational attainment was also an important predictor of influenza vaccination and diabetes prevalence, particularly for adults aged 40-54 (β = −0.176) and 55-69 (β = −0.139).

The second strongest determinant was GP age, and particularly for GPs aged 65 years or older, whose patients were less likely to receive recommended laboratory tests.

The employment rate was inversely associated with diabetes prevalence (β= −0.137, p= 0.032) and had a small positive influence on influenza vaccination rates (β= 0.086, p= 0.021).

Housing density was another important characteristic where higher density resulted in poorer access to ophthalmology care (β = −0.084, 95% CI = −0.126 to −0.043). However, the effect of high housing density was less pronounced (β = −0.038, 95% CI = −0.074 to −0.002).

The influence of GP vacancy and the proportion of Roma was limited (GP vacancy: β = −0.053, 95% CI = −0.083 to −0.022), where it achieved significance levels on laboratory testing only for immunization against influenza vaccination (low Roma proportion: β = 0.051, 95% CI = −0.006 to 0.096).

Urbanization had consistent but less significance across all the indicators. Contrary to our predictor's experiences, those practices with larger patient list sizes had the poorest performance on the process indicators overall, and adult only GMPs had better performances for laboratory tests compared to mixed practices.

We report significant regional variation in local organizations to provide diabetes services, with county coefficients clearly indicating geographic variation in care quality for diabetes.

Table 6. The whole models for the association between the structural characteristics and socioeconomic status indicators of GMPs and the standardized DM indicators and their corresponding 95%CI by multivariable linear regression analyses*.

	HemoglobinA1c Testing	**Ophthalmological Examination**	**Serum Lipid Status Checking**	**Serum Creatinine Determination**	**Influenza Vaccination**	**Prevalence of DM Aged 40–54**	**Prevalence of DM Aged 55–69**
Explanatory power of the model (*r*2)	0.114	0.210	0.113	0.105	0.039	0.130	0.119
Baranya/Budapest	**0.071 [0.030; 0.111]**	**−0.052 [−0.090; −0.014]**	**0.071 [0.031;0.111]**	**0.068 [0.027;0.108]**	**0.044 [0.002;0.085]**	−0.022 [−0.062; 0.018]	−0.012 [−0.053; 0.028]
Bács-Kiskun/Budapest	**0.086 [0.042; 0.130]**	**−0.157 [−0.199; −0.116]**	**0.086 [0.042;0.130]**	**0.071 [0.027;0.116]**	0.001 [−0.045;0.047]	−0.043 [−0.087; 0.000]	**−0.078 [−0.122; −0.035]**
Békés/Budapest	0.006 [−0.037; 0.049]	**−0.150 [−0.190; −0.109]**	0.007 [−0.036;0.050]	−0.024 [−0.067;0.019]	−0.044 [−0.089;0.000]	**−0.043 [−0.085; 0.000]**	**−0.057 [−0.100; −0.014]**
Borsod-Abaúj-Zemplén/Budapest	0.052 [−0.001; 0.104]	**−0.121 [−0.171; −0.072]**	**0.053 [0.000;0.105]**	−0.047 [−0.100;0.005]	−0.036 [−0.091;0.018]	**−0.096 [−0.148; 0.044]**	**−0.176 [−0.228; −0.123]**
Csongrád/Budapest	**0.066 [0.023; 0.110]**	**−0.051 [−0.093; −0.010]**	**0.067 [0.023;0.111]**	0.029 [−0.015;0.073]	−0.028 [−0.073;0.018]	**−0.085 [−0.129; −0.042]**	**−0.136 [−0.180; −0.092]**
Fejér/Budapest	0.023 [−0.018; 0.064]	**−0.104 [−0.143; −0.065]**	0.024 [−0.017;0.065]	−0.001 [−0.043;0.040]	−0.024 [−0.067;0.018]	−0.023 [−0.064; 0.017]	−0.035 [−0.075; 0.006]
Győr-Moson-Sopron/Budapest	0.036 [−0.005; 0.076]	**−0.244 [−0.282; −0.205]**	0.036 [−0.005;0.077]	−0.028 [−0.069;0.013]	**−0.089 [−0.132;−0.047]**	−0.013 [−0.053; 0.028]	0.013 [−0.028; 0.054]
Hajdú-Bihar/Budapest	**0.115 [0.069; 0.162]**	−0.021 [−0.065; 0.023]	**0.116 [0.069;0.162]**	**0.047 [0.000;0.094]**	**−0.063 [−0.112;−0.015]**	**−0.051 [−0.097; −0.004]**	**−0.092 [−0.138; −0.046]**
Heves/Budapest	−0.014 [−0.052; 0.024]	**−0.247 [−0.283; −0.211]**	−0.013 [−0.051;0.025]	**−0.051 [−0.089;−0.013]**	−0.011 [−0.050;0.029]	**−0.046 [−0.084; −0.009]**	**−0.077 [−0.115; −0.039]**
Komárom-Esztergom/Budapest	**−0.066 [−0.103; −0.029]**	**−0.175 [−0.210; −0.141]**	**−0.066 [0.102; −0.029]**	**−0.072 [−0.109; −0.035]**	−0.020 [−0.059; 0.018]	**−0.0067 [−0.103; −0.031]**	−0.032 [−0.068; 0.005]
Nógrád/Budapest	**−0.078 [−0.115; −0.040]**	**−0.150 [−0.186; −0.115]**	**−0.078 [−0.115; −0.040]**	**−0.056 [−0.093; −0.018]**	−0.001 [−0.040; 0.038]	**−0.084 [−0.121; −0.047]**	**−0.121 [−0.158; −0.083]**
Pest/Budapest	−0.006 [−0.059; 0.047]	**−0.176 [−0.226; −0.126]**	−0.005 [−0.058; 0.048]	−0.032 [−0.085; 0.021]	−0.045 [−0.100; 0.010]	−0.037 [−0.090; 0.015]	0.004 [−0.049; 0.057]
Somogy/Budapest	−0.004 [−0.044; 0.035]	**−0.143 [−0.180; −0.106]**	−0.004 [−0.043, 0.036]	−0.028 [−0.067; 0.012]	**0.083 [0.041, 0.124]**	0.009 [−0.030; 0.048]	0.012 [−0.028; 0.051]
Szabolcs-Szatmár-Bereg/Budapest	**0.110 [0.063; 0.156]**	**−0.135 [−0.178; −0.091]**	**0.110 [0.064; 0.157]**	**0.085 [0.038; 0.132]**	**−0.050 [−0.098; −0.001]**	**−0.056 [−0.102; −0.010]**	**−0.084 [−0.130; −0.038]**
Jász-Nagykun-Szolnok/Budapest	**0.044 [0.004; 0.085]**	**−0.189 [−0.228; −0.151]**	**0.045 [0.004; 0.086]**	−0.018 [−0.059; 0.023]	**−0.052 [−0.095; −0.010]**	−0.025 [−0.065; 0.016]	**−0.063 [−0.104; −0.022]**
Tolna/Budapest	**−0.064 [−0.099; −0.029]**	**−0.097 [−0.130; −0.064]**	**−0.064 [−0.099; −0.028]**	**0.048 [0.012; 0.083]**	**0.054 [0.018;0.091]**	0.016 [−0.019;0.051]	0.030 [−0.005; 0.065]
Vas/Budapest	**0.084 [0.048; 0.120]**	**−0.076 [−0.110; −0.042]**	**0.085 [0.049; 0.121]**	**0.072 [0.036; 0.108]**	**−0.053 [−0.090; −0.015]**	−0.014 [−0.050;0.021]	0.006 [−0.030; 0.042]
Veszprém/Budapest	−0.001 [−0.039; 0.038]	**−0.116 [−0.152; −0.080]**	0.000 [−0.038; 0.038]	−0.001 [−0.040; 0.037]	0.002 [−0.038; 0. 041]	**−0.054 [−0.091;−0.016]**	**−0.050 [−0.088; −0.012]**
Zala/Budapest	0.019 [−0.016; 0.055]	**−0.107 [−0.140; 0.073]**	0.020 [−0.016; 0.055]	0.018 [−0.018; 0.053]	**0.044 [0.007; 0.081]**	**−0.067 [−0.102;−0.032]**	**−0.070 [−0.106; −0.035]**
GMP type (adult/mixed)	**0.069 [0.021;0.117]**	0.017 [−0.029;0.062]	**0.069 [0.021; 0.117]**	**0.084 [0.035; 0.132]**	**−0.057 [−0.107; −0.007]**	−0.025 [−0.072;0.023]	0.022 [−0.026; 0.070]
Settlement type (urban/rural)	**0.059 [0.010;0.108]**	**0.048 [0.001;0.094]**	**0.059 [0.010; 0.108]**	**0.075 [0.026; 0.125]**	−0.007 [−0.058; 0.045]	**−0.058 [−0.107;−0.009]**	**−0.072 [−0.121; −0.023]**
GP (vacancy/age < 65)	0.000 [−0.029;0.029]	0.013 [−0.014;0.041]	0.000 [−0.029, 0.029]	0.014 [−0.015; 0.044]	**−0.053 [−0.083; −0.022]**	0.012 [−0.017;0.041]	0.000 [−0.030; 0.029]
GP (age ≥ 65X/age < 65)	**−0.082 [−0.110;−0.055]**	−0.025 [−0.051;0.001]	**−0.082 [−0.110; −0.055]**	**−0.086 [−0.113; −0.058]**	**−0.032 [−0.060; −0.003]**	**−0.036 [−0.063;−0.009]**	**−0.050 [−0.078; −0.023]**
List size (≤800/1201–1600)	−0.009 [−0.038; 0.021]	**−0.037 [−0.064; −0.009]**	−0.008 [−0.038; 0.021]	−0.007 [−0.037; 0.022]	0.009 [−0.021; 0.040]	−0.017 [−0.046; 0.012]	−0.017 [−0.047; 0.012]

	HemoglobinA1c Testing	Ophthalmological Examination	Serum Lipid Status Checking	Serum Creatinine Determination	Influenza Vaccination	Prevalence of DM Aged 40–54	Prevalence of DM Aged 55–69
List size (801–1200/1201–1600)	−0.019 [−0.049; 0.011]	−0.001 [−0.029; 0.028]	−0.019 [−0.049; 0.011]	−0.017 [−0.047; 0.014]	0.003 [−0.028; 0.035]	−0.021 [−0.051; 0.009]	−0.015 [−0.045; 0.015]
List size (1601–2000/1201–1600)	−0.017 [−0.048; 0.015]	**−0.031 [−0.061; −0.001]**	−0.017 [−0.048; 0.015]	−0.001 [−0.033; 0.030]	−0.016 [−0.049; 0.017]	0.014 [−0.017; 0.046]	0.016 [−0.016; 0.047]
List size (>2000/1201–1600)	**−0.068 [−0.100; −0.036]**	**−0.031 [−0.061; −0.001]**	**−0.068 [−0.100; −0.036]**	**−0.053 [−0.085; −0.021]**	**−0.040 [−0.074; −0.007]**	0.003 [−0.029; 0.035]	0.006 [−0.026; 0.038]
Level of education (low/medium)	**−0.108 [−0.153; −0.063]**	**−0.100 [−0.142; −0.057]**	**−0.108 [0.153; −0.063]**	**−0.103 [−0.148; −0.058]**	−0.005 [−0.0051; 0.042]	**0.048 [0.004; 0.093]**	0.019 [−0.026; 0.063]
Level of education (high/medium)	**0.048 [0.002; 0.094]**	0.036 [−0.007; 0.079]	**0.048 [0.002; 0094]**	0.036 [−0.010; 0.082]	0.039 [−0.009; 0.087]	**−0.176 [−0.222; −0.131]**	**−0.139 [−0.185; −0.093]**
Employment ratio (low/medium)	−0.018 [−0.064; 0.028]	−0.018 [−0.061; 0.026]	−0.018 [−0.064; 0.028]	−0.014 [−0.061; 0.032]	**0.056 [0.008; 0.104]**	**0.051 [0.005; 0.097]**	**0.061 [0.015; 0.107]**
Employment ratio (high/medium)	0.002 [−0.046; 0.050]	0.030 [−0.016; 0.075]	0.002 [−0.046; 0.050]	−0.024 [−0.072; 0.025]	0.009 [−0.041; 0.059]	**−0.067 [−0.115; −0.020]**	**−0.111 [−0.159; −0.063]**
Housing density (low/medium)	0.041 [−0.003; 0.084]	**−0.084 [−0.126; −0.043]**	0.040 [−0.003; 0.084]	0.018 [−0.025; 0.062]	−0.001 [−0.046; 0.045]	**−0.056 [−0.099; −0.013]**	**−0.049 [−0.092; −0.005]**
Housing density (high/medium)	−0.008 [−0.046; 0.031]	**−0.038 [−0.074; −0.002]**	−0.007 [−0.046; 0.031]	−0.013 [−0.051; 0.026]	0.000 [−0.040; 0.040]	**0.049 [0.011; 0.086]**	**0.047 [0.009; 0.085]**
Proportion Roma (low/medium)	−0.012 [−0.055; 0.031]	0.015 [−0.026; 0.055]	−0.012 [−0.055; 0.031]	0.016 [−0.027; 0.059]	**0.051 [0.006; 0.096]**	−0.040 [−0.083; 0.002]	0.014 [−0.029; 0.057]
Proportion Roma (high/medium)	−0.014 [−0.0060; 0.033]	−0.022 [−0.066; 0.022]	−0.014 [−0.060; 0.033]	0.014 [−0.033; 0.061]	−0.031 [−0.079; 0.018]	0.016 [−0.030; 0.063]	0.039 [−0.007; 0.086]

* Adjusted standardized linear regression coefficients with their 95% confidence intervals. Significant results bolded.

Composite DM care quality indicators and their determinants

The distributions of the composite indicators (CDMI mean±SD: $2.91 \times 10^{-17} \pm 0.996$; ACDMI mean±SD: 0.013 ± 0.925; N = 4784) is shown by **Figure 2**. The regression model ($R^2 = 0.145$; distribution of standardized residuals shown in **Figure 3**) indicated that both patient and GMP characteristics significantly influenced the CDMI (**Table 7**).

Figure 2. Distribution of the composite DM care quality indicator (CDMI) and the adjusted composite DM care quality indicator (ACDMI) for Hungarian GMPs.

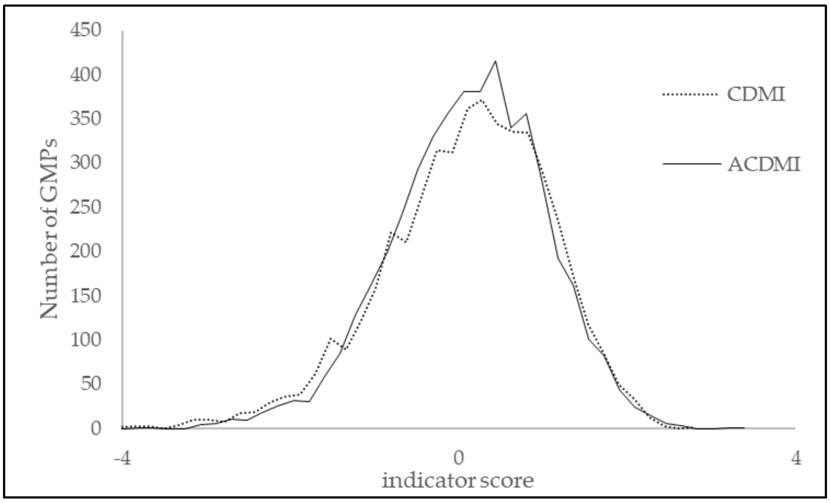


Figure 3. Distribution of the standardized residuals from the multivariable linear regression model on the relationship between the structural characteristics of general medical practices (GMPs) and the socioeconomic status of patients with the CDMI of the GMPs' performance (mean = 2.91×10^{-17}, SD = 0.996; N = 4784) with normal distribution curve.

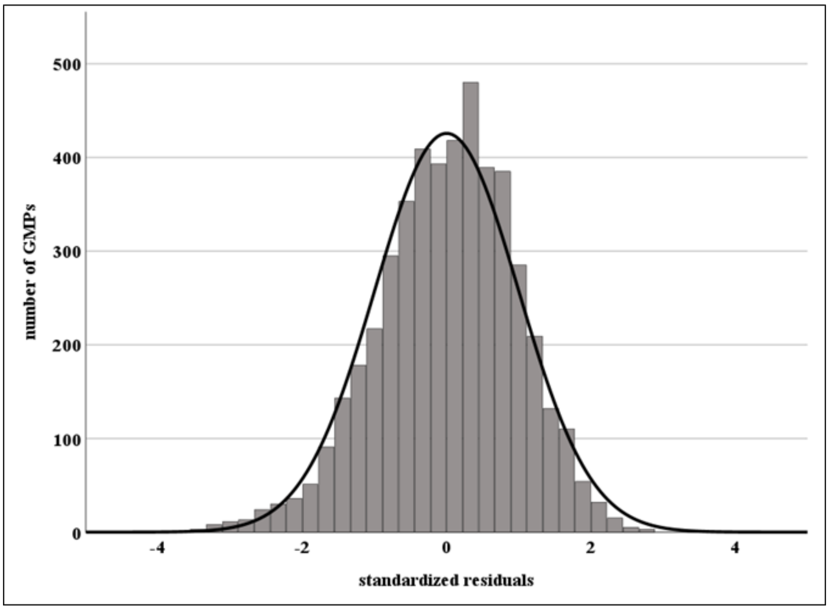


Table 7. Influence of GMPs structural characteristics and patients' socioeconomic status on the standardized CDMI of GMPs and their corresponding 95% CI according to multivariable linear regression analysis.

Explanatory Variables	**Types**	**β (95%CI *)**	***p* Value**
Type of settlement	**Urban**	**0.096 [0.058; 0.134]**	**<0.001**
	Rural	Reference	
GP	Vacancy	0.011 [−0.018; 0.041]	0.469
	age ≥ 65	**−0.083 [−0.109; −0.056]**	**<0.001**
	age < 65	Reference	
List size of GMP	≤800	−0.025 [−0.054; 0.004]	0.095
	801–1200	−0.026 [−0.055; 0.003]	0.084
	1201–1600	Reference	
	1601–2000	−0.013 [−0.044; 0.018]	0.419
	2001<	**−0.059 [−0.090; −0.027]**	**<0.001**
Level of patients' education	**Low**	**−0.139 [−0.182; −0.095]**	**<0.001**
	Medium	Reference	
	High	**0.057 [0.011; 0.102]**	**0.014**
Employment ratio among patients	Low	−0.020 [−0.066; 0.025]	0.388
	Medium	Reference	
	High	0.011 [−0.039; 0.061]	0.663
Housing density	Low	0.016 [−0.025; 0.057]	0.452
	Medium	Reference	
	High	−0.022 [−0.059; 0.016]	0.258
Roma proportion	Low	0.004 [−0.041; 0.049]	0.862
	Medium	Reference	
	High	0.002 [−0.047; 0.050]	0.943
Prevalence of DM	among 40–54-years-old	−0.021 [−0.050; 0.008]	0.167
	among 55–69-years-old	0.021 [−0.009; 0.051]	0.174
Counties	**Baranya**	**0.055 [0.015; 0.094]**	**0.007**
	Bács-Kiskun	**0.052 [0.008; 0.094]**	**0.018**
	Békés	−0.032 [−0.074; 0.010]	0.140
	Borsod-Abaúj-Zemplén	−0.009 [−0.063; 0.045]	0.746
	Csongrád	**0.048 [0.005; 0.090]**	**0.028**
	Fejér	0.001 [−0.067; 0.069]	0.973

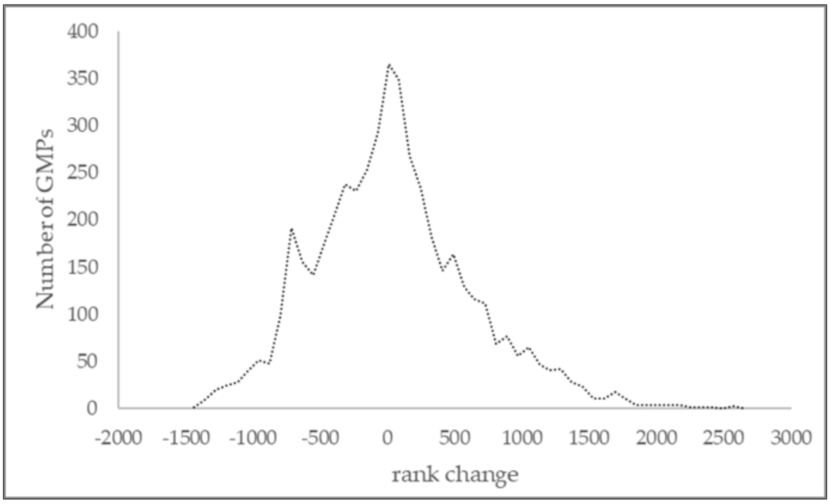
	Győr-Moson-Sopron	**−0.044 [−0.084; −0.004]**	**0.031**
	Hajdú-Bihar	**0.078 [0.031; 0.124]**	**<0.001**
	Heves	**−0.069 [−0.106; −0.031]**	**<0.001**
	Komárom-Esztergom	**−0.093 [−0.129; −0.056]**	**<0.001**
	Nógrád	**−0.107 [−0.144; −0.069]**	**<0.001**
	Budapest	Reference	
	Pest	−0.037 [−0.089; 0.015]	0.166
	Somogy	−0.038 [−0.076; 0.000]	0.054
	Szabolcs-Szatmár-Bereg	**0.075 [0.029; 0.120]**	**0.001**
	Jász-Nagykun-Szolnok	−0.009 [−0.052; 0.033]	0.679
	Tolna	**−0.054 [−0.088; −0.019]**	**0.002**
	Vas	**0.050 [0.014; 0.085]**	**0.006**
	Veszprém	−0.023 [−0.060; 0.014]	0.229
	Zala	−0.020 [−0.054; 0.014]	0.252
	Budapest	reference	

* Adjusted standardized linear regression coefficients and 95% confidence intervals. Significant results in bold.

A low level of education emerged as the most significant determinant of the CDMI (β = −0.139, 95% CI: −0.182 to −0.095). Additionally, the age of the GP (over 65 years, β = −0.083, 95% CI: −0.109 to −0.056) and a larger GMP size (β = −0.059, 95% CI: −0.090 to −0.027) were identified as negative factors affecting the CDMI. Conversely, residing in an urban area (β = 0.096, 95% CI: 0.058 to 0.134) and having a higher level of education (β = 0.057, 95% CI: 0.011 to 0.102) were positively associated with the CDMI. The regression models revealed substantial geographical inequalities in the CDMI. However, the prevalence of DM, Roma ethnicity, housing density, and employment were not significantly associated with the CDMI.

The distributions of the CDMI and ACDMI were similar (**Figure 2**), but the changes in GMP ranks were remarkable. (**Figure 4**) The average rank change (the SD for rank change distribution) was 583.

Figure 4. Distribution of the difference between general medical practices (GMPs) position ($rank_{ACDMI}$—$rank_{CDMI}$) in the rank for the composite DM care quality indicator (CDM) and for the adjusted composite DM care quality indicator (ACDMI).



A total of 91 GMPs exhibited extremely low CDMIs attributable to nonstructural factors ($lowCDMI_{nonstructural}$), while 28 GMPs displayed extremely low CDMIs linked to structural factors ($lowCDMI_{structural}$). Conversely, 120 GMPs had extremely high CDMIs, with 56 of these attributable to structural factors ($highCDMI_{structural}$) and 64 to nonstructural factors ($highCDMI_{nonstructural}$). Additionally, 28 GMPs demonstrated a not-extreme CDMI but an exceptionally low performance after adjusting for structural factors ($highACDMI_{nonstructural}$), while 56 GMPs showed high adjusted performance despite having a not-extreme CDMI ($highACDMI_{nonstructural}$). A detailed overview of DM care performance across these GMP groups is provided in **Table 8**, and visualized in **Figure 5**.

Figure 5. Spatial distribution of general medical practices (GMPs) with extreme composite indicators by the explanatory role of the structural characteristics of GMPs. (Dark blue: GMPs with extremely low CDMI and extremely low ACDMI, $lowCDMI_{nonstructural}$. Grey: GMPs with extremely low CDMI but not extremely low ACDMI, $lowCDMI_{structural}$. Dark green: GMPs with extremely high CDMI and extremely high ACDMI, $highCDMI_{nonstructural}$. Red: GMPs with extremely high CDMI and not extremely high ACDMI, $highCDMI_{structural}$. Light green: GMPs with not extreme CDMI but extremely high ACDMI, $highACDMI_{nonstructural}$. Light blue: GMPs with not extreme CDMI but extremely low ACDMI, $lowACDMI_{nonstructural}$. Size of the symbol is proportional to the number of GMPs with certain characteristics in a settlement).

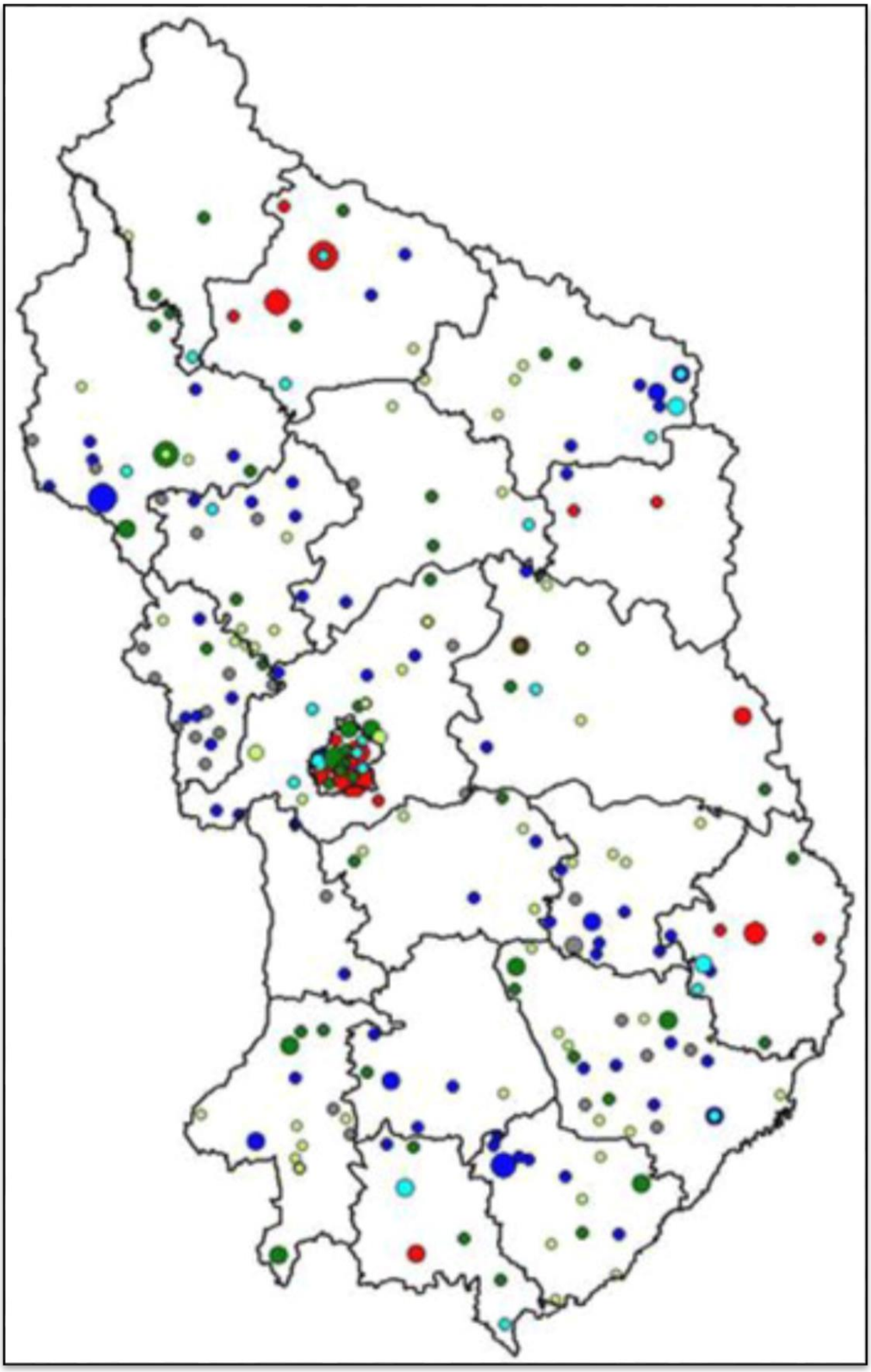


Table 8. Descriptive measures for the groups of general medical practices (GMPs) with different DM care performance according to the composite DM care quality indicators (CDMI) and to the structural characteristics (list size, GP vacancy and age, type of settlement, location by county, patients' education, housing density, Roma proportion, and DM prevalence)-adjusted composite DM care quality indicators (ACDMI).

Services	Measures	GMPs with Extremely Low CDMI and Extremely Low ACDMI $lowCDMI_{nonstructural}$	GMPs with Extremely Low CDMI but Not Extremely Low ACDMI $lowCDMI_{structural}$	GMPs with Not Extreme CDMI but Extremely Low ACDMI $lowACDMI_{nonstructural}$	GMPs with Extremely High CDMI and Extremely High ACDMI $highCDMI_{nonstructural}$	GMPs with Extremely High CDMI and Not Extremely High ACDMI $highCDMI_{structural}$	GMPs with Not Extreme CDMI but Extremely High ACDMI $highACDMI_{nonstructural}$
# GMPs		91	28	28	64	56	56
HbA1C testing	# observed cases	3897	1464	1660	6455	5471	5377
	# DM patients	8543	2751	2869	6742	5799	5850
	# expected cases	6675.1	2154.3	2240.5	5242.9	4498.2	4568.2
	relative performance *	0.584 [0.565–0.602]	0.68 [0.645–0.714]	0.741 [0.705–0.777]	1.231 [1.201–1.261]	1.216 [1.184–1.248]	1.177 [1.146–1.209]
	# excess cases	−2778.1	−690.3	−580.5	1212.1	972.8	808.8
	attributable risk	−71.3%	−47.2%	−35.0%	18.8%	17.8%	15.0%
ophthalmological examination	# observed cases	2457	698	937	3723	3135	2791
	# DM patients	8543	2751	2869	6742	5799	5850
	# expected cases	3239.1	1041.7	1091.7	2571.3	2211.7	2217.3
	relative performance *	0.759 [0.729–0.789]	0.67 [0.62–0.72]	0.858 [0.803–0.913]	1.448 [1.401–1.494]	1.417 [1.368–1.467]	1.259 [1.212–1.305]
	# excess cases	−782.1	−343.7	−154.7	1151.7	923.3	573.7
	attributable risk	−31.8%	−49.2%	−16.5%	30.9%	29.5%	20.6%
serum creatinine measurement	# observed cases	5613	1971	2099	6561	5593	5542
	# DM patients	8543	2751	2869	6742	5799	5850
	# expected cases	7362	2373.9	2472.7	5805	4988.4	5039.5

Services	Measures	GMPs with Extremely Low CDMI and Extremely Low ACDMI $lowCDMI_{nonstructural}$	GMPs with Extremely Low CDMI but Not Extremely Low ACDMI $lowCDMI_{structural}$	GMPs with Not Extreme CDMI but Extremely Low ACDMI $lowACDMI_{nonstructural}$	GMPs with Extremely High CDMI and Extremely High ACDMI $highCDMI_{nonstructural}$	GMPs with Extremely High CDMI and Not Extremely High ACDMI $highCDMI_{structural}$	GMPs with Not Extreme CDMI but Extremely High ACDMI $highACDMI_{nonstructural}$
	relative performance *	0.762 [0.742–0.782]	0.83 [0.794–0.867]	0.849 [0.813–0.885]	1.13 [1.103–1.158]	1.121 [1.092–1.151]	1.1 [1.071–1.129]
	# excess cases	−1749	−402.9	−373.7	756	604.6	502.5
	attributable risk	−31.2%	−20.4%	−17.8%	11.5%	10.8%	9.1%
influenza vaccination	# observed cases	476	177	123	482	443	481
	# DM patients	3810	1269	1211	2587	2184	2547
	# expected cases	499.7	165.4	158.6	329.6	279.9	326.4
	relative performance *	0.953 [0.867–1.038]	1.07 [0.913–1.228]	0.776 [0.639–0.913]	1.463 [1.332–1.593]	1.583 [1.436–1.73]	1.474 [1.342–1.605]
	# excess cases	−23.7	11.6	−35.6	152.4	163.1	154.6
	attributable risk	−5.0%	6.6%	−28.9%	31.6%	36.8%	32.1%
serum lipid status measurement	# observed cases	3897	1464	1660	6455	5471	5377
	# DM patients	8543	2751	2869	6742	5799	5850
	# expected cases	6673.6	2154	2240.5	5243.8	4498.5	4569.3
	relative performance *	0.584 [0.566–0.602]	0.68 [0.645–0.714]	0.741 [0.705–0.777]	1.231 [1.201–1.261]	1.216 [1.184–1.248]	1.177 [1.145–1.208]
	# excess cases	−2776.6	−690	−580.5	1211.2	972.5	807.7
	attributable risk	−71.3%	−47.1%	−35.0%	18.8%	17.8%	15.0%

* indirectly standardized ratio with 95% confidence interval.

number of GMPs, or observed cases or expected cases

Discussion

Main Findings

Our investigation demonstrates the feasibility of developing a set of seven indicators for DM care within the Hungarian context, relying solely on data available through the NHIF without the need for targeted primary data collection. The indicators were derived from templates established by the NHS and QOF and EUBIROD recommendations, ensuring that they meet general standards for evaluating healthcare performance [79],[46].

Preliminary analysis revealed that the performance of Hungarian GMPs fell short of the recommendations, with DM prevalence lower than the global reference [87]. The variability of GMP-level indicators was most pronounced for preventive services, with the standard deviation of the ISRs being 0.428 for influenza vaccination and 0.364 for the prevalence of DM in adults aged 40–54 years. Conversely, the distribution of nISRs was narrowest for glycemic status evaluation (HbA1c measurement), the most critical laboratory test in DM care, with an SD of 0.082. Similar narrow distributions were observed for serum creatinine and lipid measurements, with SDs of 0.133 for both.

The regression models indicated that GMP performance was influenced by factors beyond GMP staff characteristics. Specifically, SES proxies, particularly education level, had a more substantial impact on performance outcomes than structural characteristics of the GMPs. These findings align with previous studies [88],[89],[90],[91],[92], which emphasize the critical role of patient education, a proxy for SES deprivation, in determining the quality of DM care. Furthermore, our results show that the age of GPs and the rural or urban nature of practices significantly impacted care quality, a pattern consistent with international research [93],[94].

Geographical variation in DM care quality, a phenomenon observed globally, was also evident in our study, with notable disparities in the quality of care across regions [95],[96]..

Additionally, the presence of GP vacancies was identified as a risk factor negatively affecting DM care, specifically in relation to influenza vaccination coverage, further supporting findings from other studies [97].

The higher DM prevalence observed in disadvantaged social groups in our study mirrors trends reported in several European countries [98],[99]. Ethnic and racial minorities, particularly the Roma population, demonstrated poorer access to influenza vaccination, highlighting the well-documented risk of suboptimal DM care for these groups [100],[101],[102].

The relationship between list size and process indicators has been debated internationally, with mixed findings. Our study suggests that larger list sizes in Hungary negatively impact GMP performance, and further investigation is needed to understand the underlying causes of this variability. Additionally, the superior performance of GMPs dedicated solely to adult care in terms of HbA1c testing, serum creatinine, and lipid status measurements, alongside better influenza vaccination rates in GMPs that care for both adults and children, warrants further exploration.

Our research also suggests that higher employment rates in a community may contribute to reduced focus on optimal DM care. This inverse relationship, particularly regarding influenza vaccination coverage, aligns with previous studies indicating the impact of employment on healthcare access [97],[103]. Moreover, living conditions, such as overcrowding, were found to influence the quality of DM care, with a significant but non-monotonic relationship observed between overcrowding and ophthalmological examinations [100],[104].

Our research found that it can be done and is operationally possible to create the CDMI from secondary data available from the NHIF in Hungary with no requirement to collect primary data. The tool of CDMI accounted for 59.1% of the observed variance in diabetes care quality, from five separate measures, for general medical practices. The CDMI does not capture every element of the information residing in the individual measures but it captures meaningful and important measures of care quality and so provides a convenient and meaningful starting point for the ranking of practices, most importantly in a 'non-technical' decision-making context. Since there are well-established international care standards for diabetes care at the primary care level, composite indicators of diabetes care could be developed in other health systems directly and easily using indicators selected from studies like the DIABCARE Q-Net, the NHS QOF the EUBIROD project, National Diabetes Services Scheme, Healthcare Effectiveness Data and Information Set and the indicator system used by the Robert Koch Institute [45],[79],[43],[105] ,[106],[42].

We also identified a number of factors that, unrelated to GMP staff, influenced the CDMI based on regression modelling. These include patients' low educational attainment which is associated with many well established risk factors for poor DM outcomes; low health literacy, lower income and poor understanding of disease management strategies [107],[108]. Another significant determinant was the GP's age where GPs over 65 years old had lower CDMI scores. This probably represents a challenge for GPs over 65 years old to keep pace with DM management protocols and treatment strategies [109],[110],[111].

One potential risk factor that was observed: larger GMPs were observed to have lower CDMI scores. We suspect this is likely because larger practices have many patients and limited resources, which taxes the system [110],[111]. Rurality was related to lower scores, where CDMI scores were lower, again perhaps as access to advocated for better diabetes care [95],[112],[113]. This is consistent with population-based urban rural studies that show that urban populations had better access to diabetes care [95],[114],[115]. Interestingly, some population or contextual factors examined, such as prevalence of diabetes, proportion of Roma population, housing density, and employment rate were not significantly associated with CDMI scores. We speculate that these factors have either limited impact on the quality of diabetes care, or that their influence is moderated by other factors or determinants, such as education or availability of access to services.

Strengths and Limitations

This study's primary strength is the comprehensive nature of it, as it includes all Hungarian GMPs, as well as the entire adult population of Hungary. The wide coverage eliminates bias in selection and allows for substantial statistical power for arguably robust models. Furthermore, the standardized data collection techniques by the NHIF and the HCSO helped limit the misclassification for the variables.

While the comprehensive inclusion of participants in this study was a key strength, a number of limitations should be acknowledged. One is that we were not able to collect patient-level factors that may have affected the quality of DM care, such as social determinants of health [30], health literacy [31, 114], health behaviors [30, 32], and diabetes type [115]. The lack of these variables may have lowered the completeness of our regression model for DM care quality and, in fact, probably overestimated the importance of GPs and underestimated the contribution of external factors on DM care quality. Missing patient level variables likely impaired the completeness of our regression model and possibly inflated the personal contributions of GPs while minimizing the contributions of external factors. Another limitation presented in this study is that the data used for the dataset did not match with one another over time; for example, the SES indicators from 2011, while the GMP structural characteristics and DM care indicators were derived from the 2018 NHIF dataset. Although SES changes over a longer period of time, the seven year gap in time may have introduced some bias, in terms of diluting the courses of association strength.

Implications

The quality of DM care is influenced by patients' SES as well as, by structural aspects of general practices. Performance measures that include P4P indicators must carefully consider specific intentions of measuring the personal contributions of GMP staff, and need to statistically adjust for contextual factors in order to capture and represent the personal effects of GMP staff. More comprehensive adjustment of P4P indicators will produce more accurate performance measures to reduce the likelihood of malpractice, and get reliable comparison with other organizations.

Statistical adjustment of indicators might account for contextual inequities; however, it is important that adjustments may obscure systematic inequities that the adjustment was intended to eliminate.

For that reason, monitoring care performance should include crude indicators and adjusted indicators in order to provide a more balanced assessment of care quality.

Currently, the composite process indicator shows that 58.64% of recommended medical interventions for DM care are being delivered using the latest evidence-based practices. Obviously, given this composite process indicator, along with the extreme variation across individual indicators in Hungary, it will be useful to have more robust monitoring systems; useful to support improvement in GPs and nurses individual performance, while allowing us to identify system-level factors that can be adjusted to improve care quality and hence eventually improve DM outcomes.

Table 9. Categorization of CDMI and ACDMI Extremes with Corresponding GP Contribution, External Factors, and Suggested Interventions

	Extremely Low CDMI, but with Not Extremely Low ACDMI	**Extremely Low CDMI, and Extremely Low ACDMI**	**Extremely High CDMI and with Extremely High ACDMI**	**Extremely High CDMI but not Extremely High ACDMI**	**Not Extremely CDMI but with Extremely High ACDMI**	**Not Extremely CDMI but with Extremely Low ACDMI**
GP contri-bution	average	poor	good	average	good	poor
External factors	poor	average	average	good	poor	good

Inter-vention	improved external environment, extra external help	protocol improvement	benchmarking	reporting on the important external factors' role	benchmarking, awarding	protocol improvement

Key findings and their interpretation:

A. There were 28 GMPs with **Extremely Low CDMI** (extremely poor performance), but with **Not Extremely Low ACDMI** ($lowCDMI_{structural}$, n=28)

- Interpretation:

  These GMPs were primarily constrained by structural limitations, such as inadequate infrastructure, staffing shortages, geographic isolation, and limited access to outpatient services etc. These challenges significantly hindered their ability to deliver standard diabetes care.

  Even though the adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, shows that the personal contribution of the GP is appropriate in these GMPs.

- Conclusion:

  For this group, addressing structural deficits is essential. Interventions should focus on factors cannot be influenced by the GP. The most important external (structural) determinants should be explored and the discussion with local stakeholders to find local solutions should be initiated.

B. There were 28 GMPs with **Extremely Low CDMI** (extremely poor performance), but and **Extremely Low ACDMI** ($lowCDMI_{nonstructural}$, n=98)

- Interpretation:

  These GMPs achieved low performance, and it was not attributable only to the poor circumstances, such as adequate infrastructure, proper capacities, urban location, and good access to outpatient services etc.

The adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, suggests that the personal contribution of the GP is poor in these GMPs.

- Conclusion:

  For this group, addressing structural deficits is essential. Interventions should focus on factors can be influenced by the GP. After discussion of the problems with the GP, the reorganization of protocols should be supported (for example by postgraduate training).

C. There were 64 GMPs with **Extremely High CDMI** (extremely good performance) and with **Extremely High ACDMI** ($highCDMI_{nonstructural}$, n=64)

- Interpretation:

  These GMPs achieved high performance, and it was not attributable to the especially advantageous circumstances, such as adequate infrastructure, proper capacities, urban location, and good access to outpatient services etc.

  The adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, demonstrates the excellent personal contribution of the GP in these GMPs.

- Conclusion:

  For this group, systematic benchmarking should be implemented. The description of good clinical practice and the sharing of the protocol could contribute to the performance improvement in other GMPs.

D. There were 56 GMPs with **Extremely High CDMI** (extremely good performance) but with **not Extremely High ACDMI** ($highCDMI_{nonstructural}$, n=56)

- Interpretation:

These GMPs achieved high performance, and it was attributable to the especially advantageous circumstances, such as adequate infrastructure, proper capacities, urban location, and good access to outpatient services etc.

The adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, demonstrates the average personal contribution of the GP in these GMPs.

- Conclusion:

  For this group, systematic identification of the prognosis improving factors in the environment of the GMP could help other GMPs with poor external supports, where the local discussion could use as template the report from these lucky GMPs.

E. There were 56 GMPs with **Not Extreme CDMI** (not extreme performance) but with **Extremely High ACDMI** (highACDMI$_{nonstructural}$, n=56)

- Interpretation:

  These GMPs achieved high performance, and it was achieved against the disadvantageous circumstances, such as inadequate infrastructure, rural location, and poor access to outpatient services etc.

  The adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, demonstrates the excellent personal contribution of the GP in these GMPs.

- Conclusion:

  For this group, systematic benchmarking should be implemented. The description of good clinical practice and the sharing of the protocol could contribute to the performance improvement in other GMPs. These GMPs could demonstrate that it is possible to counterbalance the poor working environment somehow. (These GPs should be awarded.)

F. There were 28 GMPs with **Not Extreme CDMI** (not extreme performance) but with **Extremely Low ACDMI** (lowACDMI$_{nonstructural}$, n=56)

- Interpretation:

  These GMPs achieved average performance, but it was elicited by the advantageous circumstances, such as adequate infrastructure, urban location, and good access to outpatient services etc.

  The adjusted performance (ACDMI), which reflects the quality of the personal contribution of the GP and his or her staff, demonstrates the poor personal contribution of the GP in these GMPs.

- Conclusion:

  For this group, addressing structural deficits is essential. Interventions should focus on factors can be influenced by the GP. After discussion of the problems with the GP, the reorganization of protocols should be supported (for example by postgraduate training).

This finding underscores the importance of adjusting the CDMI for GP-dependent and GP-independent influences on quality for a more accurate and robust measure of GP performance. Isolating factors that are outside of GP control offers GP performance assessments that are fairer and more nuanced. For example, the performance of the GMPs was performed on factors that could be adjusted for available information about GP age and rural practice location and this had a dramatic impact on the performance rankings of GMPs.

These findings reinforce the assertion that a P4P system emphasizing the need for both structural and contextual influences to be included in their system for GP performance measurement to allow fair and appropriate comparisons to be made. Adjusting for structural and contextual influences would allow the P4P measurement system to better represent the true contribution of an individual GP, and such a representation will motivate and enable the GP to make improvements in their care of patients.

The ultimate aim of GMP performance monitoring is to help improve patient welfare. Within this framework, the processes of investigating if GMPs are underperforming and what, if any, interventions should then occur are sequential. This study demonstrates the feasibility of creating strong, composite measures of diabetes care from an amalgamation of existing health information records of DM patients. These composite measures lodge themselves in a stepwise process of evaluation that focus interventions on quality improvement activities.

Management Indicator CDMI to identify those providing particularly high or low quality care. A separate adjusted CDMI ranking could then be calculated to capture the influence of other factors that were beyond the control of GPs. The two rankings would then allow for comparisons to evaluate the performance of GMPs who were extreme outliers based on contextual or environmental factors rather than the actual performance of the staff at the GMP, or unmeasured confounding factors. The NHIF would be well positioned to conduct this initial phase of evaluation. If the results were shared transparently, this would raise public awareness of performance in diabetes care, and could help to catalyze change among GPs and other stakeholders to introduce quality improvement strategies.

The secondary evaluation stage should involve a collective interpretation of results with GPs and the relevant stakeholders. If poor performance is a result of external factors, attention should be turned to facilitating improvements to the structural and work conditions of the GMP, which would require input from policy makers, health care administrators and community partners.

Otherwise, if poor performance is attributed to the practices of the GMP staff, they should first work on remediating malpractice, or else using benchmarking to support improvement, which if based on performance will in fact need to be in a P4P scheme, whereby all GMPs could potentially be connected to the CDMI adjusted process.

Our findings show a substantial difference in rankings between scores based on adjusted indicators versus scores of unadjusted indicators - which, again illustrates the need for using adjusted indicators in P4P schemes to avoid directing incentives to the wrong place.

Depending on the specific local context, other health-care providers - diabetes case manager nurses [113],[114], public health specialists [115],[116],[117], or other healthcare professionals [118],[119],[120] or combination of these - can provide an important role in the secondary evaluation stage. They might help with the interpretation of performance data and to help develop meaningful local intervention plans specific to the barriers GMPs may face to improve their diabetes care quality in a primary care setting.

Conclusions

In conclusion, this study achieved the successful development of seven standardized indicators, CDMI, and ACDMI for monitoring DM care within Hungarian GMPs. These indicators demonstrated significant deviation from the recommended targets and highlighted considerable variability in the performance across GMPs. SES and structural GMP factors were found to significantly influence the observed variability in care quality, emphasizing their critical role in determining the effectiveness of DM care. This study demonstrates that these indicators enable the identification of those requiring intervention or suitable for benchmarking. To optimize the impact of the P4P system, it is essential to incorporate a more comprehensive set of indicators that specifically measure the personal contributions of GMP staff to patient care quality. Additionally, non-adjusted indicators should continue to be utilized in order to assess DM care quality from the patient's perspective, ensuring a more holistic approach to performance monitoring.

Our findings suggest that a stepwise approach to performance evaluation—beginning with both composite and adjusted composite measures—could be employed to identify GMPs in need of intervention. This process, which is transparent and accessible to non-experts, could enhance the motivation of GPs and other stakeholders, fostering greater engagement in the evaluation and implementation of expert recommendations. After this process, the elaboration of interventions could utilize the detailed information provided by the items of the indicator set.

Original findings

1) A lower level of patient education was consistently identified as the most significant negative factor impacting DM care process indicators, with strong associations observed across multiple outcomes: HbA1c ($\beta = -0.108$), ophthalmologic exams ($\beta = -0.100$), serum creatinine ($\beta = -0.103$), and serum lipid tests ($\beta = -0.108$). This suggests that educational interventions targeting patients may be crucial in improving the quality of DM care.
2) GPs aged 65 years and older showed a detrimental effect on several key process indicators, notably HbA1c ($\beta = -0.082$), serum creatinine ($\beta = -0.086$), and serum lipid testing ($\beta = -0.082$). This age-related decline in performance highlights the potential need for additional training or support for older GPs to ensure they stay up to date with current DM management protocols.
3) Higher influenza vaccination uptake was negatively correlated with diabetes prevalence, particularly in the 40–54 ($\beta = -0.176$) and 55–69 ($\beta = -0.139$) age groups. This suggests a potential link between preventative measures (such as influenza vaccination) and better overall health outcomes for people with DM.
4) Increased employment levels were identified as a protective factor against diabetes, especially in the 40–54 ($\beta = -0.067$) and 55–69 ($\beta = -0.111$) age groups. This finding underscores the importance of social determinants, such as employment, in managing the risk of diabetes.
5) Employment rate ($\beta = 0.056$) and GMP type (adult/mixed: $\beta = -0.057$) were found to significantly influence influenza vaccination rates. These findings highlight the role of practice organization and socioeconomic factors in the delivery of preventive care.
6) Greater housing density was associated with higher diabetes prevalence, and its impact on ophthalmologic exams varied by region. Lower and medium-density areas showed stronger associations ($\beta = -0.084$) compared to high-density regions ($\beta = -0.038$), suggesting that regional infrastructure and social conditions may influence care delivery.

7) Increased GP vacancies and higher proportions of Roma residents were associated with lower influenza vaccination rates (GP vacancy: β = −0.053, Roma population: β = 0.051). This indicates that access to healthcare and demographic factors can impact preventative health efforts in certain populations.
8) Urbanization showed a moderate but significant influence on several key indicators, including HbA1c (β = 0.059), ophthalmologic exams (β = 0.048), and serum lipid testing (β = 0.059), with stronger correlations observed in the 55–69 age group (β = −0.072). These findings highlight the differences in care quality between urban and rural areas, underscoring the need for targeted interventions in less urbanized regions.
9) Larger GMP list sizes were negatively correlated with process indicator scores, impacting HbA1c (β = −0.068), ophthalmologic exams (β = −0.031), serum creatinine (β = −0.053), and influenza vaccination (β = −0.040). These results suggest that overburdened practices may struggle to deliver high-quality DM care and that adjustments in GMP management may be necessary.
10) Adult-only GMPs demonstrated stronger associations with lab-based process indicators, including HbA1c (β = 0.069), serum creatinine (β = 0.084), and serum lipid testing (β = 0.069), compared to mixed GMPs. However, adult GMPs showed a negative association with influenza vaccination rates (β = −0.057), indicating a trade-off between different types of practices in delivering certain types of care.
11) Lower educational attainment was the strongest negative predictor of the CDMI, with a significant effect on the CDMI (β = −0.139).
12) Older GPs (aged 65+) (β = −0.083) and larger GMP sizes (β = −0.059) were significant negative influences on the CDMI.
13) Living in urban areas had a positive effect on CDMI scores (β = 0.096), suggesting better access to care and resources in urban settings.
14) Higher levels of patient education were positively correlated with better DM care outcomes (β = 0.057, 95%CI: 0.011–0.102).

15) While the CDMI and ACDMI distributions were similar, there was substantial variation in GMP rankings, with a mean rank shift of 583 between the two indicators.
16) Of the 91 cases with extremely low CDMI scores, 63 were attributed to structural factors, while 28 were influenced by nonstructural factors.
17) Among the 120 GMPs with high CDMI scores, 56 were influenced by structural factors, whereas 64 were driven by nonstructural factors.
18) In 28 GMPs, CDMI scores were not extreme, but performance was significantly low after adjusting for structural factors. Conversely, in 56 GMPs, moderate CDMI scores were observed, but performance was exceptionally high when structural factors were accounted for.
19) These new findings underscore the critical role of both structural and patient-related factors in determining the quality of DM care. Factors such as education, GP age, and GMP size significantly influence care outcomes and should be considered when evaluating and improving the quality of DM care through composite indicators and adjusted performance metrics.

Summary

Seven international standards were displayed to function as diabetes care quality indicators for monitoring GMP performance in this study. Each indicator offered an overall evaluation of diabetes care, allowing deviations in recommended practice and variability in quality of care to be discerned. This entire system of indicators actualizes an organized approach to assessing the performance of primary care and could serve as a model for monitoring diabetes care on a worldwide level. It turned out that GMP performance was quite heterogeneous and shaped by socioeconomic conditions as well as systemic issues on the level of the practice. These findings contributed new insights into the causes of quality inequalities in diabetes care and underscored the necessity for a more focused strategy in their evaluation and improvement. By identifying concrete causes for differentiated GMP execution, this study helps to explain the ways in which healthcare practitioners may enhance their practices to better facilitate patient outcomes. The current pay-for-performance plan would be really beneficial for the inclusion of a more diversified, more individualized set of performance indicators about the efficiency of every single practitioner, rather than only on a broader practice outcome. Beyond that, implementation of non-adjusted diabetes indicators ensures the care quality assessment is done from the viewpoint of the patient, thus creating a more patient-centered and effective system. These recommendations propose a revolutionary manner to upgrade the P4P model and thus establish a new standard of performance to provide higher provider accountability with better patient care.

The research findings indicated that diabetes care seems less effective in rural areas within larger practices with older GPs and in GMPs serving less educated adults. External factors unrelated to the GP have a considerable impact on diabetes care quality, indicating that inequities related to structure and socioeconomic factors play an important role in the outcome of healthcare. The study, through analysis of the relationship, disputes the conventional method of assessment of care and highlights the necessity for unique targeted interventions in addressing health inequalities that exist in primary care. Research into quality indicators of diabetes care has yielded mixed conclusions. The study encourages that

P4P schemes include an adjusted version of the composite indicator to assure that GPs are fairly and effectively motivated. The stepwise performance evaluation process consisting of composite and adjusted composite measures provides a transparent means of identifying underperforming GMPs and areas for intervention. In addition, this approach invigorates GP engagement, motivating them to take part in the assessment of their performance while assuring that the P4P model is more dynamic and equitable, hence able to deliver meaningful improvements in diabetes care.

Keywords

Primary Care; Diabetes Mellitus; Performance Indicators; Composite Indicator; Socioeconomic Status; General Medical Practice; Monitoring

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Appendix

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Registry number: DEENK//2025.PL
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