

Original article

doi:10.5633/amm.2026.0103

Patient-Related Errors in Insulin Administration: A Cross-Sectional Study in Southeastern Serbia

Ana Kundalić¹, Aleksandar Jovanović¹, Emilija Kostić¹, Milica Lilić², Aleksandra Catić-Djordjević¹

¹University of Nis, Faculty of Medicine, Department of pharmacy, Niš, Serbia

²Benu Pharmacy, Belgrade, Serbia

Contact: Ana Kundalić,

81 Dr Zorana Djindjića Blvd., 18108 Niš, Serbia

E-mail: anakundalic@gmail.com, ana.spasic@medfak.ni.ac.rs

Proper insulin administration is essential for achieving optimal glycemic control and preventing both acute and chronic complications in patients with diabetes. Nevertheless, errors in injection technique remain highly prevalent worldwide, often undermining the effectiveness of therapy. This study aimed to evaluate the prevalence and types of insulin administration errors among diabetic patients in Southeastern Serbia, as well as factors associated with these errors.

A cross-sectional study was conducted among 95 adults with type 1 or type 2 diabetes receiving insulin therapy. Data were collected during pharmacy-based counseling sessions provided by trained pharmacists, who observed injection techniques and gathered demographic and clinical information. The findings revealed that 81.1% participants made at least one error during insulin administration. The most frequent and clinically important errors were needle reuse (68.4%) and inadequate site rotation (49.5%). Correct site rotation was significantly associated with better glycemic control, as patients who rotated their injection sites were more likely to achieve HbA1c < 8% ($p=0.033$). Errors were more common in older adults (≥ 65 years), those with lower education, and patients using human insulin. Nearly half of the participants (47.4%) reported skin complications, including lipohypertrophy (13.7%), lipodystrophy (4.2%), and bruising (29.5%). The abdomen was the most

frequently used injection site (43.2%), while only 4.2% patients reported using all recommended sites.

In conclusion, insulin administration errors are widespread and clinically relevant, particularly among older adults, less educated patients, and users of human insulin. These results highlight the importance of patient education and structured pharmacist-led services to improve safety and glycemic control.

Keywords: Diabetes mellitus, Insulin administration errors, Needle reuse, Injection site rotation, pharmacists

Originalni rad

doi:10.5633/amm.2026.0103

Greške pacijenata pri primeni insulina: studija preseka u jugoistočnoj Srbiji

Pravilna primena insulina je od suštinskog značaja za postizanje optimalne glikoregulacije i prevenciju akutnih i hroničnih komplikacija kod pacijenata sa dijabetesom. Ipak, greške u tehnici primene i dalje su veoma česte i značajno narušavaju efikasnost terapije. Cilj ove studije bio je da se proceni učestalost i vrste grešaka u primeni insulina kod pacijenata sa dijabetesom u jugoistočnoj Srbiji, kao i faktori povezani sa njihovom pojavom.

Sprovedena je studija preseka među 95 odraslih pacijenata sa dijabetesom tip 1 i tip 2 koji su bili na insulinskoj terapiji. Podaci su prikupljeni tokom savetovanja u apotekama, koje su sprovodili farmaceuti-savetnici za dijabetes, posmatrajući tehniku primene insulina i beležeći demografske i kliničke karakteristike ispitanika.

Rezultati su pokazali da je 81,1% načinilo najmanje jednu grešku u primeni insulina. Najčešće i klinički najznačajnije greške bile su ponovno korišćenje igala (68,4%) i nedovoljna rotacija mesta primene (49,5%). Pravilna rotacija mesta primene bila je značajno povezana sa boljom glikoregulacijom, jer su pacijenti koji su rotirali mesta češće imali HbA1c < 8% ($p=0,033$). Greške su bile češće među starijima (≥ 65 godina), osobama sa nižim obrazovanjem i pacijentima koji koriste humane insuline. Gotovo polovina ispitanika (47,4%) prijavila je promene na koži, uključujući lipohipertrofiju (13,7%), lipoatrofiju (4,2%) i modrice (29,5%). Najčešće korišćeno mesto za primenu bio je abdomen (43,2%), dok je samo 4,2% pacijenata koristilo sva preporučena mesta.

Greške u primeni insulina su široko rasprostranjene i klinički značajne, naročito među starijim osobama, pacijentima sa nižim obrazovanjem i korisnicima humanih insulina. Ovi nalazi naglašavaju značaj edukacije pacijenata i strukturisanih farmaceutskih usluga radi bezbednije terapije i bolje glikoregulacije.

Ključne reči: diabetes melitus, greške u primeni insulina, ponovno korišćenje igle, rotacija mesta primene, farmaceuti

AMM Paper Accepted

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, action, or both. Globally, it represents one of the most pressing public health challenges, requiring integrated management that combines lifestyle modification, pharmacotherapy, glucose monitoring, and continuous patient education (1). In Serbia, approximately 10.5% of adults are currently affected by DM, and this figure is projected to increase to 12.1% by 2050 (1). These trends underscore the need for effective and sustainable strategies to optimize diabetes care.

Insulin therapy remains the cornerstone of treatment for all patients with type 1 DM and for an increasing proportion of those with type 2 DM (2). Although modern formulations and delivery devices, such as insulin analogues and pens, have simplified treatment, the success of insulin therapy still depends heavily on correct administration technique, adherence, and patient engagement (3,4). For many individuals, initiating insulin represents more than a medication change—it reorganizes daily life. The act of self-injection, coupled with dose titration, attention to timing, and regular self-monitoring, introduces a demanding routine that can evoke fear, discomfort, and uncertainty, particularly at the outset of therapy (5). Even among experienced users, technique can drift over time.

Errors in diabetes management can occur at multiple levels of care. They may include prescribing errors, such as inappropriate drug selection or dosing; dispensing errors during medication preparation and supply; and administration errors, whether by healthcare professionals or by patients themselves. A recent review of insulin errors and prevention strategies summarizes these categories and emphasizes that patient-related errors during insulin injection are widespread and have direct consequences on treatment outcomes, underscoring the need for both systemic and patient-focused preventive measures (6).

Typical problems described in the literature include incorrect insulin dosing, inappropriate injection site selection, failure to rotate injection sites, incorrect injection technique, and improper storage (7,8). Such mistakes can compromise glycemic control despite appropriate prescribed therapy,

increasing the risk of both acute complications, such as hypoglycemia and hyperglycemia, and chronic complications, including microvascular and macrovascular damage (9,10,11). They may also negatively affect patients' quality of life while simultaneously contributing to greater healthcare utilization and costs (10).

Professional guidelines emphasize that insulin administration technique is a critical determinant of therapeutic success, highlighting the need for appropriate site rotation, correct injection methods, individualized dosing, and optimal needle selection (5,12). Nevertheless, multiple studies demonstrate that even patients with long-standing insulin use often fail to apply correct techniques consistently, frequently due to insufficient initial training and a lack of ongoing education (6,13,14). These findings reinforce the importance of continuous patient support throughout insulin therapy.

Healthcare professionals, particularly pharmacists, play an essential role in addressing these challenges. As highly accessible and trusted providers, pharmacists are well-positioned to reinforce correct administration practices, identify common errors, and provide tailored counseling (15). In Serbia, to strengthen diabetes care, the Pharmaceutical Chamber of Serbia has developed a standardized pharmacy service dedicated to supporting patients with DM. Through this service, pharmacists engage directly with patients to detect common difficulties in insulin administration and provide structured education to promote safer and more effective therapy.

This study aimed to evaluate the prevalence and types of insulin administration errors among diabetic patients in Southeastern Serbia, as well as factors associated with these errors.

Materials and Methods

Study Design and Participant Selection

A cross-sectional study was conducted among patients with DM (type 1 and type 2) receiving insulin therapy who visited community pharmacies in Southeastern Serbia. Data were collected while pharmacists provided a standardized pharmacy service designed for patients with DM, which included structured counseling over four months. As part of this service, patients were interviewed about different aspects of their therapy, and those using insulin demonstrated their injection technique.

The study was approved by the Ethics Committee of the Faculty of Medicine, University of Niš (Decision No. 12-1693-1/2-1), with additional authorization from the Pharmaceutical Chamber of Serbia (No. 515/23.12.2024.). Written informed consent was obtained from all participants before inclusion.

Pharmacists trained as diabetes counselors, who voluntarily participated in the study, collected data from a total of 176 patients with DM. After applying the inclusion and exclusion criteria, 95 patients were included in the final analysis.

Inclusion criteria:

- Adults aged ≥ 18 years;
- Diagnosis of type 1 or type 2 DM;
- Current treatment with human insulin or insulin analogues.

Exclusion criteria:

- Treatment with oral antidiabetic drugs only or use of an insulin pump;
- Pregnancy at the time of data collection;
- History of gestational DM without a current diagnosis of DM.

Data Collection

For each participant, sociodemographic characteristics and selected clinical parameters were obtained, including glycated hemoglobin (HbA1c). HbA1c was categorized using 8% as the cut-off point, in line with international guidelines which recommend less stringent goals (such as $< 8.0\%$) in older adults and those with comorbidities, where stricter targets may not be safely achievable (16). In addition, patients responded to a structured set of questions regarding their insulin therapy and demonstrated their injection technique. These observations provided detailed insights into patient behaviors and enabled the identification of common errors in insulin administration.

Statistical Analysis

Descriptive statistics were applied to summarize the demographic and clinical characteristics of participants. Continuous variables were expressed as means $\pm$ standard deviations, while categorical

variables were presented as frequencies and percentages. Between-group comparisons were performed using Chi-square tests for categorical variables. A p-value <0.05 was considered statistically significant. All statistical analyses were conducted using SPSS software, version 20.

Results

A total of 95 patients with type 1 or type 2 DM on insulin therapy participated in the study (41 men and 54 women). The mean age of participants was 61.6 ± 12.7 years. Most patients (64.2%) had type 2 DM, and nearly three-quarters (75.8%) had lived with DM for more than five years. Insulin analogues were prescribed more frequently (81.1%) than human insulin (18.9%). Additional baseline characteristics are presented in Table 1.

Table1. Demographic and clinical characteristics of patients

Characteristics		n (%) (n=95)
Gender	Male	41 (43.2%)
	Female	54 (56.8%)
Age (years)	<65	53 (55.8%)
	≥65	42 (44.2%)
Education	Elementary	14 (14.8%)
	High school	52 (54.7%)
	Bachelor's degree	19 (20.0%)
	Master's degree or higher	10 (10.5%)
Smoking status	no	71 (74.7%)
	Current smoker	24 (25.3%)
Duration of diabetes (years)	<1 year	4 (4.2%)
	1-5 years	19 (20.0%)
	>5 years	72 (75.8%)
Family history of diabetes	no	59 (62.1%)
	yes	36 (37.9%)
Diabetes type	Type 1	34 (35.8%)
	Type 2	61 (64.2%)
Insulin therapy	Human	18 (18.9%)
	Analogue	77 (81.1%)
Number of drugs	≤ 5	38 (40.0%)
	>5	57 (60.0%)
Number of comorbidities	≤ 2	45 (47.4%)
	>2	50 (52.6%)

Patients frequently used insulin in combination with oral antidiabetics, most commonly metformin (57.9%), followed by SGLT2 inhibitors (23.2%) and GLP-1 receptor agonists (13.7%). Twenty-four

participants (25.3%) were treated with insulin alone. The mean number of comorbidities was 1.79 ± 1.24 , with hypertension (77.9%) and heart failure (18.9%) being the most prevalent. On average, patients used 6.42 ± 2.52 medications, with the majority (60%) prescribed more than five medications.

Out of 95 patients, 77 (81.1%) demonstrated at least one error in insulin administration. The most frequent errors were reuse of needles, failure to rotate injection sites, inadequate skin preparation, and failure to wipe the needle (Figure 1). Many patients made more than one error at the same time. In all cases, pharmacists provided targeted education, emphasizing correct technique and explaining the potential clinical consequences.

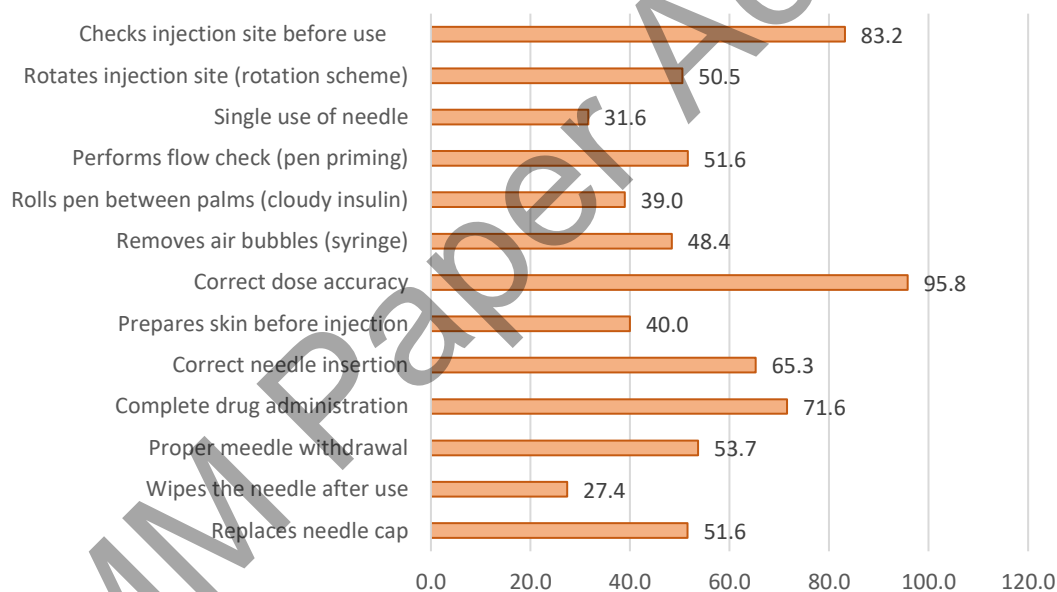


Figure 1. Insulin administration technique – correct practices

Needle reuse was reported by 65 patients (68.4%), with an average of 3.55 uses per needle. Only 8 patients (8.4%) reported using the same needle for different types of insulin. Correct site rotation was reported by 48 patients (50.5%).

Associations between errors in insulin administration (needle reuse and failure to rotate sites) and patient characteristics are presented in Table 2.

Table 2. Associations between errors in insulin administration (needle reuse and failure to rotate sites) and patient characteristics

Characteristics	Failure to rotate			Needle reuse		
	(n=47) Yes	(n=48) No	p-value	(n=65) Yes	(n=30) No	p-value
Gender, n(%)						
Male	18 (43.9%)	23 (56.1%)	0.344	27 (65.9%)	14 (34.1%)	0.639
Female	29 (53.7%)	25 (46.3%)		38 (70.4%)	16 (29.6%)	
Age (years), n(%)						
<65	20 (37.7%)	33 (62.3%)	0.01*	34 (64.2%)	19 (35.8%)	0.315
≥65	27 (64.3%)	15 (35.7%)		31 (73.8%)	11 (26.2%)	
Education, n (%)						
Elementary	11 (78.6%)	3 (21.4%)	0.036*	11 (78.6%)	3 (21.4%)	0.825
High school	24 (46.2%)	28 (53.8%)		34 (65.4%)	18 (34.6%)	
Bachelor's degree	10 (52.6%)	9 (47.4%)		13 (68.4%)	6 (31.6%)	
Master's degree or higher	2 (20.0%)	8 (80.0%)		7 (70.0%)	3 (30.0%)	
Smoking status, n (%)						
no	33 (46.5%)	38 (53.5%)	0.315	48 (67.6%)	23 (32.4%)	0.769
Current smoker	14 (58.3%)	10 (41.7%)		17 (70.8%)	7 (29.2%)	
Duration of diabetes (years), n (%)						
<1 year	3 (75.0%)	1 (25.0%)	0.375	3 (75.0%)	1 (25.0%)	0.836
1-5 years	11 (57.9%)	8 (42.1%)		12 (63.2%)	7 (36.8%)	
>5 years	33 (45.8%)	39 (54.2%)		50 (69.4%)	22 (30.6%)	
Family history of diabetes, n (%)						
no	30 (50.8%)	29 (49.2%)	0.735	41 (69.5%)	18 (30.5%)	0.774
yes	17 (47.2%)	19 (52.8%)		24 (66.7%)	12 (33.3%)	
Diabetes type, n (%)						
Type 1	14 (41.2%)	20 (58.8%)	0.227	22 (64.7%)	12 (35.3%)	0.561
Type 2	33 (54.1%)	28 (45.9%)		43 (70.5%)	18 (29.5%)	
Insulin therapy, n (%)						
Human	13 (72.2%)	5 (27.8%)	0.032*	15 (83.3%)	3 (16.7%)	0.131
Analogues	34 (44.2%)	43 (55.8%)		50 (64.9%)	27 (35.1%)	
HbA1c value, n (%)						
<8%	6 (27.3%)	16 (72.7%)	0.033*	32 (65.3%)	17 (34.7%)	0.650
≥8%	41 (56.2%)	32 (43.8%)		33 (71.7%)	13 (28.3%)	

Errors in site rotation were significantly associated with glycemic control: patients who rotated injection sites correctly were more likely to achieve HbA1c <8% compared to those who did not ($p = 0.033$). No significant associations were observed between HbA1c values and other types of errors. Sociodemographic factors such as gender, smoking status, DM type, DM duration, and family history were not consistently linked with errors. However, older patients (≥ 65 years), those with lower education levels, and those treated with human insulin more frequently demonstrated incorrect practices.

The abdomen was the most frequently used injection site (43.2%), followed by combinations of abdomen and upper arms (15.8%) or abdomen, thighs, and upper arms (12.6%). Only four patients (4.2%) reported using all four sites (abdomen, thighs, upper arms, and buttocks) (Figure 2).

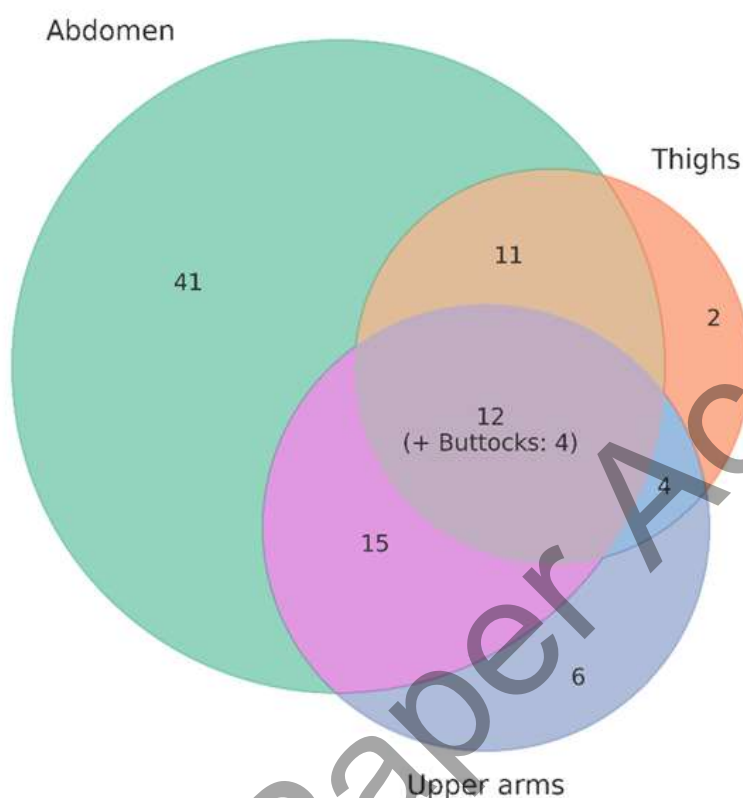


Figure 2. Insulin injection sites

Overall, 83.2% of patients reported checking the injection site before use, and nearly half (47.4%) observed skin changes, including lipohypertrophy in 13 patients (13.7%), lipoatrophy in 4 patients (4.2%), and bruising in 28 patients (29.5%).

Discussion

Our findings confirm that errors in insulin administration remain highly prevalent among patients with DM in Southeastern Serbia. More than four in five participants demonstrated at least one error, with several committing multiple errors simultaneously. Among these, needle reuse and inadequate site rotation were widespread and clinically important, which is why they received particular attention in

our analysis. Significantly, correct rotation was associated with better glycemic outcomes, consistent with prior evidence that injection technique directly affects insulin absorption and glucose variability (17–20).

Our findings align with recent reports indicating that needle reuse remains a highly prevalent practice worldwide. In our cohort, 68.4% of patients reported reusing pen needles, averaging more than three uses per needle. Similar rates have been documented in multicenter surveys from both high- and low-resource settings, where reuse prevalence ranges from 50% to over 90% depending on access to supplies and reimbursement policies (17–19). Needle reuse is strongly associated with lipohypertrophy and erratic insulin absorption (20,21), which in turn contribute to unexplained glycemic variability and hypoglycemic episodes. Although some recent randomized studies observed no short-term differences in HbA1c (22), the tissue complications and long-term risks support the consistent recommendation for single-use needles (20,21). In Serbia, the high prevalence of needle reuse may partly be explained by systemic and economic factors. Patients receive only a limited number of needles reimbursed by the national health insurance system, and the cost of purchasing additional needles may represent a significant burden given the country's lower average income and limited purchasing power. This combination of restricted supply and financial constraints likely contributes to the widespread reuse observed in our sample, underscoring the need for system-level interventions in addition to patient education.

Only half of our participants reported correct site rotation, and those who rotated were significantly more likely to achieve HbA1c <8%. This indicates that patient education is a key determinant of accurate insulin administration, directly influencing the achievement of therapeutic outcomes and improved glycemic control, which underscores the importance of structured educational services. In addition, rotation-related errors were more frequent among older adults (≥ 65 years), those with lower educational attainment, and patients using human insulin rather than analogues, which is consistent with recent evidence (17,23). Evidence from recent observational studies in Europe and Asia further demonstrates that inadequate site rotation is associated with higher HbA1c, greater glucose variability, and a higher prevalence of lipohypertrophy (12,20,24). In our sample, skin complications were reported by nearly half of patients, including lipohypertrophy (13.7%),

lipoatrophy (4.2%), and bruising (29.5%). These findings are comparable with contemporary reports, where lipohypertrophy prevalence ranges from 20% to 50% depending on population and detection method (20,25). Although the prevalence in our study appears lower, such differences may reflect under-detection by visual inspection compared to ultrasound, as previously reported (21,25).

The abdomen was the most frequently used injection site in our study, consistent with patterns described elsewhere (26). However, only a small proportion of patients used all four recommended regions (abdomen, thighs, arms, buttocks). This incomplete utilization of available sites underscores the importance of structured education using rotation scheme and practical demonstrations. International consensus statements, including the recent FITTER Forward recommendations, emphasize systematic within- and between-site rotation, combined with short, thin needles and perpendicular insertion, to optimize absorption and minimize tissue injury (21,27).

Importantly, errors were not confined to inexperienced patients. We observed that even those with long-standing DM frequently demonstrated incorrect practices. This finding is consistent with earlier research indicating that initial education alone is insufficient to sustain correct technique (23,26,28). Psychosocial and behavioral factors—such as treatment fatigue, diabetes distress, and low health literacy—further contribute to lapses despite adequate initial knowledge (29). These barriers highlight the need for ongoing reinforcement through structured diabetes self-management education and support programs (30).

Pharmacists are well-positioned to support patients in mastering insulin administration and sustaining correct practices over time. Evidence from randomized controlled trials and real-world studies confirms that pharmacist-led interventions can improve injection technique, reduce needle reuse, and, in some cases, contribute to better glycemic outcomes (31,32). In Serbia, where community pharmacies are widely available, incorporating structured technique assessments and ongoing counseling into routine services could be a feasible and scalable strategy to minimize administration errors. More broadly, these findings align with global trends emphasizing the need for continuous patient education and multidisciplinary support to ensure the safe and effective use of insulin therapy.

Conclusion

Our findings confirm that errors in insulin administration among patients with DM persist and remain clinically relevant in everyday practice. Needle reuse, insufficient site rotation, and inadequate skin care persist even among experienced patients and contribute to tissue damage and unstable glycemic control. Importantly, rotation-related errors were more frequent among older adults (≥ 65 years), those with lower educational attainment, and patients using human insulin rather than analogues, underscoring the need for tailored educational strategies for these vulnerable groups. These results highlight that patient education is a key prerequisite for correct insulin use and stable glycemic control, emphasizing the importance of structured, pharmacist-led services as a promising approach.

Acknowledgements

This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Grant No: 451-03-137/2025-03/200113.

The authors would also like to thank the Pharmaceutical Chamber of Serbia for providing permission to use and analyze the data collected during pharmacy-based diabetes care services, recognizing the importance of such research for pharmacy practice. We are especially grateful to the community pharmacists who provided consent and made available the data of their patients with diabetes: MPharm Milica Lazović, MPharm Milica Lilić, MPharm Majda Al-Abbasi, MPharm Emilija Trbović, MPharm Nemanja Milovanović, MPharm Sofija Jovanović, MPharm Milica Uskoković, MPharm Marija Jančić, MPharm Nemanja Živanović, MPharm Bojana Krstović, and MPharm Verica Uzelac. Their engagement and support were essential to the realization of this research.

References

1. International Diabetes Federation. IDF Diabetes Atlas [Internet]. 2025 (cited 2025 Jun 12). Available from: <https://diabetesatlas.org/>
2. Leroux M, Boutchueng-Djidjou M, Faure R. Insulin's discovery: new insights on its hundredth birthday: from insulin action and clearance to sweet networks. *Int J Mol Sci*. 2021;22(3):1030. doi:10.3390/ijms22031030
3. Frid AH, Kreugel G, Grassi G, Halimi S, Hicks D, Hirsch LJ, et al. New insulin delivery recommendations. *Mayo Clin Proc*. 2016;91(9):1231-55. doi:10.1016/j.mayocp.2016.06.010
4. Grassi G, Scuntero P, Trepiccioni R, Marubbi F, Strauss K. Optimizing insulin injection technique and its effect on blood glucose control. *J Clin Transl Endocrinol*. 2014;1(4):145-50. doi:10.1016/j.jcte.2014.07.006
5. Ehrmann D, Kulzer B, Wienbarg I, Sieber J, Weber S, Haak T, et al. Assessing barriers and adherence to insulin injection technique in people with diabetes: development and validation of new assessment tools. *J Diabetes Sci Technol*. 2024;18(6):1362-9. doi:10.1177/19322968231175920
6. Borkar Y, Shabaraya RA. A review on insulin errors and its prevention among diabetic patients. *Int J Pharm Res Appl*. 2023;8(6):1020-1028. doi: 10.35629/7781-080610201028
7. Blanco M, Hernández MT, Strauss KW, Amaya M. Prevalence and risk factors of lipohypertrophy in insulin-injecting patients with diabetes. *Diabetes Metab*. 2013;39(5):445-53. doi:10.1016/j.diabet.2013.05.006
8. Kalra S, Mithal A, Sahay R, John M, Unnikrishnan AG, Saboo B, et al. Indian Injection Technique Study: population characteristics and injection practices. *Diabetes Ther*. 2017;8(3):637-57. doi:10.1007/s13300-017-0243-x
9. Barola A, Tiwari P, Bhansali A, Grover S, Dayal D. Insulin-related lipohypertrophy: lipogenic action or tissue trauma? *Front Endocrinol (Lausanne)*. 2018;9:638. doi:10.3389/fendo.2018.00638

10. Gentile S, Strollo F, Ceriello A; AMD-OSDI Injection Technique Study Group. Lipodystrophy in insulin-treated subjects and other injection-site skin reactions: are we sure everything is clear? *Diabetes Ther.* 2016;7(3):401-9. doi:10.1007/s13300-016-0187-6
11. Gunhan HG, Elbasan O, Imre E, Yavuz DG. Lipodystrophy frequency according to insulin treatment regimen in type 2 diabetic patients: is insulin injection frequency matters in analog insulin era? *Acta Endocrinol (Buchar).* 2022;18(2):202-8. doi:10.4183/aeb.2022.202
12. Kalra S, Pathan F, Kshanti IAM, Bay NQ, Nagase T, Oliveria T, et al. Optimising insulin injection techniques to improve diabetes outcomes. *Diabetes Ther.* 2023;14(11):1785-99. doi:10.1007/s13300-023-01460-y
13. Badi S, Suliman SZ, Almahdi R, Aldomah MA, Elkheir HK, Ibrahim MIM, et al. The impact of the clinical pharmacist-led diabetes education on the knowledge and attitude of individuals with type II diabetes mellitus: an interventional study. *Pharmacy (Basel).* 2024;12(5):151. doi:10.3390/pharmacy12050151
14. Haoues M, Zedini C, Chadli-Chaieb M. Facteurs prédictifs du niveau des connaissances, des attitudes et de la qualité de vie des diabétiques tunisiens—à propos de 1007 cas. *Rev Epidemiol Sante Publique.* 2023;71(1):101413. doi:10.1016/j.respe.2022.10.008
15. Bukhsh A, Khan TM, Phisalprapa P, Duangjai A, Saokaew S, Nawaz MS, et al. Impact of pharmacist-led diabetes self-care education on patients with type 2 diabetes in Pakistan: a randomized controlled trial. *Front Pharmacol.* 2022;13:754999. doi:10.3389/fphar.2022.754999
16. American Diabetes Association. 6. Glycemic Goals and Hypoglycemia: Standards of Care in Diabetes—2025. *Diabetes Care.* 2025;48(Suppl 1):S128-S145. doi:10.2337/dc25-S006.
17. Ferreira MA, Cestari VRF, Gonçalves PWC, Brilhante RRDC, Sordi CC, Correia DL, et al. Errors in insulin administration reported by people with diabetes mellitus at home. *Rev Gaucha Enferm.* 2025;46:e20240321. doi:10.1590/1983-1447.2025.20240321.en
18. Shaik Alavudeen S, Akhtar MS, Alshahrani SM, Easwaran V, Shaik Mohammad AA, Abdulla Khan N, et al. A cross-sectional study evaluating insulin injection techniques and the impact of instructions from various healthcare professionals on insulin users in the southern region of Saudi Arabia. *PeerJ.* 2025;13:e19394. doi:10.7717/peerj.19394

19. Theys K, Vermander S, Annemans L, De Block C, Hermans MP, Matthys I, et al. Health-economic modelling of improved behavior in insulin injection technique in Belgium. *Pharmacoecon Open*. 2025;9(2):259-70. doi:10.1007/s41669-024-00547-x
20. Mader JK, Fornengo R, Hassoun A, Heinemann L, Kulzer B, Monica M, et al. Risk factors for lipohypertrophy in people with insulin-treated diabetes: a systematic meta-analysis. *J Diabetes Sci Technol*. 2025;19322968251325569. doi:10.1177/19322968251325569
21. Klonoff DC, Berard L, Franco DR, Gentile S, Gomez OV, Hussein Z, et al. Advance insulin injection technique and education with FITTER Forward expert recommendations. *Mayo Clin Proc*. 2025;100(4):682-99. doi:10.1016/j.mayocp.2025.01.004
22. Berlanda G, Telo GH, Gossenheimer AN, Auler A, da Silva ES, Rodrigues PG, et al. Impact of syringe and needle reuse on the clinical outcomes of patients with type 2 diabetes: a 12-week randomized clinical trial. *Diabetes Care*. 2024;47(12):2146-54. doi:10.2337/dc24-0157
23. Negash Z, Tadiwos A, Urgessa EM, Gebretekle GB, Abebe E, Fentie AM. Insulin injection practice and health related quality of life among individuals with diabetes at Tikur Anbessa Specialized Hospital, Ethiopia: a cross-sectional study. *Health Qual Life Outcomes*. 2023;21(1):38. doi:10.1186/s12955-023-02123-z
24. Mehrabbeik A, Namiranian N, Azizi R, Aghaee Meybody M, Shariati M, Mahmoudi Kohani HA. Investigation of association between insulin injection technique and blood glucose control in patients with type 2 diabetes. *Int J Endocrinol Metab*. 2022;20(4):e128392. doi:10.5812/ijem-128392
25. Zhou T, Zheng Y, Li J, Zou X. Insulin injection technique and related complications in patients with diabetes in a northwest city of China. *J Eval Clin Pract*. 2024. doi:10.1111/jep.14226
26. Yasmin S, Raveendran AV, Jayakrishnan B, Sreelakshmi R, Jose R, Chandran V, et al. How common are the errors in insulin injection techniques – a real world study. *Int J Diabetes Technol*. 2023;2(4):109-11. doi:10.4103/ijdt.ijdt_7_24
27. Tosun B, Cinar FI, Topcu Z, Masatoglu B, Ozen N, Bagcivan G, et al. Do patients with diabetes use the insulin pen properly? *Afr Health Sci*. 2019;19(1):1628-37. doi:10.4314/ahs.v19i1.38

28. Cahyaningsih I, Lambert M, Ochi T, Li F, Li X, Denig P, et al. Community pharmacist-led interventions for patients with type 2 diabetes in low- and middle-income countries: a scoping review. *Res Social Adm Pharm*. 2023;19(8):1117-30. doi:10.1016/j.sapharm.2023.04.124
29. Ahmad K, Anchah L, Ting CY, Lim SE. Effectiveness of a pharmacist-led, community group-based education programme in enhancing diabetes management: a multicentre randomised control trial. *Contemp Clin Trials Commun*. 2024;38:101280. doi:10.1016/j.conctc.2024.101280
30. Bari B, Corbeil MA, MacNeill G, Puebla-Barragan S, Vasquez A. Addressing insulin injection technique: a follow-up study of Canadian patients with diabetes. *Diabetes Ther*. 2023;14(12):2057-74. doi:10.1007/s13300-023-01479-1
31. Heinemann L, Schnell O, Gehr B, Schlott NC, Görgens SW, Görgen C. Digital diabetes management: a literature review of smart insulin pens. *J Diabetes Sci Technol*. 2022;16(3):587-95. doi:10.1177/1932296820983863
32. Steenkamp D, Eby EL, Gulati N, Liao B. Adherence and persistence to insulin therapy in people with diabetes: impact of connected insulin pen delivery ecosystem. *J Diabetes Sci Technol*. 2022;16(4):995-1002. doi:10.1177/1932296821997923