Effectiveness of Insulin Injection Technique on Glycemic Control of Fasting Plasma Glucose and HbA1c in Type II DM Patients at Hasanuddin University Hospital. Randomized Controlled Trial

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Received December 15, 2024
Revised January 02, 2025
Accepted February 24, 2025
Available online February 27, 2025

Abstract

Aims: To identify the effectiveness of insulin injection techniques (injection method, injection location, insulin pen, and drug dose) on glycemic control of HbA1c and Fasting Plasma Glucose (FPG) in Type II DM patients.

Methods: The design of this study was quantitative experimental using a Randomized Controlled Trials (RCT) research design with non-blinding in patients with Type II Diabetes Mellitus who had received insulin therapy. The sample consisted of 60 Type II DM patients and consisted of 30 intervention groups and 30 control groups.

Results: There were significant results on the level of knowledge (p=0.043), accuracy of insulin use (p=0.002), and insulin injection skills (p= 0.017) in patients in the intervention group before and after education, but there was no significant difference in the control group. In addition, in the intervention group, there was a substantial and controlled decrease in GDP and HbA1c levels with a value of p = 0.000, while in the control group, there were no significant results with p=0.104.

Conclusion: Insulin injection techniques (injection method, injection location, insulin pen, and drug dose) can significantly control FPG and HbA1c glycemic levels in Type II DM patients.

Keywords: Insulin injection technique, glycemic levels, Fasting Plasma Glucose, HbA1c, Type II DM patients.

Introduction

Diabetes Mellitus (DM) has become a serious threat to global health and is one of the top 10 causes of death, with the prevalence of DM increasing year by year and concerningly reaching 463 million or 9.3% (American Diabetes Association, 2020). The prevalence of type 1 DM worldwide is 9.5%, with an incidence rate of 15 per 100,000 population (Mobasseri et al., 2020). Meanwhile, the global prevalence of type 2 diabetes is projected to increase to 7,079 per 100,000 population, reflecting a continuous increase across all regions of the world. (Khan et al., 2020). One part of the treatment and management of collaborative diabetes therapy is insulin administration (American Diabetes Association, 2020). In type 1 DM, lifelong insulin injection therapy is received, whereas in type 2 DM, when oral medications cannot control hyperglycemia, insulin injection is required (Kalra et al., 2023). Thus, with proper management actions, DM can be controlled.

The high prevalence of diabetes makes insulin a mandatory therapeutic agent for diabetes, and many patients require short-term or lifelong management, so proper insulin injection skills are essential for optimal blood sugar control in diabetes patients (Abujbara et al., 2022). Standard injection techniques ensure that insulin is delivered correctly to the subcutaneous tissue to provide the desired effect and reduce the occurrence of pain and skin complications at the injection site (Wu Q et al, 2023). Additionally, the Forum for Injection Technique (FITTER) Injection Technique Questionnaire (ITQ) explains that insulin technique guidelines include the accuracy of drug dosage, the method of injection, and the size of the insulin pen, which will significantly affect the therapeutic effect of the drug (Barnard-Kelly et al., 2021). Good technique includes proper rotation of injection sites and not repeating daily injections at the same site for an extended period to prevent the occurrence of lesions (Barnard-Kelly et al., 2021; Kalra et al., 2023). Lesions formed due to repeated punctures lead to the development of Insulin-Derived Amyloidosis (IDA) or local inflammation up to bruising, creating amyloid deposits at the insulin injection site, thereby being ineffective in improving the blood glucose levels of diabetes mellitus patients (Liang et al., 2021). Therefore, applying the correct injection technique and providing structured education on that technique plays an important role in managing diabetes patients.

Incorrect administration of insulin (e.g., too little, too much, or at the wrong times) can result in both transient and profound hypo- and hyperglycemia, wide glycemic excursions, severe hypoglycemia, and Diabetic ketoacidosis (DKA) (Trief et al. l., 2023). When poor glycemic control, patients and providers commonly assume this is because of poor behavioral adherence (e.g., insulin omission). In one case, a patient was not properly using an insulin pen and was unaware that she was not getting any insulin. In another case, a patient was using a syringe not designed for insulin delivery and was, therefore, not getting enough insulin (Gorska-Ciebiada et al., 2020).

Administering an excessive dose will significantly risk the emergence of side effects, while a dose that is too small will not guarantee achieving the expected therapeutic level (Djahido et al., 2020). In addition, for insulin absorption to be effective, it must be injected into the subcutaneous tissue layer (SC) because it does not have an ample blood supply, and the absorption of the drug administered through this route is slower than through the IM route (Masierek et al., 2022). The key to the success of the SC injection technique is that the shortest needle, which is 4 mm, is safe, effective, less painful, and should be the first choice for all categories of patients (Kamrul-Hasan et al., 2022). The safety and efficacy of the 4 mm pen needle have been assessed and proven in several clinical trials involving adults and children, as well as in adults with diabetes who are obese and non-obese (Selvadurai et al., 2021). Additionally, the 4 mm pen needle has been recommended for use in most adult patients of all body sizes who do not require skinfold lifting (Ucieklak et al., 2022). Therefore, insulin injection techniques that adhere to guidelines are crucial for ensuring that the insulin response aligns with its pharmacokinetics and pharmacodynamics.

Many guidelines have been published for the ideal practice of insulin injection (American Diabetes Association, 2020). However, there is a significant gap between the guidelines for insulin injection techniques and the current practice of these techniques. (Kamrul-Hasan et al., 2022). A study in Ethiopia on insulin injection technique practices among adolescents with DM found that only slightly more than half of the participants often practiced injecting insulin at a 45° angle, only nearly one-third had proper rotation of injection sites, very few participants changed needles, and 83% had suboptimal glycemic control (HbA1c) > 7.5% and FPG value above 130 mg/dl and the highest is

more than 200 mg/dl (Mehrabbeik et al., 2022). The results of a study conducted in Indonesia at RSUD Dr. Saiful Anwar (RSSA) Malang found that only 20% were able to perform the insulin injection technique correctly and had glycemic control (HbA1c) > 6.5%. (Wu Q et al., 2023). In addition, several other studies also state that errors in insulin injections can cause blood glucose levels to be too low due to incorrect doses and poor nutrition and increased FPG levels above the 200 mg/dl range due to errors in injection skills causing insulin to enter the subcutaneous area incorrectly (Tulsan et al., 2024).

Based on observations in the Unhas Hospital Ward, it was found that many patients had not received education on proper insulin injection techniques before being discharged, resulting in many diabetes patients entering with repeated bruises in the injection areas every day. Additionally, according to the insulin technique guidelines for DM patients, proper insulin injection techniques significantly reduce patients' blood glucose levels. (Soetmadji, 2021). Therefore, it is essential to provide appropriate interventions to improve the practical skills of insulin injection techniques in DM patients.

Methods

This research design is quantitative experimental using a non-blinding, randomized controlled trials (RCT) research design, namely providing intervention in counseling to individuals and couples. The sample measurement method uses the Bonferroni method (P=mp) and Sidak's (P=1-(1-p)m) (Vickerstaff et al., 2019).

Determining research questions based on PICOT

Population : Patients with Type II Diabetes Mellitus who have received insulin therapy. The sample consisted of 60 Type II DM patients.
Intervention : Insulin injection technique is carried out at Hasanuddin University Hospital
Control : Patients with Type II Diabetes Mellitus without being given education on insulin injection techniques
Results : Patients can know the correct insulin injection technique
Time : The research was conducted for 5 months (July to November)

Inclusion and Exclusion Criteria

The sampling method was carried out using simple random sampling; namely, all subjects who came and met the inclusion criteria would be selected randomly until the required number of samples was met. Randomization was done to determine which subjects were included in the intervention or control groups. Inclusion criteria were patients with Type II DM, adult patients aged 18 to 75 years, patients who had received insulin therapy for 1 month, patients with HbA1c levels above 9%, FPG > 130 mg/dl, patients who were registered as inpatients at Hasanuddin University Hospital, and patients with planned outpatient care. Exclusion criteria were patients who refused intervention, type I DM patients, patients with skin infections in the injection area, and DM patients without insulin therapy. Drop criteria were patients who did not return for check-ups to the Polyclinic or died and patients who no longer used or stopped using insulin injections because they changed therapy or refused.

Determining and Implementing Interventions

Patients who receive the intervention will be given education on the correct insulin injection technique using educational media, such as leaflets and videos, for 5 minutes. Patients will first receive a questionnaire containing their knowledge of the correct insulin injection. After receiving education and demonstration, the patient will fill out

the questionnaire again to determine the patient's level of understanding. The questionnaire consists of 3 assessment topics, namely knowledge about insulin injections (categories "correct" and "incorrect"), accuracy in using insulin (categories "Yes" and "No"), and patient skills in injecting insulin (categories "done" and "not done").

After that, the patient will independently inject their insulin with the assistance of a trained expert nurse to monitor the patient's insulin injection while the patient is being treated in the Hospital. Before the respondents go home, the specialist nurse ensures that the insulin is the correct injection technique and dosage. Respondents will be asked to return for a check-up at the Polyclinic after 3 months from when the patient goes home to determine the glycemic levels of HbA1C and FPG.

Selecting Controls

The determination of the control group was carried out in a different room from the intervention group room. The control group was given no special intervention or placebo even though they received the same treatment at the Hospital. In contrast, the intervention group would receive special intervention from researchers regarding the correct insulin injection technique while still receiving the same treatment.

Results

At this stage, the researcher performs data processing and data analysis. The results of this study include:

The intervention group consisted of 50% male and female; for the control group, almost 70% were female. Patients in the intervention group were primarily self-employed (46.7%); in the control group, most were homemakers (IRT), around 33.3%. The use of insulin in the intervention group <1 year was more (46.7%) with the use of a single type of insulin (66.7), while in the control group the most insulin use was around 2-5 years (40.0%) with the use of Single insulin (83.3%) (Table 1).

A statistically significant difference was observed in the initial and final tests of the patient's FPG results in the intervention group (p = 0.000). In addition, There was a statistically significant difference in the patient's HbA1c levels for 3 months in the initial and final tests in the intervention group (p = 0.000) (Table 2). We also found there are significant differences in the results of the level of knowledge (p=0.043), accuracy of insulin use (p=0.002), and insulin injection skills (p= 0.017) in patients in the intervention group and control group before and after education (Table 3).

The table shows that in the Fasting Plasma Glucose (FPG) levels for the intervention group, there was a significant effect on the results of the patients' FPG, most of which were controlled (p: 0.000), while for the control group, there was no significant effect (p: 0.104). The HbA1c results for the intervention group showed a significant effect after education on the correct insulin injection technique (p: 0.001). In contrast, in the control group, there was no significant effect (p: 0.062) (Table 4).

Table 1. Demographic characteristics of Type II Diabetes Mellitus patients who have previously received insulin therapy

Characteristics	Group		P value
	Intervention N: 30 (%)	**Control N: 30 (%)**	
Gender			
Male	15 (50)	9 (30)	0.168*
Female	15 (50)	21 (70)	
Age (years)			
Mean±SD	46.7±7.23	53.3±7.69	0.109**
Work			
Civil servant	3 (10)	7 (23.3)	0.165*
Self-employed	14 (46.7)	9 (30.0)	
Teacher/Lecturer	3 (10)	3 (10)	
housewife	6 (20)	10 (33.3)	
There is not any	4 (13.3)	1 (3.3)	
Duration of Insulin usage			
<1 year	14 (46.7)	9 (30.0)	0.655*
2-5 years	12 (40.0)	12 (40.0)	
>5 years	4 (13.3)	9 (30.0)	
Types of Insulin			
Combination	10 (33.3)	5 (16.7)	0.922*
Single	20 (66.7)	25 (83.3)	

*chi-square test**Mann-Whitney test

Table 2. Differences in Fasting Plasma Glucose (FPG) and HbA1C Levels Pre and Post-test Education on Correct Insulin Injection Techniques

Variables	Intervention (n=30)	Mean (SD)	95% CI		P value
			Lower	**Upper**	
GDP	**Pre**	16.92 (4.86)	6,570	3,837	0.000*
	Post	22.99 (4.35)			
HbA1C	**Pre**	333.4(103.5)	183.5	255.7	0.000**
	Post	113.8(127.7)			

*Paired samples t-test, **Wilcoxon signed ranks test

Table 3. Comparison of Knowledge Level, Accuracy, and Skills of Insulin Use in Type II DM Patients

Variables	Mean (SD)		P value	Mean difference (CI 95%)
	Pre	Post		
Level of Knowledge				
Intervention (n=30)	17.89 (4.55)	22.82 (4.42)	0.043*	0.422
Control (n=30)	17.54 (4.63)	17.69 (4.66)		(-2.72-3.98)
Accuracy of Insulin Use				
Intervention (n=30)	17.48 (4.63)	22.83 (4.45)	0.002*	3.99
Control (n=30)	17.17 (4.67)	17.98 (4.99)		(0.89-6.87)
Insulin Injection Skills				
Intervention (n=30)	17.77 (4.51)	22.65 (4.32)	0.017*	3.10
Control (n=30)	17.98 (5.42)	18.00 (5.50)		(1.80-5.13)

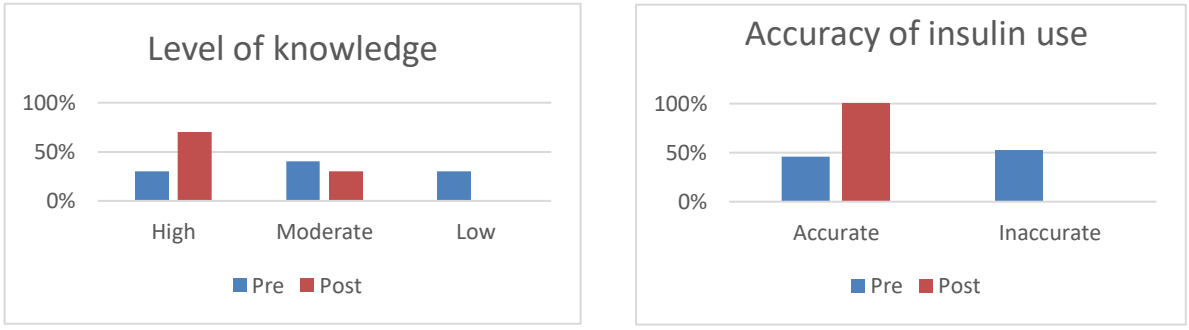
*Independent samples t-test

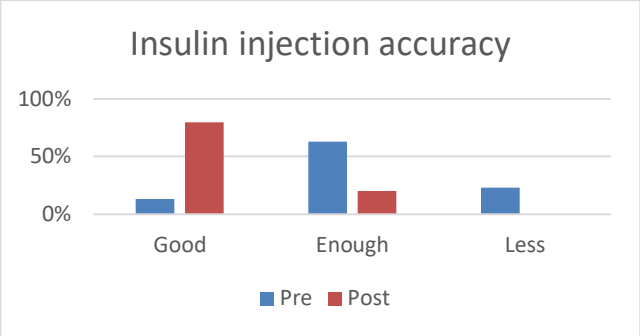
Table 4. Analysis of FPG and HbA1C results of the Intervention and Control Groups

Variables	Mean±SD		P value
	Control	**Not controlled**	
GDP			
Intervention (n=30)	19.38±3.76	16.90±3.30	0.000*
Control (n=30)	17.96±3.67	19.87±3.90	0.104**
HbA1c			
Intervention (n=30)	19.26±3.64	17.96±3.11	0.001*
Control (n=30)	17.90±3.42	18.20±3.33	0.062**

*Paired samples t-test, **Wilcoxon signed ranks test

Figure 1. Presentation Graph of Pre and Post-Insuli n Injection Education for DM Patients





Discussion

This study examines the effectiveness of an insulin injection technique appropriate for controlling glycemic control, namely HbA1c, in patients with Type 2 Diabetes (DM Type II) treated at Rumah Sakit Universitas Hasanuddin. The Randomized Controlled Trial (RCT) design provides reliable results by minimizing bias and ensuring a balanced comparison between intervention and control groups (Sastroasmoro & Ismael, 2020). This has significant implications for improving diabetes management strategies and clinical practices.

Comparison of Intervention and Control Groups

This study demonstrated a statistically significant improvement in glycemic control among patients who received structured education on insulin injection techniques compared to the control group. At baseline, both groups showed similar HbA1c levels (before intervention: 16.92 vs. 17.14, p = 0.000). However, after three months, the intervention group showed a substantial decrease in HbA1c levels (after intervention: 22.99 vs. 18.20, p = 0.002). These findings are consistent with previous studies that emphasize the important role of education and adherence to injection protocols in optimizing insulin therapy outcomes (Kalra et al., 2023; Liang et al., 2021).

The improvement in glycemic control in the intervention group may be attributed to improvements in injection techniques, including proper injection site rotation, use of appropriate needle length, and self-injection skills. Practical education will likely reduce errors such as lipohypertrophy due to repeated injections at the same site, contributing to poor insulin absorption and hyperglycemia (Ehrmann et al., 2023). In addition, a study by Selvadurai et al. (2021) showed that retraining injection techniques can improve glycemic control and reduce the risk of injection complications. These improvements are consistent with global evidence showing that precise insulin administration improves therapeutic efficacy and minimizes complications (Wu et al., 2023).

Based on diabetes guidelines, it is stated that controlling glycemic levels of HbA1c and FPG can be done after 3 months of insulin therapy. In addition, people with diabetes with HbA1c values <7% and FPG levels of 80-130 mg/dl can be said to be stable, whereas a decrease in HbA1C of 3-4% can indicate a significant decrease in the stability of blood glucose levels (American Diabetes Association, 2024)

Patient Knowledge, Accuracy, and Skills

The intervention group showed significantly improved patient knowledge, injection accuracy, and skills compared to the control group. Knowledge scores increased from 17.89 to 22.82 (p = 0.043), and injection accuracy scores significantly increased from 17.48 to 22.83 (p = 0.002). These results emphasize the importance of targeted education in empowering patients with the skills to manage their condition effectively.

Similar results were observed in studies using simulation tools and video-based training to improve patient confidence and technique (Liang et al., 2021).

Furthermore, ongoing education plays a critical role in creating consistent behavioral change. For example, a study by Mehrabbeik et al. (2022) revealed that ongoing education and psychosocial support can improve adherence to therapy protocols. Integrating these strategies into routine diabetes care may improve patient independence and long-term health outcomes.

In addition, family support in caring for patients with diabetes mellitus can help control glycemic levels by utilizing their efforts in controlling insulin therapy and administering and providing DM diets. This can be realized with family awareness when accompanying DM patients. However, it cannot be separated from medical personnel's education and health information regarding controlling patient glycemic levels at home (American Diabetes Association, 2025).

Limitations

Although this study provides valuable insights, several limitations should be noted. The sample size of 60 patients may limit the generalizability of the findings. Additionally, the short follow-up period of 3 months did not capture adherence or long-term outcomes. Future studies should consider a multicenter trial with a larger sample size and a more extended follow-up period to validate and expand on these findings. Another limitation is the potential bias introduced by the non-blinding of participants, which could affect self-reported outcomes such as injection accuracy and skill. Using objective measures, such as digital monitoring of insulin delivery, may improve the reliability of future studies.

Contribution to global nursing practice

This study has direct implications for clinical practice. The structured educational intervention used in this study can serve as a model for integrating patient-centered care into routine diabetes management. Hospitals should prioritize the development of Standard Operating Procedures (SOPs) and educational materials, such as leaflets and videos, to support patients and healthcare professionals. Implementing evidence-based SOPs can standardize care delivery and ensure consistency across clinical settings.

Conclusion

Education can influence patient and family independence in controlling glycemic, reducing morbidity in diabetes patients, and reducing the length of stay. In addition, education using simulation tools and video-based training can increase patient confidence and technique. Furthermore, these findings highlight the importance of interprofessional collaboration in optimizing diabetes care. Involving pharmacists, nurses, and physicians in providing comprehensive education can address gaps in patient understanding and encourage adherence to prescribed therapies.

Author Contribution

All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Conflict of interest

The authors state no conflict of interest.

Acknowledgment
The author would like to thank the Institute for Research and Community Service and the Unhas Hospital for contributing to the development of this research.

References

Abujbara, M., Khreisat, E. A., Khader, Y., & Ajlouni, K. M. (2022). Effect of insulin injection techniques on glycemic control among patients with diabetes. *International Journal of General Medicine, 15*, 8593–8602. https://doi.org/10.2147/IJGM.S393597

American Diabetes Association. (2020, December 19). ADA releases 2021 standards of medical care in diabetes centered on evolving evidence, technology, and individualized care. https://diabetes.org/newsroom/ADA-releases-2021-standards-of-medical-care-in-diabetes

American Diabetes Association. (2024). Facilitating positive health behaviors and well-being to improve health outcomes: Standards of care in diabetes—2024. *Diabetes Care, 47*(Suppl. 1), S77–S110. https://doi.org/10.2337/dc24-S005

American Diabetes Association. (2025). Glycemic goals and hypoglycemia: Standards of care in diabetes—2025. *Diabetes Care, 48*(Suppl. 1), S128–S145. https://doi.org/10.2337/dc25-S006

Barnard-Kelly, K. D., Mahoney, E., Baccari, L., Oliveria, T., Glezer, S., Berard, L., et al. (2021). Injection technique: Development of a novel questionnaire and user guide. *The American Diabetes Association Journal, 34*(2), 156–165. https://doi.org/10.2337/figshare.13237364

Bari, B., Corbeil, M. A., MacNeill, G., Puebla-Barragan, S., & Vasquez, A. (2023). Addressing insulin injection technique: A follow-up study of Canadian patients with diabetes. *Diabetes Therapy, 14*(12), 2057–2074. https://doi.org/10.1007/s13300-023-01479-1

Djahido, M., Wiyono, W. I., & Mpila, D. A. (2020). Insulin use patterns in type 1 diabetes mellitus patients in the outpatient installation of Prof. Dr. R. D. Kandou Manado General Hospital. *PHARMACON Scientific Journal of Pharmacy UNSRAT, 9*(1). https://doi.org/10.35799/pha.9.2020.27413

Ehrmann, D., Kulzer, B., Wienbarg, I., Sieber, J., Weber, S., Haak, T., et al. (2023). Assessing barriers and adherence to insulin injection technique in people with diabetes: Development and validation of new assessment tools. *Journal of Diabetes Science and Technology*. https://doi.org/10.1177/19322968231175920

Gorska-Ciebiada, M., Masierek, M., & Ciebiada, M. (2020). Improved insulin injection technique, treatment satisfaction, and glycemic control: Results from a large cohort education study. *Journal of Clinical and Translational Endocrinology, 19*. https://doi.org/10.1016/j.jcte.2020.100217

Kalra, S., Pathan, F., Kshanti, I. A. M., Bay, N. Q., Nagase, T., Oliveria, T., et al. (2023). Optimizing insulin injection techniques to improve diabetes outcomes. *Diabetes Therapy, 14*, 1785–1799. https://doi.org/10.1007/s13300-023-01460-y

Kamrul-Hasan, A. B. M., Hannan, M. A., Asaduzzaman, M., Rahman, M. M., Alam, M. S., Amin, M. N., et al. (2022). Prevalence and predictors of diabetes distress among adults with type 2 diabetes mellitus: A facility-based cross-sectional study of Bangladesh. *BMC Endocrine Disorders, 22*(1). https://doi.org/10.1186/s12902-022-00938-3

Khan, M. A. B., Hashim, M. J., King, J. K., Govender, R. D., Mustafa, H., & Kaabi, J. A. (2020). Epidemiology of type 2 diabetes - Global burden of disease and predicted trends. *Journal of Epidemiology and Global Health, 10*(1), 107–111. https://doi.org/10.2991/JEGH.K.191028.001

Liang, K., Xie, Q., Nie, J., & Deng, J. (2021). Study on the effect of education for insulin injection in diabetic patients with new simulation tools. *Medicine (United States), 100*(14), E25424. https://doi.org/10.1097/MD.0000000000025424

Masierek, M., Nabrdalik, K., Janota, O., Kwiendacz, H., Macherski, M., & Gumprecht, J. (2022). The review of insulin pens—Past, present, and look to the future. *Frontiers in Endocrinology, 13*. https://doi.org/10.3389/fendo.2022.827484

Mehrabbeik, A., Namiranian, N., Azizi, R., Meybody, M. A., Shariati, M., & Kohani, H. A. M. (2022). Investigation of association between insulin injection technique and blood glucose control in type 2 diabetes patients. *International Journal of Endocrinology and Metabolism, 20*(4). https://doi.org/10.5812/ijem-128392

Mobasseri, M., Shirmohammadi, M., Amiri, T., Vahed, N., Fard, H. H., & Ghojazadeh, M. (2020). Prevalence and incidence of type 1 diabetes in the world: A systematic review and meta-analysis. *Health Promotion Perspectives, 10*, 98–115. https://doi.org/10.34172/hpp.2020.18

Selvadurai, S., Cheah, K. Y., Ching, M. W., Kamaruddin, H., Lee, X. Y., & Ngajidin, R. M., et al. (2021). Pharmacist insulin injection re-education impacts glycemic control among type II diabetic patients in primary health clinics. *Saudi Pharmaceutical Journal, 29*(7), 670–676. https://doi.org/10.1016/j.jsps.2021.04.028

Soetmadji, D. W. (2021). *Practical guidelines for insulin therapy in patients with diabetes mellitus* (1st ed.).

Trief, P. M., Cibula, D., Rodriguez, E., Akel, B., & Weinstock, R. S. (2023). Incorrect insulin administration: A problem that warrants attention. *Clinical Diabetes, 34*(1), 25–33. https://doi.org/10.2337/diaclin.34.1.25

Tulsan, S. K., et al. (2024). Errors in diabetic insulin therapy and the vitality of proper precautions in Bangladesh: Real-life insights from the developing world. *Journal of Family Medicine and Primary Care, 13*(1), 292–297. https://doi.org/10.4103/jfmpc.jfmpc_484_23

Ucieklak, D., et al. (2022). Insulin-induced lipohypertrophy in patients with type 1 diabetes mellitus treated with an insulin pump. *International Journal of Endocrinology, 2022*. https://doi.org/10.1155/2022/9169296

Vickerstaff, V., Omar, R. Z., & Ambler, G. (2019). Methods to adjust for multiple comparisons in the analysis and sample size calculation of randomized controlled trials with multiple primary outcomes. *BMC Medical Research Methodology, 19*(1). https://doi.org/10.1186/s12874-019-0754-4

Wu, Q., Deng, M., Wang, W., Yu, S., Wang, M., Sun, C., et al. (2023). A self-controlled, cross-over study of intensive insulin treatment with needle-based injection versus needle-free injection in hospitalized patients with type 2 diabetes. *Frontiers in Endocrinology (Lausanne), 14*. https://doi.org/10.3389/fendo.2023.1162176