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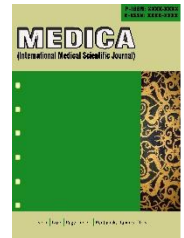

Progressive Muscle Relaxation and Warm Foot Bath Therapy for Type 2 Diabetes Patients

Ismansyah[1]✉, Arif Supriyanto[2], Frana Andrianur[1], Rini Ernawati[3]

[1] Department of Nursing, Poltekkes Kemenkes Kalimantan Timur, Samarinda City, East Kalimantan, Indonesia
[2] RSPKT (Pupuk Kaltim Hospital) Bontang, Bontang, East Kalimantan, Indonesia
[3] Department of Nursing, Universitas Muhammadiyah Kalimantan Timur, Samarinda City, East Kalimantan, Indonesia

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Abstract

Hospitalised patients with type 2 diabetes mellitus (T2DM) are often exposed to situational anxiety that activates the hypothalamic–pituitary–adrenal (HPA) axis, increases cortisol levels, and contributes to poor glycaemic control; therefore, complementary non-pharmacological nursing interventions that reduce stress may enhance standard treatment outcomes. This study aimed to compare the effects of progressive muscle relaxation (PMR) and warm water foot bath therapy (WWFB) on random blood glucose (RBG) levels among hospitalised patients with T2DM receiving standard care. A parallel three-arm randomised controlled trial was conducted in three inpatient wards of Pupuk Kaltim Hospital, Bontang, between August and September 2025, involving 48 patients with admission RBG ≥ 200 mg/dL who were randomly assigned to PMR, WWFB, or control groups in equal proportions using computer-generated randomisation with allocation concealment. The interventions were administered for 15–20 minutes once daily over three consecutive days, and outcome assessors were blinded to group allocation. Data were analysed using paired t-tests, one-way ANOVA with Tukey HSD post-hoc tests, and effect size measures. The results showed significant reductions in RBG within all groups, with greater decreases observed in the PMR and WWFB groups compared to the control group. Furthermore, there was a statistically significant difference in post-intervention RBG between groups, where both PMR and WWFB demonstrated superior effects compared to standard care, while no significant difference was found between the two intervention groups. In conclusion, both progressive muscle relaxation and warm water foot bath therapy are effective complementary nursing interventions for improving glycaemic control in hospitalised patients with T2DM and may be integrated into routine clinical practice to support diabetes management.

Corresponding Author:
✉ Ismansyah
Department of Nursing, Poltekkes Kemenkes Kalimantan Timur, Samarinda City, East Kalimantan, Indonesia
Email: ismanamin18@gmail.com

1. INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) has emerged as one of the most critical public health challenges of the twenty-first century (Yamada, Kondo, & Okazaki, 2025; Katsanou & Marakomichelakis, 2026; Spanakis et al., 2026). According to the 11th edition of the International Diabetes Federation (IDF) Diabetes Atlas, an estimated 589 million adults aged 20–79 years were living with diabetes globally in 2024, representing 11.1% of the world's adult population, of whom approximately 90% had T2DM (Genitsaridi et al., 2026). This number is projected to increase to 853 million by 2050, driven by population aging, rapid urbanization, and increasingly sedentary lifestyles, with a disproportionate burden in low- and middle-income countries (Genitsaridi et al., 2026). These trends highlight the urgent need to expand diabetes management strategies beyond pharmacological approaches alone.

In Indonesia, the 2024 National Health Survey reported a physician-diagnosed diabetes prevalence of 2.2%, equivalent to approximately 12.96 million individuals, with East Kalimantan Province showing a slightly higher prevalence of 2.4% (Health Development Policy Agency, Ministry of Health of the Republic of Indonesia, 2024). At the local level, Pupuk Kaltim Hospital (RSPKT) Bontang recorded 513 diabetes cases in 2024, while the total number of cases in the city increased from 3,905 in 2018 to 4,318 in 2024. The increasing trend underscores the need for comprehensive and evidence-based interventions, particularly in inpatient settings where patients are more vulnerable to stress-induced glycaemic instability.

The pathophysiology of T2DM involves a combination of peripheral insulin resistance and progressive pancreatic beta-cell dysfunction, resulting in chronic hyperglycemia. One key contributing mechanism is cortisol-mediated hyperglycemia, in which elevated glucocorticoid levels suppress insulin secretion, reduce glucagon-like peptide-1 (GLP-1) production, and stimulate gluconeogenesis, thereby increasing hepatic glucose output and impairing peripheral glucose uptake (Janssen, 2022). Dysregulation of the Hypothalamic Pituitary Adrenal (HPA) axis is also strongly associated with insulin resistance and poor glycaemic control (Liang et al., 2024). Although pharmacological therapies such as metformin and insulin remain the cornerstone of treatment, they are often associated with side effects, financial burden, and suboptimal adherence, especially in hospital settings (Sun et al., 2022).

Complementary non-pharmacological interventions have therefore gained attention as supportive strategies. Progressive Muscle Relaxation (PMR) works by activating the parasympathetic nervous system and suppressing HPA axis activity, leading to reduced cortisol levels and improved insulin sensitivity. Evidence shows that PMR significantly reduces HbA1c and blood glucose levels (Arunraj et al., 2024), and relaxation-based interventions have been shown to lower cortisol and fasting glucose levels (Obaya et al., 2023). Similarly, Warm Water Foot Soak (WWFS) therapy stimulates thermoreceptors, promotes vasodilation, and enhances peripheral glucose uptake. A scoping review confirmed that hydrotherapy interventions consistently improve glycaemic outcomes in T2DM patients (Chidambaram et al., 2024). Despite this evidence, previous studies have largely examined these interventions separately, with limited research comparing their effectiveness, particularly in inpatient settings.

This study addresses these gaps by conducting a three-arm randomized controlled trial to compare the effects of Progressive Muscle Relaxation and Warm Water Foot Soak therapy on random blood glucose levels among hospitalized patients with T2DM. The novelty of this study lies in its direct comparative approach and its focus on integrating complementary nursing interventions into hospital care. Therefore, this study aims to evaluate and compare the effectiveness of PMR and WWFS in improving glycaemic control, with the goal of providing evidence-based recommendations for incorporating these interventions into routine inpatient diabetes management.

2. METHOD

This study employed a parallel three-arm randomized controlled trial (RCT) with a pre- and post-intervention measurement design. Although the initial proposal described the study as quasi-experimental, the use of computer-generated randomization, allocation concealment, and a concurrent control group meets the methodological criteria of a true RCT; therefore, the design has been revised accordingly. The reporting of this study follows the Consolidated Standards of Reporting Trials (CONSORT) 2010 guidelines. The trial was conducted in three inpatient wards (Bugenville, Catelya, and Dahlia) at Pupuk Kaltim Hospital (RSPKT), Bontang, East Kalimantan, Indonesia, between August and September 2025.

The study population consisted of adult patients diagnosed with type 2 diabetes mellitus (T2DM). Eligible participants were aged 30–65 years, had a physician-confirmed diagnosis of T2DM, presented with admission random blood glucose (RBG) levels ≥ 200 mg/dL, and were able to provide written informed consent. Patients were excluded if they had acute diabetic complications such as severe hypoglycaemia or suspected diabetic ketoacidosis, active foot infections or open wounds in the plantar area, or clinically significant cognitive impairment that could interfere with participation in the interventions. The sample size was determined a priori using G*Power 3.1 for one-way ANOVA with three independent groups. Assuming a large effect size (Cohen's $f = 0.50$), a significance level of 0.05, and a statistical power of 0.80, the minimum required sample was 42 participants. To account for potential attrition, a total of 48 participants were recruited and equally allocated into three groups (16 participants per group).

Randomization was performed using a computer-generated sequence with block sizes of six, prepared by an independent statistician. Allocation concealment was ensured through sequentially numbered, opaque, sealed envelopes that were opened only after participants had completed baseline assessments. Due to the nature of the interventions, blinding of participants and intervention providers was not feasible; however, outcome assessors and data analysts were blinded to group allocation to minimize bias.

Participants in the intervention groups received either Progressive Muscle Relaxation (PMR) or Warm Water Foot Soak (WWFS) therapy. The PMR group performed a standardized 15-movement relaxation protocol lasting 15–20 minutes, guided by trained nurses using a structured audio script to ensure consistency (Marițescu et al., 2025; Pathan et al., 2023). The WWFS group immersed both feet up to the mid-calf in water maintained at 38–42°C for 15–20 minutes, with temperature monitored using a calibrated thermometer and adjusted as needed (Kuderer et al., 2022). Both interventions were administered once daily for three consecutive days. The control group received standard nursing and pharmacological care according to hospital protocols without additional complementary interventions.

To reduce potential confounding, factors influencing glycaemic levels were controlled as much as possible. Antidiabetic medication regimens (type, dosage, and timing) were documented and assessed for comparability across groups. All participants received a standardized diabetic diet provided by the hospital nutrition unit, with caloric intake adjusted according to body weight. Physical activity levels were limited to routine inpatient mobility, and no structured exercise was permitted during the study period. These variables were evaluated descriptively and considered in the interpretation of results.

The primary outcome was the change in random blood glucose (RBG) levels measured before and after each intervention session. Blood glucose was assessed באמצעות capillary blood samples obtained via fingertip puncture using a calibrated digital glucometer, with daily quality control procedures performed وفق manufacturer standards.

Ethical approval for the study was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Kalimantan Timur (DP.04.03/F.XXXIV.27/476/2025). All participants provided written informed consent after receiving a clear explanation of the study procedures, potential risks and benefits, and their right to withdraw at any time without affecting their treatment. The study adhered to the principles of the Declaration of Helsinki.

Data analysis was conducted using IBM SPSS Statistics version 26. Normality of data distribution was assessed using the Shapiro–Wilk test. Baseline characteristics were compared using one-way ANOVA for continuous variables and chi-square tests for categorical variables. Within-group differences were analyzed using paired-samples t-tests, while between-group comparisons were performed using one-way ANOVA followed by Tukey's HSD post-hoc test. Effect sizes were reported as Cohen's d for within-group changes and eta-squared (η^2) for between-group differences, along with 95% confidence intervals. A two-tailed significance level of 0.05 was applied throughout the analysis.

3. RESULTS AND DISCUSSION

Table 1. Baseline demographic and clinical characteristics by study arm.

Variable	PMR (n = 16)	WWFS (n = 16)	Control (n = 16)	p-value
Age > 40 years	16 (100.0)	15 (93.8)	15 (93.8)	0.61
Male sex	5 (31.3)	9 (56.3)	8 (50.0)	0.35
DM duration 5–10 years	11 (68.8)	10 (62.5)	9 (56.3)	0.75
DM duration > 10 years	5 (31.3)	5 (31.3)	6 (37.5)	0.89
Baseline RBG	296 ± 35.1	288 ± 34.8	364 ± 68.9	—

Note: *PMR = progressive muscle relaxation; WWFS = warm water foot soak; RBG = random blood glucose.*

Table 1 shows that the baseline characteristics of participants were comparable across the three study groups, with no statistically significant differences observed in age, sex, or duration of diabetes (all $p > 0.05$). Although the control group showed a higher mean baseline RBG compared to the intervention groups, this difference was considered descriptively, as the primary analysis focused on within-group changes and post-intervention comparisons. Overall, the findings indicate that the groups were sufficiently homogeneous at baseline.

Table 2. Within-group pre- and post-intervention RBG (paired t-test).

Group	n	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Δ (95% CI)	p-value	Cohen's d
PMR	16	296 ± 35.1	202 ± 37.3	94 (77–111)	< 0.001	2.52
WWFS	16	288 ± 34.8	200 ± 37.9	88 (70–106)	< 0.001	2.32
Control	16	364 ± 68.9	292 ± 70.3	72 (40–104)	< 0.001	1.02

Note: *RBG = random blood glucose; CI = confidence interval.*

Table 2 shows that all groups demonstrated statistically significant reductions in RBG following the intervention period ($p < 0.001$). The largest reductions were observed in the PMR and WWFS groups, both showing very large effect sizes (Cohen's d > 2), indicating strong clinical impact. The control group also exhibited a significant reduction, although with a smaller effect size, likely reflecting the influence of standard pharmacological treatment and dietary management. These results suggest that both PMR and WWFS provide additional benefits beyond routine care in reducing blood glucose levels.

Table 3. One-way ANOVA of post-intervention RBG and Tukey HSD post-hoc.

Group	n	Post Mean ± SD	Min–Max	F (df)	p-value	η^2
PMR	16	202 ± 37.3	150–290	16.99 (2,45)	< 0.001	0.43
WWFS	16	200 ± 37.9	113–277	—	—	—
Control	16	292 ± 70.3	198–423	—	—	—

Note: *Tukey HSD pairwise comparisons: PMR vs Control (p < 0.001); WWFS vs Control (p < 0.001); PMR vs WWFS (p = 0.98).*

Table 3 shows that the one-way ANOVA revealed a statistically significant difference in post-intervention RBG between the three groups, with a large effect size ($\eta^2 = 0.43$), indicating that group allocation accounted for a substantial proportion of the variance in outcomes. Post-hoc analysis showed that both PMR and WWFS groups had significantly lower RBG levels compared to the control group, while no significant difference was observed between the PMR and WWFS groups. This finding indicates that both interventions are equally effective in improving glycaemic control. The wider range of RBG values observed in the WWFS group may reflect variability in individual physiological responses to hydrotherapy.

In this three-arm randomized controlled trial involving hospitalized patients with T2DM, both Progressive Muscle Relaxation (PMR) and Warm Water Foot Soak (WWFS) demonstrated significantly greater reductions in random blood glucose (RBG) compared to standard pharmacological care alone. The magnitude of the observed effects was substantial, with very large within-group effect sizes and a large between-group effect. Interestingly, PMR and WWFS produced nearly identical outcomes despite operating through different primary mechanisms, suggesting that both interventions may converge on a shared pathway of stress reduction rather than relying solely on distinct physiological processes commonly emphasized in the literature.

The direction and magnitude of these findings are consistent with previous studies. Arunraj et al. (2024) reported clinically meaningful reductions in HbA1c and fasting blood glucose following a three-month PMR intervention, while Obaya et al. (2023) demonstrated significant decreases in cortisol levels and fasting glucose through structured mind–body interventions. Similarly, evidence from hydrotherapy studies, including the scoping review by Chidambaram et al. (2024) and the controlled trial by Kuderer et al. (2022), indicates that warm-water interventions can produce modest to moderate improvements in glycaemic control. However, inconsistencies exist in the literature, as some hydrotherapy studies in healthier populations or those with shorter intervention durations have reported minimal or non-significant effects, and certain PMR studies in outpatient settings have shown smaller effect sizes. The larger reductions observed in the present study may be explained by the high baseline RBG levels among hospitalized patients, which provide greater potential for measurable improvement compared to outpatient populations with relatively controlled glycaemia.

Although this study did not directly measure physiological biomarkers such as cortisol or catecholamines, the proposed mechanisms remain theoretically supported. PMR is believed to reduce blood glucose levels through activation of the parasympathetic nervous system and suppression of the Hypothalamic Pituitary Adrenal (HPA) axis, thereby decreasing hepatic glucose production (Dimitriadis et al., 2021; Janssen, 2022; Voronova et al., 2022). In contrast, WWFS may exert its effects through peripheral vasodilation, which enhances glucose uptake by skeletal muscles (Hulett et al., 2022; Russell et al., 2021), as well as through thermal-induced relaxation that promotes parasympathetic activation and endorphin release (Kuderer et al., 2022). These complementary mechanisms provide a plausible explanation for the comparable effectiveness of both interventions, as they ultimately target the stress-related pathways contributing to hyperglycaemia in hospitalized patients.

Several factors should be considered when interpreting these findings. All participants continued their prescribed antidiabetic treatments during the study, and the significant reduction observed in the control group reflects the combined effects of pharmacological therapy, standardized dietary intake, and regression to the mean from elevated baseline glucose levels. Therefore, the observed benefits of PMR and WWFS should be interpreted as additive rather than independent effects. Additionally, although factors such as diet, hydration, and physical activity were standardized during hospitalization, they were not quantitatively measured, which may have introduced residual confounding. While outcome assessors were blinded, participants were not, which may have contributed to expectation-related effects.

From a clinical perspective, both PMR and WWFS are safe, cost-effective, and feasible interventions that can be implemented by trained nursing staff without the need for specialized equipment. Their integration into routine nursing care may enhance glycaemic control as complementary strategies alongside pharmacological treatment. This approach aligns with evidence suggesting that nurse-led interventions can improve diabetes management outcomes (Bilgehan & İnkaya, 2025; Xu et al., 2025; Xu & Chen, 2025). For healthcare settings such as RSPKT Bontang, where structured non-pharmacological protocols are not yet established, these findings support the potential for pilot implementation with careful monitoring and evaluation prior to wider adoption.

Despite its contributions, this study has several limitations. The sample size, although sufficient for statistical analysis, was relatively small and limited to a single center, which may affect generalizability. The short duration of the intervention allows only the assessment of acute glycaemic changes and does not provide insight into long-term outcomes such as HbA1c. Furthermore, the absence of direct biomarker measurements limits the ability to confirm the underlying physiological mechanisms. The inability to blind participants and intervention providers may also introduce bias, and the lack of detailed measurement of potential confounders such as dietary intake and physical activity restricts the ability to fully adjust for these variables. Future studies are recommended to involve larger, multicenter samples, longer follow-up periods, and the inclusion of objective biomarkers such as cortisol, HbA1c, and heart rate variability to better elucidate the mechanisms and sustainability of these interventions.

4. CONCLUSION

This study aimed to compare the effects of Progressive Muscle Relaxation (PMR) and Warm Water Foot Soak (WWFS) therapy on random blood glucose levels among hospitalized patients with type 2 diabetes mellitus. The findings indicate that both PMR and WWFS are effective complementary nursing interventions that are associated with greater reductions in blood glucose levels compared to standard pharmacological care alone. No meaningful difference was observed between the two interventions, suggesting that both approaches offer comparable benefits in improving glycaemic control.

These results highlight the important role of stress-reduction and relaxation-based interventions in supporting diabetes management in inpatient settings. The findings also reinforce the value of integrating non-pharmacological strategies into routine nursing care to enhance treatment outcomes. Therefore, PMR and WWFS may be considered practical, safe, and cost-effective complementary interventions to support glycaemic control among hospitalized patients with T2DM, while further studies are needed to assess their long-term effectiveness and underlying mechanisms.

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