

ORIGINAL ARTICLE

Diabetic Foot Exercises Using Marbles on Blood Sugar Levels: A Quasi-Experimental Study

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ABSTRACT

OBJECTIVE: To investigate the impact of diabetic foot exercises with marbles on blood sugar in type 2 diabetes (DM) individuals.

METHODOLOGY: A quasi-experimental pretest-posttest control group design was utilized in the Diabetes Centre of Manado City. This research was conducted for seven months from August 2025 to February 2026. A total of 178 participants were randomly assigned to the intervention group (n=89), who practiced marble-based foot exercises, and the control group (n=89), who performed regular foot exercises for 12 sessions over four weeks. We analyzed the data using paired t-tests and independent t-tests for bivariate comparisons, multiple linear regression (backward elimination) to identify predictors of RBS reduction, and binary logistic regression to estimate the probability of clinically meaningful RBS decline (≥ 30 mg/dL) ($\alpha=0.05$).

RESULTS: Both groups showed significant reductions in blood sugar levels ($p<0.001$). Compared with the control group, the intervention group showed larger reductions in RBS ($\Delta=48.86$ vs 21.22 mg/dL) and FBS ($\Delta=29.78$ vs 12.62 mg/dL), with large effects (Cohen's $d=1.14$ and 1.04 , respectively). The marble intervention was the strongest predictor ($\beta=0.469$; $OR=5.376$, $p<0.001$), followed by baseline RBS, BMI, and DM duration. The marble intervention was the strongest predictor ($\beta = 0.469$; $OR = 5.376$, $p < 0.001$).

CONCLUSION: Diabetic foot exercises using marbles significantly reduced RBS and FBS levels more than regular foot exercises ($p < 0.001$; Cohen's $d > 0.8$). Intervention type, baseline RBS, BMI, and DM duration were significant predictors, yet the model explained only 43.3% of the variance, indicating the need for further investigation.

KEYWORDS: Diabetic Foot Exercises, Marbles, Blood Sugar Levels, Type 2 Diabetes Mellitus, Non-Pharmacological Intervention

INTRODUCTION

Diabetes Mellitus (DM) is a chronic metabolic disease and a rising global health threat. As a long-term metabolic condition, it can cause progressive damage¹. Type 2 DM is the most prevalent type of DM, accounting for 90%–95% of all diabetes cases globally², and is characterized by insulin resistance and defective insulin secretion, leading to high blood glucose level³. Diabetes complications, such as insulin resistance, atherosclerosis, chronic inflammation, oxidative stress, and damage to mitochondria, are mediated by its molecular-pathological mechanisms⁴.

Diabetes mellitus in Indonesia is a very serious national health issue⁵. Adherence to insulin therapy was only 33.3%⁶. This low goal achievement reflects the extent of the requirements for adjunctive therapy in addition to pharmacologic therapy. Interventions such as physical activity are among the factors governing glycemic control as mentioned above. Prior research has shown that exercise is particularly linked to improvements in glycemic control⁷. Regular exercise significantly lowers insulin resistance, plasma insulin, fasting blood sugar, postprandial blood sugar, and HbA1c⁸.

A pyramid aerobic exercise program for 8 weeks significantly reduced fasting blood sugar, 2-hour postprandial glucose, insulin resistance, and HbA1c, and low-volume high-intensity interval training also reduced glucose, HbA1c, insulin, and insulin resistance⁹. While physical exercise is effective, major research gaps remain. Poor adherence to exercise programs remains a major barrier (10.7% of patients adhere to regular exercise), and irregular exercise is associated with poor glycemic control (HbA1c >10%)¹⁰.

The marble intervention incorporates reflexology principles. Evidence demonstrates that stimulating reflex points on the plantar surface of the feet effectively lowers blood sugar levels by restimulating points that affect blood glucose and stimulating blood circulation¹¹. Foot reflexology has been shown to improve glycemic control, reduce HbA1c levels, and reduce the severity of diabetic foot complications¹².

The objective of this study is to evaluate the effect of diabetic foot activities with marbles on blood sugar in patients with diabetes mellitus. This study is novel in its use of marbles, which may stimulate reflex points on the soles of the feet while also enhancing peripheral circulation and proprioceptive input, thereby improving leg muscle coordination and strength. Additionally, this intervention offers an affordable, non-pharmacological option that patients can easily perform independently at home.

METHODOLOGY

Research Design

This study used a quasi-experimental pretest-posttest control group design to evaluate the effect of diabetic foot exercises using marbles on blood sugar levels in patients with type 2 diabetes mellitus. The study was conducted at the Manado City Diabetes Centre, which has 322 registered diabetes mellitus patients and adequate facilities for the intervention program, in North Sulawesi Province, Indonesia. This research was conducted for seven months from August 2025 to February 2026.

Population, Sample, and Sampling Techniques

The study population comprised of 322 diabetes mellitus patients registered at the Manado City Diabetes Centre, and the target population was of type 2 diabetes mellitus patients. The sample size followed the Slovin formula with a 5% margin of error, corresponding to at least 178 respondents, who were randomly selected and assigned to the intervention (n=89) or control (n=89) group. The sampling method was simple random sampling using a random number table, followed by allocation to groups by sealing envelopes (lottery method).

Variables

The independent variable was the type of diabetic foot exercise (marbles vs normal exercise without devices). The dependent variable was blood glucose levels measured in mg/dL using the Random Blood Sugar Level Test (RBS) and the Fasting Blood Sugar Level Test (FBS). Confounding variables were age, sex, education level, occupation, diabetes duration, BMI, history of foot complications, oral contraceptive use, and insulin use, controlled by means of baseline homogeneity tests and multivariate analysis.

Instruments

The instruments used were: demographic profile; standardized digital glucometer (accuracy $\pm 15\%$ based on ISO 15197:2013), test strips, sterile lancets, and alcohol swabs; foot exercise appliances (marbles with dimensions of ± 1.5 cm, plastic containers, a chair, and footwear); anthropometric instruments (digital scales and stadiometers) and observation sheets for attendance/compliance.

Data Collection Procedures

The preparation phase included obtaining research permits, coordinating with the Diabetes Centre, and two days of enumerator training. The recruitment phase involved patient identification, research socialization, signing informed consent, and eligibility screening. Pretest measurements included random blood glucose (GDS) and fasting blood glucose (FBS) measurements (after an 8-hour fast) using a glucometer, anthropometric measurements, and demographic questionnaires for the entire sample. The intervention lasted four weeks and included 12 sessions (30 minutes each). The intervention group performed activities including picking up and moving marbles, rolling marbles under the soles of the feet, squeezing marbles, and ankle rotations using marbles with the toes, preceded by a warm-up and concluded with a cool-down. The control group performed regular foot exercises (toe flexion-extension, dorsiflexion-plantarflexion, ankle rotation, and knee exercises) with the same duration and frequency. We conducted posttest measurements 30 minutes after each session for GDS and anthropometric measurements. For GDP measurements, we conducted the posttest the following morning after patients fasted for 8 hours to ensure consistency of the measurement protocol with the pretest protocol and minimize the influence of the acute glycemic response to physical

activity. We applied this posttest measurement procedure uniformly to both groups after each intervention session.

Data Formulation and Analysis

Using SPSS, data were processed. Univariate analyses used frequency distributions (categorical variables) and means, medians, and standard deviations (numerical variables), with the Shapiro-Wilk test for normality. Bivariate analyses assessed baseline equivalence between groups. Categorical variables were examined using the Chi-Square test, while the Kolmogorov-Smirnov test was employed to evaluate the normality of continuous variable distributions. For between-group comparisons, we used independent-samples t-tests, whereas we assessed within-group pre-post differences using paired-samples t-tests. Effect sizes for all mean comparisons were quantified using Cohen's d to determine the practical significance of observed differences. The significance level was determined as $\alpha = 0.05$. For multivariate analysis, we used multiple linear regression (backward elimination) to identify factors affecting RBS decline and binary logistic regression to estimate the probability of RBS decline ≥ 30 mg/dL. We selected candidate variables through bivariate selection ($p < 0.25$). We assessed model fit using the linear regression assumptions test and the Hosmer-Lemeshow test for logistic regression.

Ethical Consideration

Ethical approval for this study was obtained from KEPK Poltekkes Kemenkes Manado (Protocol Number: IRB-2025-0338) on August 9, 2025, and the study was conducted in accordance with the Declaration of Helsinki.

RESULTS

According to **Table I**, the most respondents were female 60.1%, aged 50-59 years 41.0% with a mean age of 56.15 ± 8.46 years. Educated until senior high school (41.6%). and unemployed/housewife (34.3%). The mean DM duration was 6.65 ± 4.04 years, with a mean BMI of 26.26 ± 3.80 kg/m². All respondents are Type 2 DM patients. Tests of homogeneity revealed no significant differences in demographic characteristics between the intervention and control groups (all p-values > 0.05). This indicates that both groups were comparable at baseline.

Table I: Respondent Characteristics

Characteristic	Category	Intervention Group (Marble)		Control Group (Regular)		Total		p-value
		n	%	N	%	n	%	
Gender	Male	34	38.2	37	41.6	71	39.9	0.652 ^a
	Female	55	61.8	52	58.4	107	60.1	
Age (years)	40-49	18	20.2	16	18.0	34	19.1	0.874 ^b
	50-59	35	39.3	38	42.7	73	41.0	
	60-69	28	31.5	27	30.3	55	30.9	
	≥70	8	9.0	8	9.0	16	9.0	
	Mean ± SD	56.42±8.31		55.87±8.56		56.15±8.46		0.661 ^c
	Elementary School	12	13.5	10	11.2	22	12.4	0.791 ^b
Education	Junior High School	19	21.3	22	24.7	41	23.0	
	Senior High School	38	42.7	36	40.4	74	41.6	
	Higher Education	20	22.5	21	23.6	41	23.0	
	Unemployed/Housewife	32	36.0	29	32.6	61	34.3	0.718 ^b
Occupation	Civil Servant/Retired	18	20.2	21	23.6	39	21.9	
	Entrepreneur	24	27.0	22	24.7	46	25.8	
	Farmer/Laborer	9	10.1	12	13.5	21	11.8	
	Others	6	6.7	5	5.6	11	6.2	
Duration of DM (years)	1-5	38	42.7	40	44.9	78	43.8	0.823 ^b
	6-10	33	37.1	31	34.8	64	36.0	
	>10	18	20.2	18	20.2	36	20.2	
	Mean ± SD	6.78 ± 3.94		6.52 ± 4.12		6.65±4.04		0.672 ^c
Body Mass Index (BMI)	Normal (18.5-24.9)	29	32.6	31	34.8	60	33.7	0.905 ^b
	Overweight (25.0-29.9)	41	46.1	39	43.8	80	44.9	
	Obese (≥30.0)	19	21.3	19	21.3	38	21.3	
	Mean ± SD	26.34±3.72		26.18±3.85		26.26±3.80		0.774 ^c
Types of Diabetes Mellitus	Type 2 DM	89	100.0	89	100.0	178	100.0	-
	Present	26	29.2	24	27.0	50	28.1	0.738 ^a
History of Foot Complications	Absent	63	70.8	65	73.0	128	71.9	
Use of OHD (Oral Hypoglycemic Drugs)	Yes	78	87.6	80	89.9	158	88.8	0.641 ^a
	No	11	12.4	9	10.1	20	11.2	
Use of Insulin	Yes	22	24.7	19	21.3	41	23.0	0.598 ^a
	No	67	75.3	70	78.7	137	77.0	

Note: ^aChi-Square test, ^bKolmogorov-Smirnov test, ^cIndependent t-test, p-value > 0.05 indicates no significant difference between the two groups at baseline (homogeneous).

Table II shows that, in both cohorts, the decrease in Random Blood Sugar (RBS) and Fasting blood sugar (FBS) levels was statistically significant ($p < 0.05$). In the intervention group (foot exercises with marbles), the decrease in both RBS ($\Delta = 48.86$ vs 21.22 mg/dL) and fasting blood sugar (FBS) ($\Delta = 29.78$ vs 12.62 mg/dL) was larger than in the control group. The difference was statistically significant ($p < 0.001$) with a large effect size (Cohen's $d > 0.8$). This indicates that diabetic foot exercises with marbles were more effective in lowering blood sugar levels.

Table II: Bivariate Analysis of the Effect of Diabetic Foot Exercises Using Marbles on Blood Sugar Levels

Variables	Group (n = 89 per group)	Pre-test Mean $\pm$ SD (mg/dL)	Post-test Mean $\pm$ SD (mg/dL)	Δ Within-Group Mean $\pm$ SD (mg/dL)	t (df = 88)	p-value (within)	Δ Between-Group (mg/dL)	95% CI (between)	t (df = 176)	p-value (between)	Cohen's d
RBS	Intervention (Marbles)	267.48 $\pm$ 62.35	218.62 $\pm$ 51.47	48.86 $\pm$ 28.14	16.378	0.000*	27.64	20.46 – 34.82	7.595	0.000	1.14
	Control (Regular)	264.73 $\pm$ 60.82	243.51 $\pm$ 57.29	21.22 $\pm$ 19.67	10.178	0.000*					
FBS	Intervention (Marbles)	178.34 $\pm$ 42.18	148.56 $\pm$ 35.62	29.78 $\pm$ 18.43	15.247	0.000*	17.16	12.28 – 22.04	6.945	0.000	1.04
	Control (Regular)	176.89 $\pm$ 41.53	164.27 $\pm$ 39.84	12.62 $\pm$ 14.28	8.335	0.000*					
Post-test Comparison							Mean Diff (mg/dL)	95% CI	t (df = 176)	p-value	
RBS	Post-test	Intervention vs Control	-	218.62 vs 243.51	-	-	24.89	8.72 – 41.06	3.049	0.003	-
FBS	Post-test	Intervention vs Control	-	148.56 vs 164.27	-	-	15.71	4.58 – 26.84	2.774	0.006	-

* $p < 0.05$ (significant), Cohen's $d > 0.8$ = large effect, RBS = Random Blood Sugar, FBS = Fasting Blood Sugar, Δ = mean difference, Within-group analyzed with paired t-test, Between-group analyzed with independent t-test.

Table III presents the multivariate analysis results using linear regression and logistic regression to identify factors influencing the reduction of GDS levels in DM patients at the Manado City Diabetes Centre. Of the ten variables analyzed, four passed bivariate selection ($p < 0.25$) and were significant in the final backwards-elimination model ($p < 0.05$): type of intervention, pre-test GDS, BMI, and duration of DM. The type of marble intervention was the strongest predictor ($\beta = 0.469$; OR = 5.376), followed by pre-test baseline GDS ($\beta = 0.344$; OR = 1.012) and BMI ($\beta = 0.140$; OR = 1.091). The variable duration of DM showed a negative coefficient ($\beta = -0.756$; OR = 0.925; $p = 0.031$), which means the longer the duration of DM, the smaller the reduction in GDS levels achieved. This is consistent with evidence that longer duration of diabetes is associated with progressive decline in pancreatic beta cell function and increased insulin resistance, thus limiting therapeutic response (American Diabetes Association, 2024; UK Prospective Diabetes Study Group, 1998). The linear regression model explained 43.3% of the variance (Adj. $R^2 = 0.420$; $F = 33.035$; $p = 0.000$) without multicollinearity (VIF < 10) and autocorrelation (Durbin-Watson = 1.892), while the logistic regression model showed good

consistency (Hosmer-Lemeshow $\chi^2 = 6.842$; $p = 0.554$; Nagelkerke $R^2 = 0.392$) with a classification accuracy of 74.7%.

Table III: Multivariate Analysis of Factors Influencing the Decrease in RBS Levels in DM Patients at the Manado City Diabetes Centre

Variables	Bivariate Selection (p)	Linear Regression-Final Model (Backwards Elimination)					Logistic Regression (RBS Decrease ≥30 mg/dL)				
		B	β	p	95% CI for B	VIF	OR	p	95% CI for OR		
Intervention Type (Marble = 1; Regular = 0)	0.000	25.742	0.469	0.000*	19.194 - 32.290	1.028	5.376	0.000	2.718 - 10.632		
RBS Pre-test (Baseline)	0.001	0.172	0.344	0.000*	0.113 - 0.231	1.052	1.012	0.000	1.006 - 1.018		
Body Mass Index (BMI)	0.078	0.934	0.140	0.023*	0.132 - 1.736	1.038	1.091	0.038	1.005 - 1.184		
Long-term Suffering	0.098	-0.756	- 0.133	0.031*	-1.443 - 0.069	1.056	0.925	0.040	0.858-0.997		
Age	0.187	-	-	Not significant (eliminated)	-	-	-	-	-		
Use of OHD	0.214	-	-	Not significant (eliminated)	-	-	-	-	-		
Insulin Use	0.168	-	-	Not significant (eliminated)	-	-	-	-	-		
History of Foot Complications	0.231	-	-	Not significant (eliminated)	-	-	-	-	-		
Gender	0.342	-	-	Not a candidate	-	-	-	-	-		
Education	0.412	-	-	Not a candidate	-	-	-	-	-		

Model Summary:

Parameter	Linear Regression (Final Model)	Logistic Regression
R / -2 Log Likelihood	R = 0.658	178.436
R ² / Cox & Snell R ²	0.433 / Adj. R ² = 0.420	0.284
Nagelkerke R ²	-	0.392
F/Chi-Square (Hosmer-Lemeshow)	F = 33.035; p = 0.000	$\chi^2 = 6.842$; p = 0.554
Durbin-Watson	1.892	-
Classification Accuracy	-	74.7%

Information: $p < 0.25$ (fulfills the multivariate candidate requirements), $*p < 0.05$ (statistically significant), B = unstandardized regression coefficient, β = standardized regression coefficient, OR = Odds Ratio, CI = Confidence Interval, VIF = Variance Inflation Factor, OHD = Oral Hypoglycemic Drugs, BMI = Body Mass Index, RBS = Random Blood Sugar, DM = Diabetes Mellitus. Variables No. 5-8 passed the bivariate selection but were eliminated in the backward elimination stage because they were not significant ($p > 0.05$). Variables No. 9-10 did not meet the bivariate selection criteria ($p \geq 0.25$). All VIFs were < 10 (no multicollinearity). Hosmer-Lemeshow $p > 0.05$ indicates a good fit of the logistic model.

DISCUSSION

Table I shows that most of the respondents were female (60.1%), aged 50-59 (41.0%), with a mean age of 56.15 ± 8.46 years, had high school education (41.6%), and were unemployed/housewives (34.3%). These demographic characteristics align with the epidemiological profile of type 2 DM patients in Indonesia, with higher prevalence in women and middle-aged to elderly groups¹³. The mean body mass index (BMI) of participants was 26.26 ± 3.80 kg/m² (the majority of the participants were overweight [44.9%]), which is an important risk factor in the pathogenesis of insulin resistance leading to type 2 diabetes. Homogeneity tests showed no significant differences in any demographic variable between the intervention and control groups (all p-values > 0.05), enabling comparison between the groups at baseline.

The literature has well explained the physiological mechanisms of diabetic foot exercises, which supports these results. In actively moving muscles, there is an increase in contraction so that the permeability of cell membranes to glucose increases, insulin resistance decreases, and insulin sensitivity increases¹⁴. This is the mechanism by which diabetic foot exercise, particularly when marbles are added as a medium that increases the intensity of contraction of small leg muscles, results in a larger drop in blood sugar. Foot exercises can increase Nitric Oxide Synthesis, arterial vasodilation, and blood sugar burning, which result in lower blood sugar levels¹⁵. Post-test comparison between the two groups (**Table II**) revealed significant differences in RBS (218.62 vs 243.51 mg/dL, $p = 0.003$) and FBS (148.56 vs 164.27 mg/dL, $p = 0.006$). Both groups' blood sugar levels remained higher than normal, but the marble group had a greater decrease, suggesting potential clinical relevance.

Multivariate analysis (**Table III**) identified four factors that significantly influenced the reduction in RBS levels: type of intervention ($\beta = 0.469$; $p = 0.000$), baseline RBS level ($\beta = 0.344$; $p = 0.000$), BMI ($\beta = 0.140$; $p = 0.023$), and duration of diabetes ($\beta = -0.133$; $p = 0.031$). Intervention type was the strongest predictor, with the highest standardized coefficient, indicating that marble-based leg exercises contributed most to RBS reduction. The linear regression model explained 43.3% of the variance in RBS reduction ($R^2 = 0.433$). In contrast, logistic regression showed that patients who received the marble intervention were 5.376 times more likely to experience an RBS reduction of ≥ 30 mg/dL (OR = 5.376; 95% CI: 2.718-10.632). Several studies have confirmed that baseline blood glucose levels are a strong predictor of glycemic response; for example, Mosikian et al. found that higher baseline HbA1c was significantly associated with a better glycemic response to liraglutide therapy¹⁶. **Tarekegn et al.**¹⁷ also confirmed the influence of BMI on glycemic control, reporting that obesity (AOR = 5.32; 95% CI: 2.02–14.04) and overweight (AOR = 3.77) were significant factors associated with poor glycemic control. Similarly, longer diabetes duration was consistently associated with poorer glycemic control^{18,19}.

To clarify the effect of BMI on RBS reduction ($B = 0.934$; $p = 0.023$), we observed that higher BMI was associated with greater insulin resistance, with a greater proportion expected to respond to physical exercise. In contrast, the duration of DM was negatively associated ($B = -0.756$; $p = 0.031$), suggesting that the progressive deterioration of pancreatic beta cell function in patients with longer duration of DM indicates that the response to physical exercise interventions is more diminished, indicating that the duration of diabetes is a risk factor that plays a role in foot self-care and its complications. Participants with a duration of DM > 10 years have a different risk profile.

The variables of age, OHD use, insulin use and a history of foot complications were deleted in the final model because they were not statistically significant after adjusting for other variables. The effect of the marbles intervention is independent of the above-mentioned factors. Lack of physical activity can lead to poor metabolic control and increase DM complications, so structured foot exercise interventions using appropriate media are very important in DM management^{20–22}.

The findings of this study have significant clinical relevance for nursing practice in managing type 2 diabetes. Diabetic foot exercises have been suggested as an efficient, easy-to-perform, and economical independent nursing intervention²³. DM patients can do foot exercises independently to improve blood circulation and help control blood sugar^{18,24,25}. When introducing this therapy, it is necessary of understand supporting factors of the successful adoption of diabetic foot exercises in diabetes patients, such as motivation, compliance, and the use of proper media²⁶.

Conceptually, the findings of reduced RBS/FBS in the leg exercise group, particularly when leg muscle contractions were enhanced through adjunctive media, align with the literature that positions physical activity as a key component of glycemic management and complication prevention in type 2 diabetes^{27–29}. Synthesized evidence suggests that exercise programs (including foot/ankle exercises) improve HbA1c/fasting glucose, although glycemic effects vary across studies and measurement tools^{30,31}. These results reinforce the biological rationale that structured lower extremity exercise can provide both metabolic and functional benefits³².

Based on the findings of this study, several recommendations can be made. First, healthcare facilities should integrate diabetic foot exercises using marbles into standard type 2 diabetes management protocols, given their statistically and clinically significant effectiveness (Cohen's $d > 0.8$). Second, nurses and diabetes educators need training in this technique so they can teach it to patients as a low-cost, self-help intervention that can be easily performed at home. Finally, the integration of diabetic foot exercises using marbles into chronic disease management programs at the community health centre level is highly recommended as an effective and low-cost community-based diabetes control effort.

Limitation

This study was conducted at a single site (Manado City Diabetes Centre), which may limit the generalizability of the findings to other populations or clinical settings with different demographic and socioeconomic profiles.

CONCLUSION

This study provides evidence that diabetic foot exercises using marbles effectively lower blood sugar levels in patients with type 2 diabetes mellitus at the Manado City Diabetes Centre. In the marble intervention group, fasting and random blood sugar levels decreased significantly with a large clinical effect, while the control group showed only a smaller decrease. The mechanisms underlying this effectiveness include increased muscle contractions, which increase cell membrane permeability to glucose, improve insulin sensitivity, and trigger arterial vasodilation, thereby optimizing peripheral glucose metabolism. Multivariate analysis showed that the type of intervention was the strongest predictor of blood sugar reduction, followed by baseline blood sugar level, body mass index, and duration of diabetes. The regression model explained most of the variance in random blood sugar reduction and provided of strong classification boundary. Based on these findings, we recommend that healthcare workers at Community Health Centres and diabetes care centres integrate diabetic foot exercises using marbles as a stand-alone intervention in glycemic education and management programs, given its clinically significant effectiveness, ease of implementation, cost, and ability to be practised independently by patients at home.

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AUTHOR CONTRIBUTION

All authors contributed equally.

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