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Glycemic Control and Sleep Hygiene: Investigating their Association Among Type 2 Diabetes Patients in Primary Care

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ABSTRACT

Background: Diabetes, a metabolic disorder, mainly involves chronic hyperglycemia. Sleep is a reversible state of inactivity associated with a reduced response to the external environment. Good sleep hygiene, an environment, and daily routines that promote consistent, uninterrupted sleep. There is evidence that links sleep to metabolic responses. Methods: Quantitative case-control study, longitudinal, retrospective, observational. 126 questionnaires, including the Sleep Hygiene Index and the recollection of data survey for this study, were applied to adult diabetic patients who came for consultation at the CADIMSS program in the Family Medicine Unit No. 47 in San Luis Potosí, from August to December 2023. Results: Inadequate glycemic control in type 2 diabetic patients was associated with poor sleep hygiene, with a treatment-adjusted odds ratio of 44.64. Half of the patients do not comply with the exercise regime, and two out of three do not follow the dietary regime. The most frequently used treatments in cases are insulin and SGLT-2 inhibitors. On the other hand, controls were treated with metformin. The number of hours slept was not different in both groups. Conclusions: Inadequate glycemic control in type 2 diabetic patients treated at CADIMSS was associated with poor sleep hygiene.

Keywords: Type 2 diabetes, sleep hygiene, glycemic control, sleep quality.

INTRODUCTION

Diabetes mellitus is a disease categorized based on its underlying causes and clinical presentation. According to the American Diabetes Association, Type 1 diabetes is characterized by the autoimmune destruction of pancreatic beta cells, resulting in a complete absence of insulin production. Conversely, Type 2 diabetes (T2DM) is marked by a gradual decline in insulin secretion, frequently associated with a history of insulin resistance or metabolic syndrome. Accurate classification of diabetes is essential, as the specific type determines the most effective treatment strategy and management approach. [1,2]

T2DM is a chronic metabolic and multifactorial disease, characterized by its progressive nature and influenced by various factors, including physical activity, nutrition, and obesity. Risk factors for T2DM include non-modifiable elements, such as sex, age, ethnicity, and family history, as well as modifiable factors. The risk of developing T2DM increases with age, but lifestyle changes can help mitigate other modifiable risk factors. These include diet, physical inactivity, obesity, tobacco use, and conditions like depression, obstructive sleep apnea, fatty liver, and an unhealthy environment. Managing these modifiable factors through lifestyle adjustments and medical interventions can significantly impact T2DM prevention and management. [3,4]

T2DM treatment and management are complex and require a multifaceted approach that prioritizes effective control of associated risk factors. Tobacco use is a critical factor to address, as it significantly heightens the risk of death from microvascular complications in diabetic patients. A comprehensive treatment plan for T2DM should include essential non-pharmacological strategies such as patient education, regular glucose monitoring, nutritional counseling, and encouragement of physical activity. These non-pharmacological measures should be complemented with pharmacological interventions. Metformin, for instance, is a key medication that can improve diabetes control and should be considered even when HbA1c levels are not markedly elevated. This combined approach is essential for the optimal management of T2DM. [2,4]

According to the 2022 National Health and Nutrition Survey, the prevalence of T2DM in Mexico was 18.3% (95% CI: 15.9%–21.1%). In 2023, this prevalence remained relatively stable at 18.1% (95% CI: 15.4%–21.9%). The prevalence rates varied by age group: 12.8% among individuals aged 20-39, 27.1% among those aged 40-59, and 32.8% among those aged 60 and older. [5,6]

The Mexican Social Security Institute (IMSS) is the largest healthcare provider in Mexico, serving approximately 65 million people in a country with a population of 138 million. It primarily provides medical and social services to individuals employed in the formal sector and their families [6]. In 2021, it was estimated that 12.4% of IMSS adult beneficiaries—equivalent to 4,747,174 patients—had T2DM, making it the second leading cause of medical visits within the family medicine service. However, the National Institute of Public Health of Mexico reports that 21.8% of the IMSS-affiliated population has T2DM. [5,7,8]

Due to the significant impact and consequences of T2DM in Mexico, IMSS has implemented an integrated model of medical care aimed at enhancing self-care among patients with T2DM. This program, initially launched in 2008 as DiabetIMSS and now known as CADIMSS, includes monthly group educational sessions and individual medical consultations, both held on the same day over a six-month period. The medical team for these appointments includes a family physician, a general nurse, a nutritionist dietitian, and a social worker. According to the latest data from IMSS, Mexico has 134 CADIMSS centers. The program aims to establish a strategy that provides comprehensive medical and healthcare attention, aimed at preventing acute and chronic complications to minimize damage. Additionally, the program promotes patient and family accountability in participating in their treatment. [8]

Among all the risk factors associated with glycemic control in patients with T2DM, achieving good sleep is crucial. The association between sleep and metabolic control has been previously studied. In patients with T2DM, a sleep duration of less than five hours and/or poor sleep quality have been associated with adverse metabolic responses, including increased HbA1c levels. Specifically, a sleep duration of less than 5 hours is associated with approximately 1.3 times higher odds of elevated fasting glucose levels and a greater likelihood of using hypoglycemic medications compared to those who sleep between 5 and 8 hours. [9–12]

Good sleep hygiene involves establishing an optimal bedroom environment and adhering to daily routines that support consistent and uninterrupted sleep. Essential practices for good sleep hygiene include maintaining a regular sleep schedule, ensuring the bedroom is comfortable and free from distractions, following a relaxing bedtime routine, and fostering healthy daytime habits. These practices can be personalized to suit individual needs. [13] Therefore, the main objective of this study was to assess the relationship between glycemic control and sleep hygiene quality in CADIMSS patients.

MATERIAL AND METHODS

This was an observational, analytic, retrospective study employing a case-control design conducted in the city of San Luis Potosí, San Luis Potosí, Mexico. According to the 2020 census, the population of the San Luis Potosí metropolitan area was 1,243,980 inhabitants. In 2018, it was estimated that Family Medicine Unit No. 47 of the IMSS provided care to a user population of 268,683 beneficiaries, with an average annual population growth rate of 3.9%. The study was approved by the IMSS Ethics and Research Committee (R-2023-2402-033).

Between August and December 2023, we enrolled 126 T2DM patients affiliated with IMSS who participated in the CADIMSS program. Sample size calculation was conducted using OpenEpi Software with a 95% confidence level and 80% power, considering a 45% risk in controls and 71% risk in cases [14]. The case-control ratio was 1:1 (63 cases and 63 controls). Cases were defined as patients with T2DM meeting specific ADA criteria (American Diabetes Association), including HbA1c levels ≥7%. Controls were selected from patients with T2DM whose HbA1c levels were <7%. All participants were recruited from the IMSS Family Medicine Unit No. 47 in San Luis Potosi, San Luis Potosí, Mexico.

The subjects were required to provide sociodemographic information such as gender, age, marital status, height, and weight. Additionally, they answered questions related to their disease, including details about medication or insulin use, illness duration, and their exercise and dietary habits. Regarding sleep hygiene, participants reported their usual bedtime, wake-up time, and average hours of sleep per night. The Sleep Hygiene Index questionnaire, consisting of 10 items assessing sleep-related behaviors, was used to evaluate the quality of sleep hygiene, with a score <18 indicating good sleep hygiene.

Continuous variables were assessed for normality using the Shapiro-Wilk test and described using appropriate measures of central tendency and dispersion based on their distribution. Absolute numbers and relative frequencies were calculated for categorical variables. To compare continuous variables between cases and controls, measures of central tendency were analyzed using Student's t-test or the Mann-Whitney U test, as appropriate. Statistical analyses were performed using SPSS 26.0, and a p-value <0.05 (two-tailed) was considered statistically significant. For categorical variables, differences were analyzed using 2x2 tables (bivariate analysis). The Chi-square test corrected with the Mantel-Haenszel or Fisher's exact test was used, as appropriate. Multivariate logistic regression analysis was conducted to estimate the

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odds ratio (OR) associated with factors that showed statistically significant associations in the bivariate analysis.

RESULTS

From the 126 participants, sociodemographic information is detailed in Table 1. No significant differences were observed in sociodemographic variables between cases and controls, indicating that both groups were comparable. The mean age of the participants was 55 years, with the majority being female (65.1%). Despite a mean BMI of 29.5, a substantial portion of participants fell into the category of obesity (47.6%).

Table 1: Sociodemographic characteristics of patients without and with glycemic control.

Variable		All	Cases	Controls	*p*
n (%)		126	63 (50%)	63 (50%)	----
Age, median (25th-75th percentile)		55 (45.5-62.0)	53 (44.0-63.0)	56 (47.0-62.0)	0.552
Sex	Male	44 (34.9%)	22 (34.9%)	22 (34.9%)	>0.999
	Female	82 (65.1%)	41 (65.1%)	41 (65.1%)	
Civil status	Divorced	10 (7.9%)	5 (7.9%)	5 (7.9%)	0.786
	Widowed	11 (8.7%)	4 (6.3%)	7 (11.1%)	
	Married	68 (54.0%)	34 (54.0%)	34 (54.0%)	
	Single	37 (29.4%)	20 (31.7%)	17 (27.0%)	
Weight (kg), median (25th-75th percentile)		73 (65.0-83.3)	71 (62.0-82.0)	74 (65.0-85.0)	0.373
Height (m), median (25th-75th percentile)		1.56 (1.5-1.7)	1.56 (1.5-1.7)	1.57 (1.5-1.7)	0.548
BMI (kg/m^2), median (25th-75th percentile)		29.5 (25.6-32.4)	29.3 (25.7-32.4)	30.1 (25.4-32.7)	0.545
BMI classification	Normal	24 (19.0%)	12 (19.0%)	12 (19.0%)	0.723
	Overweight	42 (33.3%)	23 (36.5%)	19 (30.2%)	
	Obesity	60 (47.6%)	28 (44.4%)	32 (50.8%)	
For categorical variables, the Chi-square test with Mantel-Haenszel correction was used; for continuous variables, the Mann-Whitney U test was used. Cases were patients with T2DM with an HbA1c ≥7%, controls were T2DM with an HbA1c <7%					

All participants were enrolled in a primary healthcare center within the CADIMSS program, receiving medical treatment, nutritional plans, and exercise counseling. The mean duration of T2DM from onset to the study was 8 years, and this duration was similar in both groups, indicating it is not a factor influencing glycemic control in this study (Table 2).

As expected, there was a statistically significant difference in HbA1c levels between the groups, with an average difference of more than four percentage points. The median HbA1c was 10.8% in cases compared to 6.5% in controls. Regarding medications for managing T2DM, patients with poor metabolic control more frequently used SGLT-2 inhibitors and insulin, showing significant differences. Conversely, patients with good glycemic control more commonly used metformin. Despite all patients being enrolled in the CADIMSS program, 50% of participants did not adhere to their exercise program, and 64.3% did not follow the nutritional recommendations (Table 2).

The Sleep Hygiene Index questionnaire, consisting of 10 items that assess the presence and frequency of sleep-related behaviors, was administered to the participants. According to the questionnaire's validation, a score greater than 18 indicates poor sleep hygiene. When analyzing the average sleep duration between both groups, no significant differences were observed, with most patients sleeping an average of eight hours per night (Table 2). However, there was a significant difference in the quality of sleep between the groups, with mean scores of 19 points for the case group and 12 points for the control group (p<0.00001). Consequently, 68.3% of the case group exhibited poor sleep hygiene compared to only 6.3% of the control group (p<0.00001) (Table 2).

Table 2: Clinical characteristics of patients without and with glycemic control.

Variable		All	Cases	Controls	*p*
n (%)		126	63 (50%)	63 (50%)	----
Time of diagnosis (years), median (25th-75th percentile)		8.0 (3.0-13.0)	9.0 (3.0-14.0)	7.0 (3.0-13.0)	0.322
HbA1c (%), median (25th-75th percentile)		7.5 (6.5-10.8)	10.8 (9.0-12.0)	6.5 (6.1-6.8)	**<0.00001**
T2DM pharmacological treatment, n (%)	None	2 (1.6%)	1 (1.6%)	1 (1.6%)	>0.999
	Metformin	28 (22.2%)	9 (14.3%)	19 (30.2%)	**0.041**
	Pioglitazone	22 (17.5%)	12 (19.0%)	10 (15.9%)	0.640
	SGLT-2 inhibitor	32 (25.4%)	21 (33.3%)	11 (17.5%)	**0.041**
	DPP4 inhibitor	23 (18.3%)	14 (22.2%)	9 (14.3%)	0.251
	Sulfonylurea	15 (11.9%)	4 (6.3%)	11 (17.5%)	0.055
	GLP-1receptos antagonist	4 (3.2%)	2 (3.2%)	2 (3.2%)	>0.999
Insulin, n (%)	Yes	47 (37.3%)	30 (47.6%)	17 (27.0%)	**0.017**
	No	79 (62.7%)	33 (52.1%)	46 (73.0%)	
Exercise, n (%)	Yes	63 (50.0%)	26 (41.3%)	37 (58.7%)	0.301
	No	63 (50.0%)	37 (58.7%)	26 (41.3%)	
Exercise (days per month), median (25th-75th percentile)		20 (20.0-30.0)	20 (10.0-30.0)	20 (10.0-25.0)	0.689
T2DM diet, n (%)	Yes	45 (35.7%)	24 (38.1%)	21 (33.3%)	0.578
	No	81 (64.3%)	39 (61.9%)	42 (66.7%)	
Sleep hours, median (25th-75th percentile)		8.0 (6.0-8.0)	8.0 (6.0-8.0)	8.0 (6.0-8.0)	0.748
Sleep hygiene index (point), median (25th-75th percentile)		14.0 (9.8-20.0)	19.0	12.0 (8.0-15.0)	**<0.00001**

			(11.0-21.0)		
Sleep hygiene index	Good	79 (62.7%)	20 (31.7%)	59 (93.7%)	**<0.00001**
	Poor	47 (37.3%)	43 (68.3%)	4 (6.3%)	
For categorical variables, the Chi-square test with Mantel-Haenszel correction was used; for continuous variables, the Mann-Whitney U test was used. Cases were patients with T2DM with an HbA1c ≥7%, controls were T2DM with an HbA1c <7%.					

There was a higher frequency of alcohol, tobacco, or coffee consumption before sleeping among cases, showing a significant difference (p=0.002). Most cases reported using their bed for activities other than sleeping and having sex (p=0.005). Furthermore, there was a notable difference in the perception of bedroom comfort: 60% of participants in the control group always perceived their bedroom as a comfortable place to sleep, compared to only 30% in the uncontrolled group (p=0.014). Additionally, over half of the patients in the control group had a comfortable bed to sleep in, while only 20% in the cases group reported the same (p=0.034) (Table 3). All other variables did not show significant differences between groups.

Table 3: Determinants of the sleep hygiene index.

Variable	All	Cases	Controls	*p*
n (%)	126	63 (50%)	63 (50%)	----
In the evenings, I go to bed at different times				0.170
Never	19 (15.1%)	7 (11.1%)	12 (19.0%)	
Rarely	19 (15.1%)	6 (9.5%)	13 (20.6%)	
Sometimes	30 (23.8%)	19 (30.2%)	11 (17.5%)	
Frequently	25 (19.8%)	14 (22.2%)	11 (17.5%)	
Always	33 (13.5%)	17 (27.0%)	16 (24.5%)	
An hour before going to sleep, I exercise				0.297
Never	59 (46.8%)	32 (50.8%)	27 (42.9%)	
Rarely	16 (12.7%)	7 (11.1%)	9 (14.2%)	
Sometimes	23 (18.3%)	13 (20.6%)	10 (15.9%)	
Frequently	13 (10.3%)	2 (4.8%)	10 (15.9%)	
Always	15 (11.9%)	7 (12.7%)	15 (11.1%)	
I consume alcohol, tobacco, or coffee four hours before going to bed				**0.002**
Never	70 (55.6%)	26 (41.3%)	44 (69.8%)	

Rarely	15 (11.9%)	6 (9.5%)	9 (14.3%)	
Sometimes	15 (11.9%)	11 (17.5%)	4 (6.3%)	
Frequently	6 (4.8%)	4 (6.3%)	2 (3.2%)	
Always	20 (15.9%)	16 (25.4%)	4 (6.3%)	
I go to sleep feeling stressed, upset, sad, or nervous				0.237
Never	43 (34.1%)	18 (28.6%)	25 (39.7%)	
Rarely	25 (19.8%)	11 (17.5%)	14 (22.2%)	
Sometimes	30 (23.8%)	18 (28.6%)	12 (19.0%)	
Frequently	19 (15.1%)	9 (14.3%)	10 (15.9%)	
Always	9 (7.1%)	7 (11.1%)	2 (3.2%)	
I use my bed for activities other than sleeping or having sexual relations				**0.005**
Never	40 (31.7%)	13 (20.6%)	27 (42.9%)	
Rarely	12 (9.5%)	3 (4.8%)	9 (14.3%)	
Sometimes	30 (23.8%)	10 (31.7%)	10 (15.9%)	
Frequently	21 (16.7%)	11 (17.5%)	10 (15.9%)	
Always	23 (18.3%)	16 (25.4%)	7 (11.1%)	
My bed is not comfortable to help me sleep				**0.014**
Never	58 (46.0%)	22 (34.9%)	36 (57.1%)	
Rarely	15 (11.9%)	6 (9.5%)	9 (14.3%)	
Sometimes	14 (11.1%)	11 (17.5%)	3 (4.8%)	
Frequently	10 (7.9%)	8 (12.7%)	2 (3.2%)	
Always	29 (23.0%)	16 (25.4%)	13 (20.6%)	
My bedroom is not comfortable to help me sleep				**0.034**
Never	66 (52.4%)	25 (39.7%)	41 (65.1%)	
Rarely	14 (11.1%)	8 (12.7%)	6 (9.5%)	
Sometimes	17 (13.5%)	9 (14.3%)	8 (12.7%)	
Frequently	6 (4.8%)	5 (7.9%)	1 (1.6%)	
Always	23 (18.3%)	16 (25.4%)	7 (11.1%)	
I engage in activities that can keep me awake or alert before going to bed				0.706

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Never	60 (47.6%)	29 (46.0%)	31 (49.2%)	
Rarely	19 (15.1%)	9 (14.3%)	10 (15.9%)	
Sometimes	25 (19.8%)	12 (19.0%	13 (20.6%)	
Frequently	14 (11.1%)	7 (11.1%)	7 (11.1%)	
Always	8 (6.3%)	6 (9.5%)	2 (3.2%)	
I eat food two hours before going to sleep				0.486
Never	17 (13.5%)	6 (9.5%)	11 (17.5%)	
Rarely	13 (10.3%)	6 (9.5%)	13 (11.1%)	
Sometimes	30 (23.8%)	17 (27.0%)	13 (20.6%)	
Frequently	22 (17.5%)	10 (15.9%)	12 (19.0%)	
Always	44 (34.9%)	24 (38.1%)	20 (31.7%)	
I use some type of non-pharmacological aid to sleep				0.745
Never	100 (79.4%)	48 (76.2%)	52 (82.5%)	
Rarely	6 (4.8%)	3 (4.8%)	3 (4.8%)	
Sometimes	14 (11.1%)	7 (11.1%)	7 (11.1%)	
Frequently	5 (4.0%)	4 (4.0%)	1 (1.6%)	
Always	1 (0.8%)	1 (1.6%)	0 (0.0%)	
The test used was the Chi-square test.				

The logistic regression analysis showed that poor sleep hygiene and insulin use were associated with an increased likelihood of poor glycemic control in T2DM patients (OR of 44.64, 95%CI: 12.86-155.0, p<0.0001, Table 4). This suggests that participants with poor glycemic control are 44.64 times more likely to exhibit poor sleep hygiene and 4.44 times more likely to use insulin compared to patients with glycemic control.

Table 4: Description of stratified analysis for identified risk factors for poor glycemic control.

Variable	Crude OR	*p*	Adjusted OR*	*p*
Poor sleep hygiene	31.71 (10.11-99.47)	**<0.000**	44.64 (12.86-155.0)	**<0.000**
Insulin use	2.46 (1.17-5.18)	**0.016**	4.44 (1.45-13.51)	**0.008**
SGLT-2 inhibitor use	2.36 (1.03-5.45)	**0.039**	1.63 (0.49-5.38)	0.424
Metformin use	0.37 (0.16-0.94)	**0.030**	0.59 (0.15-2.42)	0.466
*Multiple logistic regression model: β-1.641, p=0.0003, this model explains 69.6% of the cases. OR calculated with 95%CI.				

DISCUSSION

In our study, 33.3% of participants were classified as overweight, while 47.6% had obesity. These percentages represent a slight variance from those reported in the ENSAUT 2022, where

38.3% of the population were overweight and 36.9% had obesity. Our findings suggest that our population exhibits a higher prevalence of obesity compared to the national surveys reported two years ago. [15,16]

According to the IMSS clinical practice guideline, the initial pharmacological treatment for patients with type 2 diabetes is metformin. Although there was no statistical difference in disease duration between cases and controls, a higher frequency of metformin use was observed among controls. In contrast, cases showed a higher prevalence of insulin and SGLT-2 inhibitors. This could be explained by the guideline's recommendation to start these medications if HbA1c levels are 1.5% above target. [17] Therefore, this finding aligns with the fact that cases are patients with HbA1c levels >7%. Also, the greater prevalence of metformin use among the controls is in line with findings from other studies where patients with good glycemic control tend to use this medication more frequently. This suggests that patients who respond well to metformin are more likely to achieve better HbA1c control. [18–20]

Nutritional therapy is considered pivotal for diabetes prevention and management. However, only 50% of our patients were engaged in regular exercise, and 35.7% were following the dietary recommendations provided at CADIMSS. These results diverge from those reported by Perez A., et al., in the city of Tabasco, Mexico, where 96.9% of CADIMSS patients demonstrated high treatment adherence. They also contrast with findings from ENSANUT 2022, where 46.9% of participants adhered to the nutritional plan. [21,22] These initial findings underscore the critical importance of not only enhancing exercise regimens but also integrating them as a fundamental aspect of treatment to improve overall health outcomes and significantly reduce obesity prevalence. By fostering a stronger commitment to physical activity, patients can achieve better weight management, improve metabolic health, and decrease the risk of associated comorbidities.

Patients' glycemic control was strongly associated with sleep quality (adjusted OR of 44.64) rather than sleep duration. This means that patients with poor sleep quality are much more likely to experience poor glycemic control. Our results agree with the proposal that sleep manipulation can have a positive impact on weight loss and glycemic control in T2DM patients. Other authors have proposed sleep hygiene as part of the adjuvant treatment for diabetic patients. [10, 23–25] Therefore, focusing on improving sleep quality should be a priority in managing patients with glycemic concerns, as it can have a profound effect on outcomes.

In our population, the consumption of alcohol, tobacco, or coffee within four hours before sleep was more frequent among cases than in controls. Among patients with adequate glycemic control, 84.1% never or rarely consume these substances before sleep, while this percentage drops to 50.8% among cases. Specifically, 31.7% of cases and 9.5% of controls frequently or always consume these substances before sleep. Other studies have shown that the consumption of alcohol, tobacco, or coffee can diminish both the duration and quality of sleep. Moreover, increased consumption of these substances has been linked to psychological distress. [26–30]
Another factor more frequent in cases than in controls was using the bed for activities other than sleeping or sexual relations. This outcome may be attributed to the use of electronic devices in bed, which is known to interfere with sleep quality. Blue light emitted from screens can suppress melatonin production, delay sleep onset, and potentially cause longer-term sleep disturbances. [31,32]

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Lastly, another noteworthy finding from our study was the perception of the bedroom or bed was not comfortable for sleep. Authors such as Baranwal et al. have reported that optimizing the bedroom environment with factors like darkness and silence enhances sleep quality. Moreover, Fumiharu et al. have noted that a cooler environment is linked to deeper sleep.[33,34] Therefore, it may be appropriate to provide counseling on these characteristics to improve sleep conditions.

While the lack of waist circumference and body fat percentage measurements presents a limitation, our diverse approach still enabled us to capture a well-rounded profile of the participants, contributing valuable insights to the study's findings. Future research could benefit from incorporating these additional measurements for an even more thorough analysis.

Ethical Statment

This project was approved by the Ethical Committee local hospital. This project follows the National and Local regulations for human health research.

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None.

Data Avaibility

None.

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