

# The Relationship between HbA1c Levels and Leg Muscle Strength and Body Flexibility in Diabetes Mellitus Patients

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## ABSTRACT

**Background.** Type 2 diabetes mellitus (T2DM) is a metabolic disorder characterized by hyperglycemia and insulin resistance. These conditions contribute to impaired muscle function, including reduced muscle strength and flexibility, which may adversely affect mobility. However, the relationship between glycemic control, as measured by HbA1c, and physical function remains underexplored, particularly in Indonesia.

**Objective.** To examine the association between HbA1c levels and leg muscle strength and body flexibility among patients with T2DM.

**Methods.** This descriptive-analytic cross-sectional study was conducted among patients with T2DM in primary health care facilities in Penjarangan and Mangga Besar sub-districts. HbA1c levels were measured using the Clover A1c Self Analyzer. Leg muscle strength and body flexibility were assessed using the 30-second Chair Stand Test and Sit-and-Reach Test, respectively. Data were analyzed using the independent (unpaired) t-test to compare outcomes between HbA1c groups.

**Results.** A total of 30 respondents were included. HbA1c levels ranged from 6.6% to 14.0% (mean 9.54%). Leg muscle strength ranged from 6 to 16 repetitions (mean 10.8), while body flexibility ranged from 5 to 22 cm (mean 13.2). Higher HbA1c levels were significantly associated with lower leg muscle strength (mean difference = 2.53; 95% CI: 1.03–4.03;  $p = 0.0018$ ) and reduced body flexibility (mean difference = 2.70; 95% CI: 0.04–5.36;  $p = 0.0466$ ).

**Conclusion.** HbA1c levels were significantly associated with both leg muscle strength and body flexibility among patients with T2DM. These findings underscore the potential impact of glycemic control on physical function.

**Keywords:** diabetes mellitus, HbA1c, blood sugar levels, muscle strength, flexibility

## INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by hyperglycemia and insulin resistance resulting from impaired insulin secretion, insulin action, or both. The World Health Organization (WHO) reported a 3% increase in global diabetes-related mortality between 2000 and 2019, with a 13% rise in lower-middle-income countries.<sup>1,2</sup> According to the International Diabetes Federation (IDF), approximately 537 million adults aged 20–79 years had diabetes in 2021 (10.5% of the global population), a number projected to reach 783 million by 2045 (12.2%).<sup>3</sup> In Indonesia, the 2018 Basic Health Research (Risksdas) showed that the prevalence of physician-diagnosed diabetes reached 2% among adults  $\geq 15$  years,



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up from 1.5% in 2013, with the highest rate observed in Jakarta (3.4%).<sup>4</sup>

Insulin resistance in diabetes contributes to decreased muscle quality and contractility, cartilage degradation, and impaired mobility.<sup>5-11</sup> At the cellular level, chronic hyperglycemia and lipid-dependent oxidative metabolism increase reactive oxygen species (ROS) and nitric oxide (NO), which may promote muscle dysfunction and reduced flexibility.<sup>5</sup>

Previous studies have reported inconsistent findings on muscle strength in individuals with T2DM. Lee et al. found significantly lower muscle strength among people with T2DM in a large Korean population study.<sup>12</sup> Wai Ng et al. identified BMI, plantar flexor strength, and proprioception as key factors influencing flexibility in diabetic adults.<sup>13</sup> Conversely, Rahimi et al. and Bavaresco et al. reported no significant differences in muscle strength between diabetic and non-diabetic individuals.<sup>14,15</sup> These discrepancies highlight the need for further research, particularly using direct physical performance assessments rather than questionnaires. Therefore, this study aimed to examine the relationship between HbA1c levels and leg muscle strength and flexibility among patients with T2DM using a descriptive-analytic cross-sectional design.

## MATERIALS AND METHODS

### Study Design

This study employed a descriptive-analytic cross-sectional design and was conducted in primary health care facilities located in Penjaringan Subdistrict and Mangga Besar Urban Village, Jakarta from November 2023 to January 2024.

### Ethical Considerations

The study protocol was reviewed and approved by the Ethical Research Committee (Komisi Etika Penelitian [KEP]) of the School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia (Approval No. 15/09/KEP-FKIKUAI/2023). Written informed consent was obtained from all participants prior to inclusion.

### Study Population

The target population comprised community-dwelling individuals with diabetes mellitus. The accessible population included individuals with diabetes mellitus and glycated hemoglobin (HbA1c) levels  $\geq 6.5\%$ . Participants were selected based on predefined inclusion and exclusion criteria. Inclusion criteria were: (1) HbA1c  $\geq 6.5\%$ ; (2) age 17 to 59 years; and (3) provision of written informed consent. Exclusion criteria included: age  $\geq 60$  years; class III obesity (body mass index  $>40$  kg/m<sup>2</sup>); reduced muscle strength, flexibility, or mobility; lower limb amputation; severe postural abnormalities; history of cardiopulmonary disease with dyspnea; history of stroke or spinal cord injury; and known balance or motor coordination disorders.

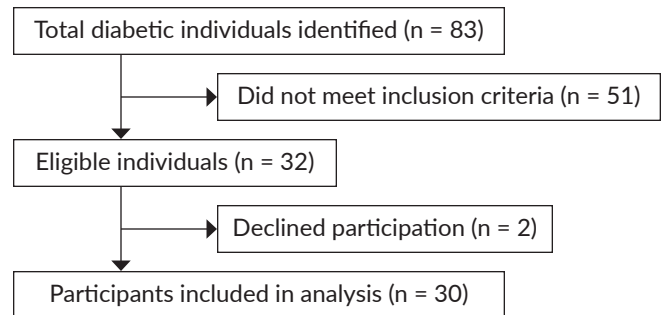


Figure 1. Study flow diagram.

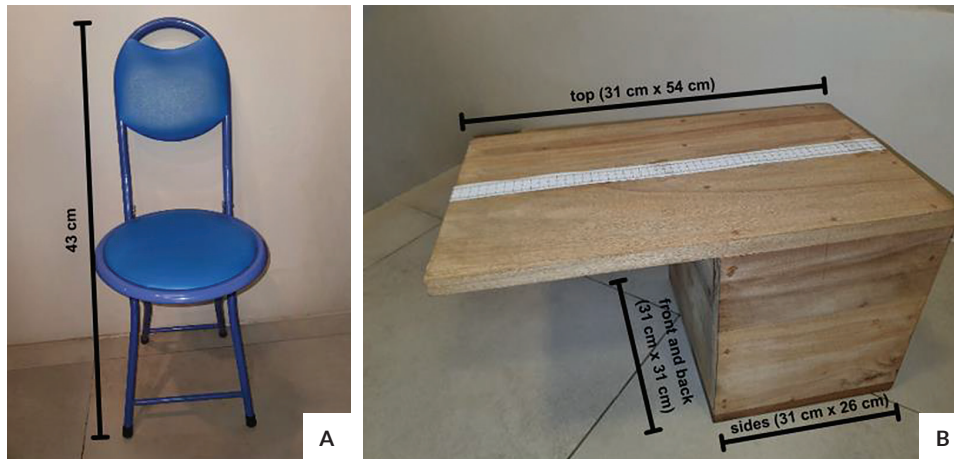
A total of 83 individuals with diabetes mellitus were identified from the selected primary health centers. Among them, 32 met the inclusion and exclusion criteria, while 51 did not meet the criteria. Of those eligible, 30 agreed to participate and completed all study procedures, whereas two declined participation. The participant flow is illustrated in Figure 1. The study population consisted of 32 individuals with diabetes mellitus in the selected primary health centers. The minimum required sample size, calculated using Slovin's formula with a 5% margin of error, was 29.63 participants. A total of 30 individuals met the inclusion criteria and agreed to participate, while 2 declined participation. This sample size was therefore considered adequate for this descriptive-analytic, cross-sectional study.

The main exposure variable was glycated hemoglobin (HbA1c), measured using the Clover A1c Self Analyzer. The primary outcome variables were leg muscle strength and body flexibility, assessed using the Chair Stand Test (30-second version) and the Sit-and-Reach Test, respectively.

### Muscle Strength and Flexibility Evaluation

Leg muscle strength was evaluated based on the number of repetitions completed during the 30-second Chair Stand Test. The test utilized a chair with a height of 43 cm (Figure 2A) and a stopwatch. Participants were instructed to rise from a seated position to a fully upright standing position and return to sitting as many times as possible within 30 seconds, with arms crossed over the chest. Timing commenced at the initiation of movement. Only repetitions completed without the use of hands were counted; repetitions assisted by the hands were excluded. To ensure standardized positioning, participants began the test seated with hips and knees flexed at approximately 90°, and feet flat on the floor. Each participant performed two trials, and the highest number of repetitions was recorded for analysis. All measurements were conducted by a single examiner to minimize inter-observer variability.

Body flexibility was assessed using the Sit-and-Reach Test, with performance measured as the maximum distance reached. The equipment included a measuring tape and a standard Sit-and-Reach box with dimensions of 31 cm × 31 cm (front and back), 31 cm × 26 cm (sides), and 31 cm × 54 cm (top) (Figure 2B). The test was performed on the floor



**Figure 2.** Tools used in the “Chair Stand Test (30-Second Version)” and “Sit and Reach Test”. (A) A chair with a height of 43 cm, (B) Sit and Reach.



**Figure 3.** Participants Performing the “Sit and Reach Test”.

with the box positioned against a wall. Participants sat with legs extended straight and feet placed against the front of the box. They were instructed to reach forward slowly with both hands, keeping the knees extended and hands parallel, and to hold the maximal position for two seconds while breathing normally (Figure 3). Each participant performed two trials, and the best result was used for analysis. Flexibility was recorded as the farthest distance reached.

The Chair Stand Test (30-second version) and Sit-and-Reach Test have been previously validated and shown to be reliable.<sup>16,17</sup> All measuring instruments, including the stopwatch and flexibility box, were calibrated daily prior to data collection to ensure accuracy and consistency.

### Data Analysis

Data were analyzed using STATA version 15.1. The association between HbA1c levels and the outcome variables (leg muscle strength and body flexibility) was assessed using

the independent (unpaired) t-test. Prior to analysis, normality of data distribution was evaluated using the Shapiro–Wilk test. HbA1c was treated as a continuous variable but was dichotomized based on the mean value (9.54%) to enable comparison between lower and higher glycemic control groups. Given that the outcome variables were continuous and normally distributed, the independent t-test was deemed appropriate for comparing mean differences between groups.

Correlation or regression analyses were not performed, as the primary objective was to compare group differences rather than to model predictive relationships. No subgroup or interaction analyses were conducted. Adjustment for confounders and sensitivity analyses were not undertaken due to the single-variable comparative design. All data were complete, with no missing values. To minimize measurement bias, all assessments were conducted at similar times of day, and participants were instructed to avoid vigorous physical activity prior to testing.

## RESULTS

The results of the study obtained a sample of 30 people, consisting of six men (20%) and 24 women (80%). The age of respondents ranged from 43 to 59 years, with an average of 54.07 years. The respondents' BMI ranged from 18.9-39.2 kg/m<sup>2</sup>, with an average of 25.96 kg/m<sup>2</sup> (overweight). The results of the respondents' HbA1c ranged from 6.6-14%, with an average of 9.54%. The level of leg muscle strength ranged from 6 to 16 repetitions, with an average of 10.8 repetitions.

**Table 1.** Respondent Characteristics

	Number of Respondents	Percentage
<b>Gender</b>		
Male	6	20
Female	24	80
	<b>Range</b>	<b>Mean (SD)</b>
<b>Age (years)</b>	43-59	54.07 (4.1)
<b>BMI (kg/m<sup>2</sup>)</b>	18.9-39.2	25.96 (4.2)
<b>HbA1c (%)</b>	6.6-14	9.54 (1.9)
<b>Leg Muscle Strength Level (repetitions)</b>	6-16	10.80 (2.4)
<b>Body Flexibility Level (cm)</b>	5-22	13.20 (3.8)

SD = Standard Deviation

**Table 2.** Distribution of Age and Gender against the Average Value of Leg Muscle Strength Level

	Leg Muscle Strength Level	
	Male	Female
<b>Age (years)</b>		
40-49	-	12.0 (2.5)
50-59	10.7 (2.9)	10.5 (2.1)

Data is presented in the form of Mean (SD) with repetition units.

**Table 3.** Distribution of Age and Gender against the Average Value of Body Flexibility Level

	Body Flexibility Level	
	Male	Female
<b>Age (years)</b>		
40-49	-	13.7 (5.6)
50-59	10.7 (4.7)	13.2 (2.8)

Data is presented in the form of Mean (SD) with centimeter units.

The results of the respondents' body flexibility levels ranged from 5-22 cm, with an average of 13.2 cm. (Table 1)

This study found that female respondents aged 40-49 years had an average level of leg muscle strength of 12 repetitions. The average value of muscle strength was below the normative data of 19 repetitions. Female respondents aged 50-59 years had an average value of leg muscle strength of 10.5 repetitions. The average value of muscle strength was below the normative data of 17 repetitions. Male respondents aged 50-59 years had an average value of leg muscle strength of 10.7 repetitions. The average value of muscle strength was below the normative data of 18 repetitions.<sup>18</sup> (Table 2)

Table 3 shows that female respondents aged 40-49 years have an average body flexibility level of 13.7 cm. The average flexibility value is below the normative data of 24 cm and is categorized as "Needs Improvement". Female respondents aged 50-59 years have an average body flexibility level of 13.2 cm. The average flexibility value is below the normative data of 24 cm and is categorized as "Needs Improvement". Male respondents aged 50-59 years have an average body flexibility level of 10.7 cm. The average flexibility value is below the normative data of 15 cm and is categorized as "Needs Improvement".<sup>19</sup>

Table 4 shows that the results of the unpaired t-test on HbA1c levels against leg muscle strength levels and body flexibility levels have p values of 0.0018 (mean difference = 2.53, 95% CI 1.03 – 4.03, p <0.05) and 0.0466 (mean difference = 2.7, 95% CI 0.04 – 5.36, p <0.05). This shows that HbA1C levels have a significant relationship with leg muscle strength levels and body flexibility levels.

## DISCUSSION

The mean HbA1c level in this study (9.54%) was higher than that reported by Cholil (8.3%) among Indonesian populations.<sup>20</sup> This finding suggests suboptimal glycemic control among residents of Penjaringan and Mangga Besar villages. Poor glycemic control may be attributable to both dietary patterns and socioeconomic conditions. A review by Yuantari identified irregular and unhealthy dietary practices as major contributors to diabetes mellitus in Indonesia, with imbalanced nutritional intake and inconsistent meal timing leading to poor glycemic regulation.<sup>21</sup> In addition, socio-economic factors appear to play an important role. Hawara

**Table 4.** Relationship between HbA1c Levels and Muscle Strength and Body Flexibility

	n	Mean	Mean Difference (95% CI)	P-value*
<b>Leg Muscle Strength</b>				
HbA1c patients below 9.54%	15	12.0667	2.53 (1.04-4.03)	0.0018
HbA1c patients above 9.54%	15	9.5333		
<b>Body Flexibility</b>				
HbA1c patients below 9.54%	15	14.1333	2.7 (0.04-5.35)	0.0466
HbA1c patients above 9.54%	15	11.4333		

Data are presented using an unpaired t-test.

demonstrated an association between lower socioeconomic status and reduced treatment adherence among patients with diabetes mellitus in Depok, Indonesia, likely due to limited access to healthcare services, which in turn contributes to inadequate glycemic control.<sup>22</sup>

This study demonstrated a significant association between HbA1c levels and both leg muscle strength and body flexibility in individuals with diabetes mellitus. These findings are consistent with previous studies by Yokota and Almurthi, which reported reduced lower limb muscle strength in patients with type 2 diabetes mellitus.<sup>23-25</sup> Hyperglycemia and insulin resistance are known to promote inflammatory processes mediated by reactive oxygen species (ROS), resulting in mitochondrial dysfunction and disruption of the Akt signaling pathway. These mechanisms contribute to lipid accumulation, increased muscle protein degradation, and ultimately reduced skeletal muscle quality and strength.<sup>23-25</sup> Almurthi further described intramuscular fat infiltration, which impairs blood flow, insulin diffusion, and increases fatty acid concentrations, thereby exacerbating insulin resistance in skeletal muscle.<sup>26</sup> This process may lead to muscle atrophy, characterized by reduced muscle volume and increased intramuscular fat content.<sup>26</sup> These mechanisms may explain the observed lower muscle strength among respondents aged 40–59 years compared with normative values for individuals of similar age.<sup>18</sup>

The normative reference used in this study was limited to adults aged below 60 years, consistent with the inclusion criteria. However, normative datasets specific to the Indonesian population remain limited. As such, international reference values were used for contextual comparison, as these best represent adults within the same age range. Although more recent datasets are available, many include older populations (>65 years), limiting their comparability with the present study.

Similarly, flexibility outcomes in this study were lower among respondents with diabetes mellitus, as both male and female participants aged 40–59 years fell into categories classified as "needs improvement" according to normative data.<sup>19</sup> Several mechanisms may underlie this finding. Neumann reported that hyperglycemia contributes to collagen damage and cartilage alterations, including increased expression of matrix metalloproteinases, which promote cartilage degeneration.<sup>7,27</sup> These changes result in reduced cartilage density and structural irregularities. Schuller also reported an association between diabetes mellitus and limited joint flexibility, attributed to poor glycemic control and aging, both of which contribute to reduced passive range of motion (ROM).<sup>28</sup> Furthermore, a systematic review by Mahmoud demonstrated that T2DM adversely affects intervertebral disc integrity in animal models through mitochondrial stress, ROS accumulation, and inflammatory cytokine release, leading to disc degeneration.<sup>29</sup> These changes may impair spinal loading and ROM, thereby reducing overall flexibility.

In contrast, some studies have reported differing results. Bavaresco found no significant differences in lower limb muscle strength or flexibility between individuals with and without type 2 diabetes mellitus.<sup>15</sup> Similarly, Rahimi, using a Digi Hand Dynamometer and manual muscle testing (MMT), reported no significant effect of diabetes mellitus on upper or lower limb muscle strength.<sup>14</sup> These discrepancies may be explained by differences in study populations, particularly age distribution. Studies including participants aged over 60 years may be confounded by sarcopenia, which independently contributes to reduced muscle strength and may obscure the specific effects of diabetes mellitus.<sup>30</sup> Differences in measurement methods and outcome definitions may also account for variability across studies.

### Study Limitation

This study included nearly the entire accessible population (30 of 32 eligible individuals), enhancing representativeness within the study area. However, the relatively small sample size may have limited statistical power to detect smaller effect sizes and restricts the generalizability of the findings to broader populations. Participants were dichotomized based on the sample mean HbA1c value (<9.54% vs. ≥9.54%) in the absence of a predefined clinically relevant threshold for the local population; this approach is acknowledged as a methodological limitation.

Despite these constraints, the study provides preliminary evidence on the association between glycemic control and physical function in adults with type 2 diabetes mellitus. Furthermore, several references cited in this manuscript are relatively dated, reflecting the limited availability of recent studies specifically examining muscle strength and flexibility among adults under 60 years with type 2 diabetes mellitus, particularly in Indonesian or comparable Southeast Asian populations. Nonetheless, these sources remain relevant, as they provide foundational and widely accepted normative data applicable to the present study.

### CONCLUSION

This study demonstrates a statistically significant association between HbA1c levels and both leg muscle strength ( $p = 0.0018$ ) and body flexibility ( $p = 0.0466$ ) among individuals with diabetes mellitus. These findings highlight the potential impact of glycemic control on physical function. Future studies should incorporate socioeconomic variables, including stratification by economic status, to provide a more comprehensive and representative understanding of these relationships within the population.

### Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

## Author Disclosure

All authors declared no conflicts of interest.

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