

Article

Waist Circumference and Handgrip Strength as Potential Nursing Vital Signs in Type 2 Diabetes: A Preliminary Assessment

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Abstract

Background and aims: The aim of this study was to examine the relationships between muscle function, dietary quality, body composition markers, and metabolic status in ambulatory patients with type 2 diabetes. The study sought to validate low-cost tools, such as handgrip strength and waist circumference, as potential “nursing vital signs” for metabolic risk stratification. **Methods:** A cross-sectional observational study was conducted with adult patients with type 2 diabetes. Muscle function was assessed through handgrip strength (dynamometry) and metabolic status via the HOMA-IR index. Visceral adiposity was estimated using waist circumference and the Lipid Accumulation Product (LAP); dietary quality was evaluated with the Spanish Healthy Eating Index (IASE), and cellular health through the phase angle (PhA) obtained by electrical bioimpedance. Non-parametric tests and Spearman correlations were applied due to the non-normal distribution of the data. **Conclusions:** In this ambulatory diabetic population, waist circumference emerged as a practical and potent surrogate for insulin resistance burden. Although metabolic dysfunction was not directly associated with dietary quality or phase angle, a high prevalence of probable sarcopenia (36.1%) and poor dietary quality (77.8%) were detected. The implementation of non-invasive tools like waist circumference and handgrip strength in nursing consultations could optimize early risk stratification and allow for more targeted lifestyle interventions.



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Keywords: type 2 diabetes mellitus; insulin resistance; waist circumference; HOMA-IR; 25-hydroxyvitamin D; fatty liver index; metabolic dysfunction-associated steatotic liver disease; sarcopenic obesity; handgrip strength; phase angle

1. Introduction

Type 2 diabetes mellitus (T2DM) is a highly prevalent chronic non-communicable disease and a major contributor to cardiovascular morbidity, disability, and healthcare costs worldwide [1–3]. According to the International Diabetes Federation, diabetes affects roughly one in nine adults globally, and a substantial proportion of cases remain undiagnosed, highlighting the need for simple markers that can support risk stratification and timely metabolic assessment in routine care [1]. In Spain, population-based studies likewise report a high burden of diabetes, including many previously unrecognized cases, which further supports the use of feasible anthropometric and biochemical indicators to identify individuals at higher cardiometabolic risk [4,5].

Insulin resistance (IR) is central to T2DM pathophysiology and contributes not only to hyperglycaemia but also to dyslipidaemia, low-grade inflammation, and vascular complications [6–8]. In observational and real-world research, IR is commonly estimated using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), derived from fasting glucose and insulin [9].

Although body mass index (BMI) is widely used to describe adiposity, fat distribution—especially abdominal/visceral adiposity—has distinct metabolic implications [10]. Waist circumference (WC) is an inexpensive and practical measure of central obesity, and it has been proposed as a routine “vital sign” because it captures abdominal fat accumulation better than BMI and provides additional prognostic information for morbidity and mortality risk [11]. Meta-analyses also show that measures of central adiposity, including WC, are strongly associated with incident diabetes and cardiometabolic outcomes [12,13]. Mechanistically, excess visceral fat promotes IR through increased free fatty acid flux, adipose tissue inflammation, altered adipokine signalling, and ectopic fat deposition, all of which impair insulin action [10]. Abdominal obesity is also embedded in the metabolic syndrome framework through ethnicity-specific WC thresholds, reflecting its close relationship with IR and downstream cardiometabolic risk [14]. Despite this, WC is still not consistently measured in routine clinical settings [11].

Importantly, IR in T2DM often clusters with other metabolic conditions. Steatotic liver disease is common in people with T2DM and has recently been reframed in some contexts as metabolic dysfunction-associated steatotic liver disease (MASLD) and metabolic dysfunction-associated steatohepatitis (MASH) [15]. MASLD is increasingly recognized as a relevant diabetes-associated complication and is linked to both liver-related and cardiovascular outcomes [16]. Updated evidence syntheses confirm a high prevalence of fatty liver and clinically significant fibrosis among individuals with T2DM [17]. Reflecting this, European and diabetes-focused guidance documents recommend evaluation or risk stratification for fatty liver disease in people with T2DM using feasible non-invasive approaches integrated into routine care pathways [18–20]. When imaging is not readily available, simple algorithms may help triage risk; the Fatty Liver Index (FLI), based on BMI, WC, triglycerides, and GGT, was developed to estimate the probability of hepatic steatosis and can support selection of patients for further assessment or intensified lifestyle counselling [21].

Vitamin D insufficiency/deficiency is also common in adults with metabolic disease and has been repeatedly associated with IR and adverse cardiometabolic profiles, although causality remains debated. Both observational meta-analyses and umbrella-level evidence syntheses of supplementation trials report heterogeneous findings across populations and study designs [22–24]. Considering WC, IR, fatty liver risk proxies (e.g., FLI), and vitamin D status together may therefore provide a more integrated picture of metabolic vulnerability in adults with T2DM, particularly in small outpatient cohorts where comprehensive phenotyping is uncommon. Identifying these vulnerabilities is particularly critical from a nursing

perspective. Integrating functional markers like handgrip strength and simple anthropometry such as waist circumference into routine consultations could allow for a more proactive, rather than reactive, management of diabetic complications. This study seeks to validate these low-cost tools as potential “nursing vital signs” for metabolic health stratification.

Against this background, this cross-sectional study investigated the relationship between central adiposity and insulin resistance in adults with T2DM followed in an ambulatory setting in Spain. The primary objective was to assess the clinical utility of a multi-marker screening approach (combining WC, HOMA-IR, and FLI) in a real-world outpatient setting. Instead of focusing solely on the well-known link between adiposity and insulin resistance, we specifically aimed to characterize the broader burden of ‘silent’ metabolic risk—including hepatic steatosis (via FLI) and vitamin D deficiency (assessed by serum 25-hydroxyvitamin D levels)—that is often overlooked in routine care [11,17,21].

2. Materials and Methods

2.1. Study Design and Participants

A cross-sectional observational study was conducted involving adult patients diagnosed with type 2 diabetes mellitus (T2DM). The study was carried out at the Catholic University of Valencia (Valencia, Spain). Participants were recruited through accidental non-probability sampling from the university’s nutrition clinics, associated healthcare centers and associations. For recruitment, the collaboration of the Valencian Diabetes Association (AVD) was also secured, which promoted the study among its members. This association is the leading organization in the province, with active involvement in education, psychological support, and support for people with diabetes and their families. It is estimated to have more than 1000 members. Dissemination was broad and every possible effort was made, although it is difficult to estimate the exact number of people who became aware of the project. Following the screening and recruitment process, a total of 37 participants were enrolled and completed the full assessment.

Inclusion criteria were:

- adults aged ≥ 18 years;
- confirmed diagnosis of type 2 diabetes mellitus;

Exclusion criteria included: diagnosis of Type 1 Diabetes, pregnancy, presence of acute infections.

The study protocol adhered to the ethical guidelines of the Declaration of Helsinki and was approved by the Ethics Research Committee of the Catholic University of Valencia (Protocol Code: UCV/2024-2025/079). All participants provided written informed consent prior to data collection.

2.2. Anthropometric Measurements

Anthropometric variables were measured by trained personnel following standardized protocols [25]. Weight was measured to the nearest 0.1 kg using a calibrated digital scale, with participants wearing light clothing and no shoes. Height was measured to the nearest 0.1 cm using a stadiometer. Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2).

WC was measured using a non-stretchable flexible tape at the midpoint between the lowest rib and the iliac crest, with the subject in a standing position and at the end of a normal expiration [26].

2.3. Biochemical Analysis and Calculated Indices

Fasting venous blood samples were collected after an overnight fast of at least 8 h. Serum glucose, insulin, glycosylated hemoglobin (HbA1c), lipid profile (triglycerides, HDL-cholesterol), liver enzymes (GGT, ALT, AST), and 25(OH)D levels were analyzed using standard laboratory techniques.

Insulin resistance was evaluated using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), calculated according to the formula: $\text{HOMA-IR} = [\text{Fasting Insulin } (\mu\text{U/mL}) \times \text{Fasting Glucose } (\text{mg/dL})] / 405$ [9]. A cut-off value of ≥ 3.8 was used to define the presence of insulin resistance in this population.

The risk of hepatic steatosis was estimated using the Fatty Liver Index (FLI), an algorithm based on BMI, waist circumference, triglycerides, and GGT [21]. FLI scores range from 0 to 100, with a score < 30 ruling out fatty liver and a score ≥ 60 indicating a high probability of hepatic steatosis.

2.4. Muscular Function and Sarcopenia Screening

Handgrip strength was measured using a digital hydraulic dynamometer (Takei TKK 5401, Takei Scientific Instruments (Niigata, Japan)). Participants performed two maximum contractions with each hand; the highest value was recorded. Probable sarcopenia was defined following the European Working Group on Sarcopenia in Older People (EWGSOP2) criteria, using sex-specific cut-points (< 27 kg for men and < 16 kg for women) [27].

2.5. Dietary Quality Assessment

Nutritional habits were assessed using the Spanish Healthy Eating Index (IASI) [28], a validated 12-item questionnaire that evaluates food frequency consumption and overall diet quality. The index includes food groups recommended for daily consumption (fruit, vegetables, cereals, and milk and dairy products), weekly consumption (meat and pulses, with meat intake calculated as the mean of white and red meat consumption), and occasional consumption (soft drinks), as well as dietary variety, a key component of a healthy diet. Scoring followed the standard IASE criteria, with each item assigned a maximum of 10 points when recommendations established by the Spanish Society of Community Nutrition (SENC) were met [29], yielding a maximum total score of 80. Based on the total score, diet quality was classified into three categories: healthy (> 80 points), needs improvement (50–80 points), and unhealthy (< 50 points).

2.6. Bioelectrical Impedance Analysis (BIA)

Phase angle (PhA) was obtained through a multi-frequency BIA device (Tanita MC-780MA, TANITA Health Equipment H.K. Limited. (Tokyo, Japan)). Measurements were taken under standardized conditions (fasting, empty bladder, and supine position). PhA was calculated as the arctangent of the ratio of reactance to resistance at 50 kHz, serving as a proxy for cellular membrane integrity and nutritional status.

2.7. Statistical Analysis

Statistical analyses were conducted using Jamovi software (version 2.3) [30]. Categorical variables were summarized as frequencies and percentages, while continuous variables were assessed for normality using the Shapiro–Wilk test. As key metabolic variables, including HOMA-IR and triglycerides, exhibited non-normal distributions, non-parametric methods were applied throughout all inferential analyses. Continuous data are presented as mean $\pm$ standard deviation and median with interquartile range, as appropriate.

Associations between continuous variables—such as waist circumference, lipid accumulation product, and phase angle—with HOMA-IR were examined using Spearman's rank correlation coefficient. Group comparisons involving continuous outcomes, including differences in HOMA-IR between participants with and without probable sarcopenia, were performed using the Mann–Whitney U test.

Associations between categorical variables were explored to identify clinically relevant patterns. The relationships between insulin resistance status (HOMA-IR > 3.8) and both probable sarcopenia and lipid accumulation product categories were analyzed using Fisher's exact test, given the small sample size. The association between dietary quality categories, as defined by the IASE [30], and insulin resistance status was assessed using the chi-square test.

A *p*-value below 0.05 was considered statistically significant. Owing to the pilot nature of the study and recruitment via accidental non-probability sampling, no a priori power calculation was performed. Nevertheless, a post hoc sensitivity analysis was conducted to aid interpretation of non-significant results, recognizing that the limited sample size (*N* = 37) may reduce the ability to detect moderate effect sizes.

Given the pilot nature of this study, a post hoc sensitivity analysis was performed using G*Power (version 3.1). With a sample size of *N* = 37 and an alpha level of 0.05, the study was powered to detect large effect sizes (Spearman's $\rho \approx 0.45$). Consequently, while the study effectively identified strong correlations (e.g., WC and HOMA-IR), it may have been underpowered to detect moderate or small associations among other metabolic variables.

3. Results

3.1. Characteristics of the Study Population

The study population consisted of 37 participants, comprising 22 women (59.50%) and 15 men (40.50%). Fatty liver risk was assessed using FLI, which was available for 34/37 participants. Based on standard thresholds, 10/34 (29.4%) had FLI < 30, 11/34 (32.4%) had FLI 30–59, and 13/34 (38.2%) had FLI ≥ 60 ; FLI could not be computed in 3 participants due to missing data.

Table 1 summarizes the anthropometric and biochemical characteristics of the study cohort. The mean age of the participants was 66.1 ± 8.91 years. Anthropometric assessment revealed a mean weight of 76.6 ± 21.2 kg and a mean Body Mass Index (BMI) of 28.8 ± 6.23 kg/m², placing the average participant in the overweight category. The mean waist and hip circumferences were 95.6 ± 15 cm and 101 ± 13.1 cm, respectively.

Regarding metabolic parameters, the mean Fasting Plasma Glucose (FPG) was 121 ± 26.1 mg/dL, and the mean Glycated Hemoglobin (HbA1c) was $7.19 \pm 0.972\%$, indicating hyperglycemic tendencies within the group. Insulin resistance, measured by HOMA-IR, showed a mean value of 7.05 ± 10.3 ; however, the median value was notably lower at 3.68, suggesting a skewed distribution driven by outliers (Max = 53.5). The mean serum 25-hydroxyvitamin D level was 26.6 ± 18.4 ng/mL. Liver enzyme levels showed mean values of 27.7 U/L for GGT, 29 U/L for ALT, and 23.8 U/L for AST.

Table 1. Anthropometric and biochemical characteristics of the study cohort (N = 37).

	Age (years)	Weight (kg)	BMI (kg/m ²)	Waist Circumference (WC) (cm)	Hip Circumference (HC) (cm)	Fasting Plasma Glucose (FPG) (70–110 mg/dL)	Homeostatic Model Assessment for Insulin Resistance (Homa-IR)	Glycated Hemoglobin (HbA1c) (%)	25- hydroxyvitamin D(25(OH)D) (ng/mL)	Gamma-glutamyl Transferase (GGT) (U/L)	Alanine Aminotransferase (ALT) (U/L)	Aspartate Aminotransferase (AST) (U/L)
Mean (M)	66.1	76.6	28.8	95.6	101	121	7.05	7.19	26.6	27.7	29	23.8
Median	66	68.7	28.4	90	100	120	3.68	7.18	23.3	22	21.5	21
Standard Deviation (SD)	8.91	21.2	6.23	15	13.1	26.1	10.3	0.972	18.4	16.3	24	10.9
Min	40	38	15.6	68	76	71.9	0.193	5.45	5.74	11	10	15
Max	83	143	46.7	133	150	192	53.5	9.87	102	73	150	75

Legend: BMI: Body Mass Index; WC: Waist Circumference; HC: Hip Circumference; FPG: Fasting Plasma Glucose; HOMA-IR: Homeostatic Model Assessment for Insulin Resistance; HbA1c: Glycated Hemoglobin; 25(OH)D: 25-hydroxyvitamin D; GGT: Gamma-glutamyl Transferase; ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase.

3.2. Association Between Waist Circumference and Insulin Resistance

A significant positive correlation was observed between waist circumference and insulin resistance levels. Spearman's correlation (Figure 1A) analysis revealed that higher waist circumference values were associated with higher HOMA-IR scores ($r = 0.42$; $p = 0.012$). This finding suggests that central adiposity is directly linked to the degree of metabolic dysfunction in this patient group.

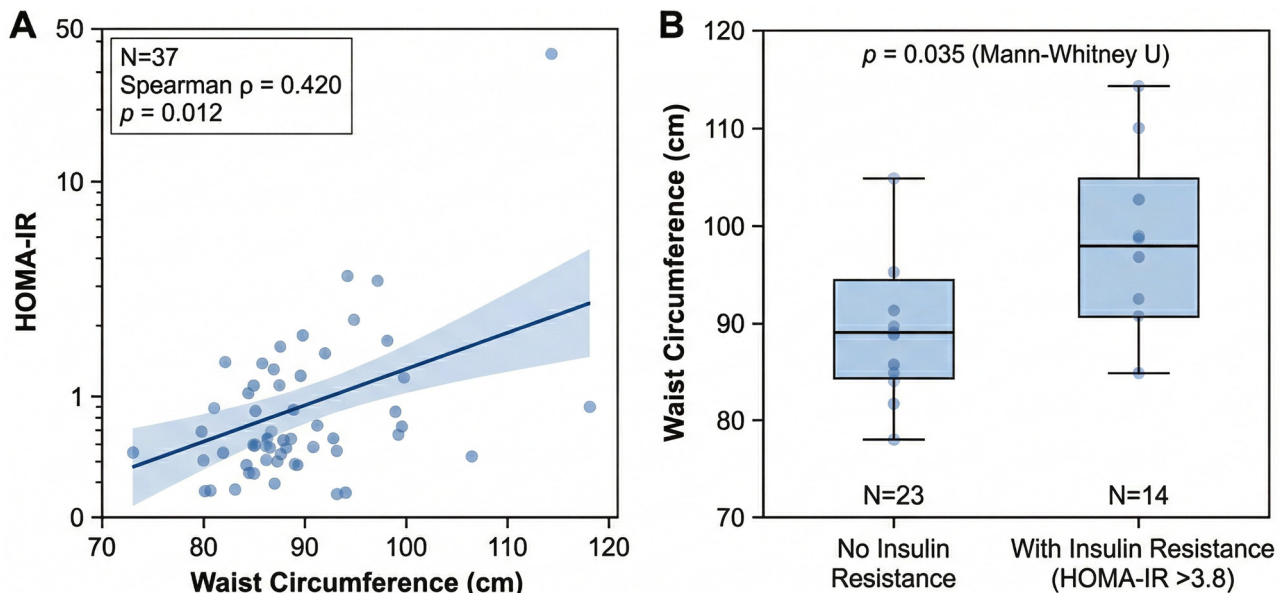


Figure 1. Relationship and Comparison of Central Adiposity with Insulin Resistance Status. Panel (A) presents a scatter plot showing the correlation between waist circumference (WC) and the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) ($N = 37$). Panel (B) shows a box-plot comparison of waist circumference between participants categorized by insulin resistance status.

3.3. Comparison to Insulin Resistance Status

To further explore this relationship, participants were stratified according to the presence of insulin resistance (defined as $\text{HOMA-IR} \geq 3.8$). The group with insulin resistance ($n = 22$) exhibited a larger waist circumference (102.0 ± 15.5 cm vs. 91.3 ± 13.5 cm; $p = 0.035$) compared to the group without insulin resistance ($n = 15$). These results indicate that patients with established insulin resistance have, on average, a waist circumference approximately 10.7 cm larger than those with better insulin sensitivity (Figure 1B).

3.4. Secondary Outcomes: Vitamin D Status and Fatty Liver Risk

We analyzed secondary metabolic parameters to further characterize the study population. Regarding vitamin D status, serum 25(OH)D levels were generally low, with a median value of 23.3 ng/mL (IQR: 15.0–29.7 ng/mL). As shown in Figure 2, only 25.0% of the participants achieved sufficiency levels (>30 ng/mL). Most of the sample (75.0%) presented suboptimal levels, being distributed between insufficiency (38.9%; 20–30 ng/mL) and deficiency (36.1%; <20 ng/mL).

Additionally, the assessment of hepatic health using the FLI-based stratification suggested a relevant burden of fatty liver risk in this cohort. Among participants with available data ($n = 34$), 13/34 (38.2%) had $\text{FLI} \geq 60$ (high probability of steatosis), while 11/34 (32.4%) fell in the indeterminate range (FLI 30–59) and 10/34 (29.4%) had $\text{FLI} < 30$.

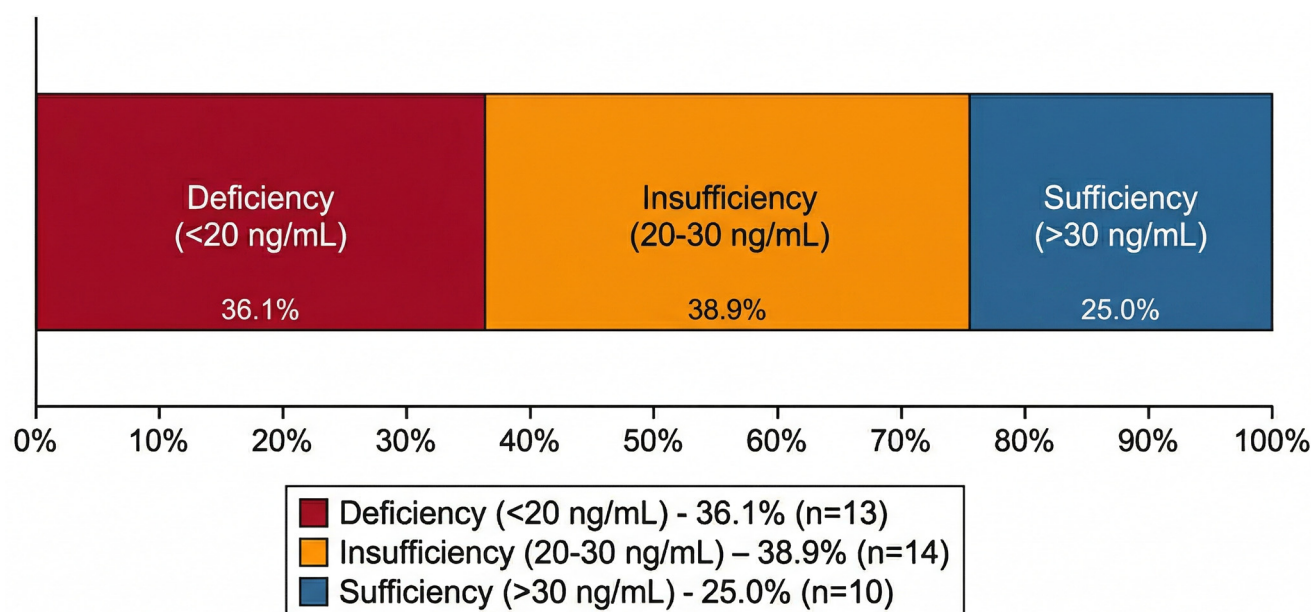


Figure 2. Distribution of vitamin D status based on serum 25(OH)D levels. The stacked bar chart illustrates the prevalence of vitamin D categories within the study population (N = 37). Most participants (75.0%) presented suboptimal levels, categorized as deficiency (<20 ng/mL; 36.1%) or insufficiency (20–30 ng/mL; 38.9%). Only 25.0% reached sufficiency levels (>30 ng/mL).

3.5. Muscular Function and Sarcopenia Screening

Functional assessment indicated that 36.1% of participants (n = 13) met the criteria for probable sarcopenia based on reduced handgrip strength, whereas the remaining 63.9% (n = 23) exhibited strength values within normal clinical ranges. Although the Mann–Whitney U test revealed no statistically significant differences in HOMA-IR levels between sarcopenic and non-sarcopenic individuals ($U = 127.5$; $p = 0.400$), a clinically relevant pattern emerged. More than half of the participants with probable sarcopenia (53.8%) presented insulin resistance ($\text{HOMA-IR} > 3.8$), compared with 39.1% among those with preserved muscle strength.

3.6. Lipid Accumulation Product (LAP) and Metabolic Status

The Lipid Accumulation Product (LAP) was calculated as an indicator of visceral adiposity. However, Spearman correlation analysis demonstrated no linear association between LAP values and HOMA-IR levels ($r = -0.010$; $p = 0.956$). This finding suggests that, within this cohort, the extent of visceral lipid accumulation does not directly reflect alterations in glucose metabolism.

3.7. Dietary Quality (IASE) and Nutritional Compliance

Assessment using the Spanish Healthy Eating Index (IASE) showed that only 22.2% of participants adhered to a diet classified as “Healthy,” while the majority (77.8%) fell into the “Needs Improvement” or “Unhealthy” categories. No significant association was observed between IASE scores and HOMA-IR ($p = 0.493$), indicating that suboptimal dietary quality was a widespread characteristic of the sample, irrespective of insulin resistance status.

3.8. Cellular Health and Phase Angle (PhA)

Bioelectrical impedance analysis revealed a high degree of homogeneity in cellular health across participants. Individuals without insulin resistance exhibited a mean phase angle of $5.65 \pm 1.11^\circ$, while those with HOMA-IR values above 3.8 showed a comparable mean of $5.61 \pm 0.89^\circ$. Spearman correlation analysis found no significant relationship

between phase angle and metabolic dysfunction ($r = -0.034$; $p = 0.845$). While these preliminary data do not show marked differences in cellular membrane integrity within this cohort, the limited sample size precludes definitive conclusions regarding the preservation of cellular health in the broader ambulatory diabetic population.

4. Discussion

In this cross-sectional cohort of adults with T2DM followed in a real-world ambulatory setting in Spain, WC was positively associated with insulin resistance, with higher WC values corresponding to higher HOMA-IR. More importantly, this real-world pilot assessment demonstrates that evaluating central adiposity alongside FLI and vitamin D uncovers significant metabolic vulnerabilities that remain undetected by standard glycemic monitoring alone. Participants classified as insulin resistant also had a higher mean WC than those below the HOMA-IR cut-off. Taken together, these findings suggest that central adiposity remains closely linked to IR burden in people living with T2DM, even in a relatively small outpatient sample [6,10].

Our observations are in line with prior evidence supporting WC as an informative anthropometric marker of insulin resistance in T2DM. In particular, WC has been reported to outperform BMI in predicting HOMA-IR, highlighting the added value of capturing fat distribution rather than overall adiposity alone [31]. This relationship is also biologically plausible. Visceral adipose tissue is metabolically active and may contribute to insulin resistance through increased lipolysis (with higher circulating free fatty acids), chronic low-grade inflammation, oxidative stress, and altered adipokine and cytokine secretion that interferes with insulin signalling [10,22]. In this context, WC can be viewed as a simple proxy for the fat compartment most strongly implicated in metabolic dysfunction.

There is also growing emphasis on the routine use of WC in clinical practice. A global consensus statement has proposed WC as a “vital sign”, given its strong association with cardiometabolic risk and its feasibility in everyday settings [11]. Our findings support this pragmatic approach in ambulatory T2DM care: measuring WC may help identify individuals more likely to have marked insulin resistance, information that can help prioritize counselling and support more intensive lifestyle strategies aimed at reducing abdominal adiposity [11].

Central obesity is a core feature of the metabolic syndrome framework. The harmonized definition includes abdominal obesity (using population- and ethnicity-specific thresholds) because of its close relationship with insulin resistance and cardiometabolic outcomes [14]. In older adults with T2DM, WC may be especially informative, as age-related body composition changes can increase visceral fat even when BMI changes modestly [10]. From a practical standpoint, routine WC assessment can support clearer, more individualized risk communication and reinforce behavioral strategies known to reduce visceral adiposity.

A high prevalence of suboptimal 25(OH)D status was also observed. This aligns with previous work showing that low vitamin D status commonly co-occurs with metabolic disease and is often associated with insulin resistance [22,23]. Observational studies frequently report inverse relationships between 25(OH)D and IR markers, but causality remains uncertain because vitamin D status may be influenced by factors such as adiposity-related sequestration, reduced sun exposure, lifestyle patterns, and inflammation [22]. Trial evidence is mixed, and umbrella-level syntheses indicate heterogeneous effects of supplementation on glycemic indices and HOMA-IR, depending on baseline deficiency, dose, duration, and population characteristics [24]. For these reasons, our vitamin D findings should be interpreted primarily as descriptive and hypothesis-generating.

Regarding liver-related metabolic risk, FLI suggested a substantial burden compatible with elevated hepatic steatosis risk in this outpatient cohort. This is consistent with evidence that steatotic liver disease, recently reframed in some contexts as MASLD/MASH, is highly prevalent in T2DM and increasingly recognized as a relevant diabetes-associated complication with hepatic and extra-hepatic consequences [15–17]. Reflecting this, major guidance documents recommend evaluation or risk stratification for fatty liver disease in people with T2DM using feasible non-invasive approaches embedded within routine care pathways [18–20,32–34]. The updated joint European guidelines emphasize stepwise pathways and prioritization of fibrosis risk assessment in metabolically at-risk individuals, particularly those with T2DM [32]. Similarly, the ADA consensus report and the most recent ADA Standards of Care support structured screening/risk stratification approaches for steatotic liver disease and key comorbidities in people with diabetes [32,34].

The FLI itself was developed as a simple steatosis-risk predictor based on routinely available variables (BMI, WC, triglycerides, and GGT), with commonly used thresholds to rule out (<30) or rule in (≥ 60) steatosis likelihood in population settings [21]. In outpatient practice, where imaging is not always available, combining WC with FLI may offer a pragmatic way to capture central adiposity and liver-related metabolic vulnerability, helping to guide lifestyle counselling and the selection of patients who may benefit from further diagnostic assessment [18–21,35].

From a translational standpoint, future studies should test whether embedding WC and simple non-invasive indices (e.g., HOMA-IR and FLI) into routine outpatient pathways improves early identification of clustered cardiometabolic–hepatic risk and optimizes referral to fibrosis-oriented assessment within stepwise MASLD strategies [11,32–34].

4.1. The Nexus of Sarcopenia, Central Adiposity, and Insulin Resistance

The observed prevalence of probable sarcopenia (36.1%) and the clinical trend linking reduced muscle strength to higher HOMA-IR levels (53.8% in the sarcopenic group) highlight the critical role of “sarcopenic obesity” in the T2DM population. Muscle tissue is the primary site for insulin-mediated glucose disposal; therefore, the age-related decline in muscle quality—compounded by the pro-inflammatory state of central adiposity—creates a metabolic “vicious cycle.” As noted by Mesinovic J et al. (2023) [35], even in the absence of weight loss, the deterioration of muscle function significantly impairs glycemic control and increases cardiovascular risk in primary care settings. These findings suggest that for nursing interventions to be effective, they must move beyond weight reduction and prioritize resistance-based exercise to preserve the metabolically active lean mass.

4.2. Discordance Between Lipid Overaccumulation and Glucose Dysfunction

The lack of a linear correlation between the LAP index and HOMA-IR ($p = 0.956$) in this pilot study suggests a complex “metabolic phenotype” in T2DM patients where visceral lipid storage and insulin signaling dysfunction do not always progress in parallel. Interestingly, while the LAP index—which incorporates both waist circumference and triglycerides—failed to correlate with HOMA-IR, waist circumference alone showed a significant positive association ($r = 0.42$, $p = 0.012$). This suggests that in this specific ambulatory cohort, the physical distribution of visceral fat may be a more sensitive indicator of current insulin resistance than biochemical lipid accumulation indices. This finding reinforces the clinical utility of waist circumference as a standalone, non-invasive screening tool that can be easily implemented in resource-constrained primary care settings. This discordance may be explained by the “adipose tissue expandability” hypothesis, which posits that metabolic distress occurs not just from the amount of fat, but from the inability of subcutaneous depots to store excess lipids, leading to ectopic deposition in the liver and

muscle. Our results support the need for a multidimensional assessment; as Mundi et al. (2023) argue [36], using a single marker like BMI or even HOMA-IR may overlook patients with “silent” visceral overaccumulation (high LAP) who currently maintain euglycemia but remain at high risk for future hepatic and vascular complications.

4.3. Nutritional Patterns and Cellular Vitality: Implications for Primary Care Nursing

The high percentage of participants requiring significant dietary changes (78%) according to the IASE emphasizes a profound gap between clinical guidelines and real-world behavior. Poor adherence to a Mediterranean-style pattern is directly linked to systemic low-grade inflammation and oxidative stress, markers that correlate with the PhA values observed in our cohort. Although PhA values were relatively homogeneous across our IR groups, de Moraes et al. (2025) have demonstrated that PhA serves as a superior longitudinal predictor of nutritional decline compared to traditional anthropometry [37]. For nurse-led clinics, integrating BIA-derived markers and validated dietary indices like the IASE provides a more sensitive framework for “Therapeutic Patient Education.” This shift from focusing on calorie counting to focusing on cellular health and food quality is essential for the secondary prevention of diabetic complications. From a clinical standpoint, these findings advocate for a paradigm shift in nurse-led diabetic clinics. Instead of a traditional weight-centric approach based solely on BMI, a functional-metabolic framework is proposed. By adopting handgrip strength to screen for probable sarcopenia—found in 36.1% of our sample—and waist circumference to monitor visceral adiposity, nursing professionals can identify “metabolically at-risk” patients even when glycated hemoglobin levels appear stable. This multidimensional assessment facilitates more targeted “Therapeutic Patient Education,” focusing on resistance exercise and dietary quality rather than just caloric restriction. From a nursing perspective, these findings advocate for a shift from traditional weight-centric counseling to a functional-metabolic approach. Integrating handgrip strength and WC as ‘nursing vital signs’ facilitates the early identification of patients requiring intensive lifestyle interventions even when HbA1c levels appear stable.

4.4. Strengths and Limitations

Strengths of this study include the real-world outpatient setting, standardized anthropometric assessment, and the integrated evaluation of insulin resistance (HOMA-IR), vitamin D status, and FLI, using low-cost and scalable measures that provide a clinically meaningful metabolic profile.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference; central adiposity may contribute to insulin resistance, but insulin resistance, treatment factors, and reverse causation may also influence fat distribution. Second, the sample size was small and based on non-probability sampling from a single centre, which may limit generalizability and increase the risk of selection bias. Due to this limited sample size ($N = 37$), the study was primarily powered to detect large effect sizes, which may explain why certain moderate metabolic associations did not reach statistical significance. However, this cohort represents a high-fidelity “real-world” snapshot of patients in a specialized nutrition unit. While the sample size limits multivariate modeling, this study serves as a hypothesis-generating proof-of-concept pilot, demonstrating the feasibility and informative value of implementing this enhanced screening protocol in resource-constrained ambulatory settings. Given the exploratory nature of this work, the observed trends should be interpreted as preliminary indicators of metabolic vulnerability rather than definitive causal links. Third, HOMA-IR is a surrogate index and does not replace gold-standard methods (e.g., the euglycaemic-hyperinsulinaemic clamp); in addition, HOMA-IR cut-offs vary across populations and clinical contexts [9]. Fourth, FLI is

a proxy of steatosis risk and does not assess fibrosis; it may also be influenced by factors affecting triglycerides and GGT, including medications and alcohol intake. Furthermore, potential confounders such as diabetes duration, medication classes (e.g., insulin, GLP-1 receptor agonists, SGLT2 inhibitors), physical activity, diet, alcohol intake, and menopausal status were not fully modelled and may have affected the observed associations. Larger longitudinal studies incorporating liver imaging and fibrosis-oriented non-invasive tests could better define temporal relationships and clinically actionable thresholds. Finally, a critical limitation is the lack of adjustment for specific glucose-lowering medications, such as GLP-1 receptor agonists or SGLT2 inhibitors. These pharmacological classes are known to significantly influence body composition, visceral adiposity, and metabolic markers. Future longitudinal studies with larger cohorts should include these treatments as covariates to better isolate the independent effects of muscle function and dietary quality on metabolic status.

5. Conclusions

In this real-world pilot study of adults with T2DM, waist circumference emerged as a practical and potent surrogate for insulin resistance burden. Beyond simple anthropometry, our integrated assessment revealed a complex “metabolic-functional” cluster: a high prevalence of probable sarcopenia (36.1%), significant hepatic steatosis risk (38.2% with FLI $\geq$ 60), and widespread nutritional deficiencies, characterized by suboptimal vitamin D levels (75%) and poor diet quality (78%).

These preliminary findings suggest that traditional glycemic monitoring may be insufficient to capture the full spectrum of metabolic vulnerability in primary care. The frequent co-occurrence of central adiposity, muscle dysfunction, and “silent” hepatic risk supports further exploration of a multidimensional phenotyping approach. Within the limitations of this pilot cohort, implementing low-cost, non-invasive tools such as WC, FLI, and BIA-derived phase angle within nurse-led clinics shows potential to optimize risk stratification and allow for targeted lifestyle interventions. Ultimately, the proposed inclusion of handgrip strength and waist circumference as routine nursing assessments could bridge the gap between metabolic theory and ambulatory practice, providing a more holistic view of the patient with type 2 diabetes that warrants validation in larger longitudinal studies.

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Data Availability Statement: The data presented in this study are available upon reasonable request to the corresponding author.

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