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Comparison of Blood Glucose Testing Methods: Analyzer, Glucometer, and Spectrophotometer at Kuta Alam Health Center

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Abstract. Blood glucose, a form of sugar present in the bloodstream, is derived from dietary carbohydrates and stored as glycogen in the liver and skeletal muscles. Blood glucose levels of ≥ 140 mg/dL in random testing or
> 120 mg/dL in fasting tests the indication of diabetes mellitus (DM). According to the World Health Organization (WHO) in 2021, DM is among the top ten leading causes of death globally. Blood glucose levels can be measured using various methods, including chemistry analyzers, glucometers, and spectrophotometers. This study aims to evaluate the differences in blood glucose levels obtained using these three analytical methods. The study aims to compare blood glucose levels measured using a chemistry analyzer, glucometer, and spectrophotometer. A descriptive research method was applied, with samples collected through random sampling, comprising 25 normal and 25 elevated blood glucose level samples. The majority of participants were women (76.0 %, n=38), while men represented 24.0 % (n=12), with an average participant age of 57.8 years. In the normal group, blood glucose levels measured using the chemistry analyzer ranged from 72 mg/dL to 116 mg/dL, with a mean of 90.52 mg/dL. Measurements using the glucometer showed a range of 75 mg/dL to 129 mg/dL, with a mean of 95.88 mg/dL, while the spectrophotometer results ranged from 74 mg/dL to 120 mg/dL, with a mean of 93.00 mg/dL. In the high blood glucose group, measurements using the chemistry analyzer ranged from 195 mg/dL to 342 mg/dL, with a mean value of 272.04 mg/dL. Measurements with the glucometer ranged from 200 mg/dL to 358 mg/dL, with a mean value of 278.44 mg/dL, while the spectrophotometer results ranged from 199 mg/dL to 354 mg/dL, with a mean value of 275.48 mg/dL. Based on the results, the chemistry analyzer demonstrated higher precision and accuracy in measuring blood glucose levels compared to the glucometer and spectrophotometer.

Keywords: Venous blood, serum, blood glucose, chemistry analyzer, spectrophotometer, glucometer.

INTRODUCTION

Clinical laboratory services play a critical role in healthcare by providing essential diagnostic support. These services aid in identifying the underlying causes of disease and offer vital information that clinicians utilize to make accurate diagnoses, guided by the patient's medical history. Laboratory test results also form an integral component of health screening and preventive medicine Among the various laboratory tests, blood glucose testing is a primary method for assessing sugar levels [1].Use the "Insert Citation" button to add citations to this document.

Blood glucose serves as a critical fuel for metabolic processes and is the primary energy source for the brain. It is derived from dietary carbohydrates and stored as glycogen in the liver and skeletal muscles. Blood glucose levels of ≥ 140 md/dL in random testing or > 120 mg/dL in fasting tests are indicative of diabetes mellitus, a metabolic disorder characterized by elevated blood sugar levels due to impairments in insulin secretion, insulin action, or both. This condition can be diagnosed using various tests, including fasting blood glucose tests and random blood glucose tests, among others. Diabetes mellitus (DM) is among the top ten leading causes of death globally, according to the World Health Organization (WHO) in 2021. Diabetes Mellitus is a systemic condition commonly encountered in both developed and developing nations, including Indonesia. This prevalence is partly attributed to the unhealthy lifestyles and limited physical activity, such as a lack of exercise, among some segments of the Indonesian population[2]. Individuals with diabetes must closely monitor their blood glucose levels to prevent severe complications, including cardiovascular disease, kidney failure, blindness, limb amputation, and mortality. Regular monitoring is particularly crucial for individuals at risk of developing diabetes [3]. Blood glucose testing can be conducted using whole blood, serum, or plasma. Notably, serum contains a higher water content than whole blood, resulting in higher glucose concentrations in serum compared to whole blood [4]

Blood glucose levels can be measured using three primary tools: a chemistry analyzer, a glucometer, and a spectrophotometer. The chemistry analyzer is widely utilized in clinical chemistry to assess the concentration of various substances in the blood. Its primary advantage lies in its ability to rapidly process a large number of samples simultaneously, making it highly effective and time-efficient for healthcare facilities that prioritize responsive patient care. However, the chemistry analyzer also has limitations. It requires a relatively large sample volume and is incapable of identifying abnormal cell count [5]. Despite these drawbacks, its speed and capacity make it an indispensable tool in clinical laboratory settings.

In the determination of blood glucose concentrations, three analytical methods are commonly employed: glucometer, clinical chemistry analyzer, and spectrophotometer. Each method exhibits distinct strengths and limitations, making their selection dependent on clinical requirements, accuracy expectations, and operational settings.

The glucometer is a point-of-care device widely utilized for self-monitoring, particularly among patients with diabetes. It offers advantages in terms of portability, ease of use, and rapid result delivery, making it highly suitable for daily home-based testing. However, despite its practicality, the glucometer is generally less accurate compared to laboratory-based instruments. Its performance can be influenced by various factors, including hematocrit variability, ambient temperature, and improper sampling techniques. Consequently, glucometer readings should be interpreted with caution, especially in clinical decision-making scenarios that demand high precision.

On the other hand, the clinical chemistry analyzer is a highly reliable laboratory instrument designed to provide accurate and reproducible glucose measurements. It facilitates automated processing of multiple samples simultaneously, thereby minimizing human error and ensuring high throughput. For this reason, it is considered the gold standard in routine clinical diagnostics. Nonetheless, its use entails several limitations: high cost, lack of portability, requirement for trained personnel, and longer processing times, which limit its suitability for immediate or bedside testing.

The spectrophotometer is another powerful tool, particularly in research settings where flexibility and accuracy are paramount. It enables quantitative glucose analysis in purified or chemically treated samples by measuring absorbance at specific wavelengths following reagent-based reactions. While spectrophotometric methods yield highly accurate results under controlled laboratory conditions, they are often labor-intensive, requiring manual reagent preparation, frequent calibration, and technical expertise. These factors render the method impractical for routine clinical or emergency applications.

In conclusion, each method offers unique benefits that must be balanced against its limitations. The glucometer excels in accessibility and speed but may compromise accuracy. The chemistry analyzer ensures superior precision and is optimal for centralized testing but requires significant resources. The spectrophotometer provides high analytical accuracy for controlled samples yet lacks operational convenience for clinical practice. These methodological differences underscore the importance of choosing the appropriate analytical tool based on the diagnostic context, accuracy demands, and resource availability.The glucometer is a simple laboratory device designed primarily for analyzing capillary blood samples rather than serum or plasma. Its widespread use is attributed to its affordability, rapid result delivery, and minimal sample requirement, making it suitable for both

capillary and venous blood testing. The glucometer offers several advantages: it is user-friendly and can be operated by nurses, patients, or family members for monitoring purposes. Additionally, it requires only a small blood sample, can be used bedside, is compact and portable, and does not necessitate a dedicated laboratory space. However, the glucometer has notable limitations. Its testing capabilities are restricted, and the precision and accuracy of results obtained using the Point of Care Testing (POCT) method are suboptimal. Other drawbacks include inadequate quality control and documentation processes, reliance on invasive sampling methods, and limited sample volume compared to tools like the spectrophotometer, which can process larger samples [5]

Glucometers are simple laboratory devices designed specifically for capillary blood samples rather than serum or plasma. These devices are widely used due to their affordability and the rapid availability of results. Glucometers require only a small volume of whole blood, making them suitable for both capillary and venous blood testing. The advantages of glucometers include ease of use, allowing operation by nurses, patients, or family members for patient monitoring. They require minimal blood volume, can be used bedside, are compact and portable, and do not require a dedicated laboratory space. However, glucometers also have limitations. They are restricted to specific types of tests, and the accuracy and precision of results obtained via the Point of Care Testing (POCT) method are sub optimal [6]. Additionally, the quality control (QC) processes and result documentation are inadequate. The devices rely on invasive sampling methods and utilize smaller blood volumes, unlike spectrophotometers, which are capable of processing larger samples [5] The use of a glucometer to measure blood sugar levels is useful in monitoring glycemic control with quick and easy results [7], [8].

A spectrophotometer is an instrument used to measure absorbance by directing light of a specific wavelength through a glass or quartz cuvette. The device quantifies the amount of light absorbed versus transmitted. One of the primary advantages of the spectrophotometer is its use of serum or plasma, which eliminates interference from blood cells. However, its disadvantages include requiring larger blood volumes, longer processing times, and higher costs. Despite these limitations, the spectrophotometer is widely utilized in clinical laboratories due to its high accuracy in determining blood glucose levels. It is often regarded as the gold standard for blood glucose measurement [9]. Blood glucose levels can be assessed using three primary methods: glucometers, chemistry analyzers, and spectrophotometers. In health centers, Point of Care Testing (POCT) methods, such as glucometers (e.g., Accu-Chek), are commonly employed for their convenience, while clinical laboratories typically use chemistry analyzers and spectrophotometers [10], [11]

The use of a spectrophotometer in the examination has a number of advantages, including high precision and accuracy, good specificity, and relative freedom from interferences such as hematocrit levels, vitamin C, lipids, sample volume, and temperature. However, this method also has some disadvantages, such as dependence on reagents, the need for a large number of blood samples, and maintenance of tools and reagents that require special space and high costs [12], [13]

The strip method, on the other hand, has the advantages of providing quick results, requiring a small number of samples, not requiring special reagents, and being practical and easy to use by anyone without requiring special skills. The disadvantages of this method include uncertain accuracy and limitations that are influenced by factors such as hematocrit levels, interference of other substances (vitamin C, lipids, bilirubin, and hemoglobin), temperature, insufficient sample volume, and its function which is only for monitoring glucose levels, not for clinical diagnosis [12], [13]

This study aims to determine whether significant differences exist between blood glucose levels measured using these three methods.

METHODOLOGY

This study employs a descriptive research design. A total of 50 samples were collected through random sampling, comprising 25 samples with normal blood glucose levels and 25 with elevated levels. The samples were analyzed using a chemistry analyzer glucometer, and spectrophotometer to evaluate differences in blood glucose measurements across these three methods.

Instruments and Materials

Instruments

The instruments utilized in this study included a chemistry analyzer, glucometer, spectrophotometer, centrifuge, and tourniquet.

Materials

The materials used in this study comprised venous blood samples, glucose oxidase enzyme reagent, blood glucose strips, disposable syringes, alcohol swabs, adhesive plasters, red-cap vacutainers, micropipettes, blue tips, and serum cups.

Procedure

Sampling

A blood sample was obtained via venipuncture, and a tourniquet was applied to the upper arm to occlude blood flow. Then, the venipuncture site (antecubital fossa) was cleaned with 70% alcohol using a circular motion, and it was allowed to air dry. Next, venipuncture was performed using a sterile syringe. Afterward, the tourniquet was released, and blood was drawn slowly until 3 mL was collected. Subsequently, the needle was removed, and the blood was carefully transferred to a red-cap vacutainer tube by allowing it to flow along the tube wall. Finally, the puncture site was covered with sterile cotton or an adhesive plaster, and the vacutainer tube was labeled with the patient's identification details for proper documentation [14] [15]

Enzymatic Method Procedure (Spectrofotometer)

All necessary instruments and materials were prepared, and the test tubes were labeled as Sample 1 and Sample 2. Then, 3000 µL of glucose reagent was transferred into each test tube using a 1000 µL micropipette. Next, 30 µL of blood serum sample was added to each corresponding test tube according to the labeling, using a 30 µL micropipette. Afterward, the serum and reagent were mixed by vortex for a few seconds. The mixture was then incubated for 20 minutes. After the incubation period, the contents of the tube were transferred into a cuvette, and it was inserted into the spectrophotometer. Finally, the absorbance result obtained from the spectrophotometer was recorded.

Chemistry Analyzer Procedure (Chemistry Analyzer)

All necessary instruments and materials were prepared, and the test tubes were labeled as Sample 1, Sample 2, and Sample 3. For Sample 1 (Blank), 1000 µL of reagent was added. Similarly, for Sample

2 (Standard), 1000 µL of reagent was added, followed by 10 µL of serum. Likewise, for Sample 3 (Sample), 1000 µL of reagent was added, followed by 10 µL of serum. Then, the contents were mixed, and the test tubes were incubated at 37°C for 10 minutes or at 25°C for 15 minutes, depending on the protocol. Afterward, the absorbance was measured using the chemistry analyzer. Finally, the results obtained were recorded.

POCT Method Procedure (Glucometer)

The glucometer device was prepared, and the test strip was inserted into the designated slot on the glucometer. Next, the collected venous blood sample was applied to the strip by placing it on the designated absorption area. Then, the glucose concentration result was displayed on the screen, and the result was recorded. Finally, the test strip was removed from the glucometer.

RESULTS AND DISCUSSION

This research analyzed 25 samples with normal blood glucose levels and 25 samples with elevated blood glucose levels. Statistical tests were applied to assess the mean differences in blood glucose levels measured by the three methods. The results are presented in a tabular format to illustrate the discrepancies among the measurement tools.

Baseline Characteristics of Study Participants

The analysis of blood glucose levels using a chemistry analyzer, glucometer, and spectrophotometer, conducted in June 2024 at Kuta Alam Health Center, Banda Aceh City is presented (Table 1).

Table 1. Blood Glucose Levels Measured Using Three Testing Instruments Based on Normal Blood Glucose Levels and High Blood Glucose Level**s**

		Normal intermittent blood glucose test results (mg/dL)	
	Chemistry analyzer	**Glucometer**	**Spectrophotometer**
Minimum blood glucose level	72 mg/dL	75 mg/dL	74 mg/dL
Maximum blood glucose Level	116 mg/dL	129 mg/dL	120 mg/dL

Based on the data presented in Table 1, the majority of participants were women (76.0%, n= 38), while men comprised 24.0% (n=12). The mean age of the participants was 57.8 years. In the normal blood glucose group, measurements using the chemistry analyzer ranged from 72 mg/dL to 116 mg/dL, with a mean of 90.52 mg/dL. Measurements with the glucometer ranged from 75 mg/dL to 129 mg/dL, with a mean of 95.88 mg/dL, while the spectrophotometer recorded values from 74 mg/dL to 120 mg/dL, with a mean 0f 93.00 mg/dL. In the high blood glucose group, measurements using the chemistry analyzer ranged from 195 mg/dL to 342 mg/dL, with a mean 272.04 mg/dL. Glucometer readings ranged from 200 mg/dL to 358 mg/dL, with a mean of 278.44 mg/dL, and spectrophotometer readings ranged from 199 mg/dl to 354 mg/dL, with a mean of 275.48 mg/dL

Statistical Comparison of Blood Glucose Levels Across Measurement Methods

The research results were subjected to statistical analyses, including homogeneity tests, normality tests, and subsequent t-tests. The homogeneity test for the normal glucose group yielded a significance value of 0.625, while the high blood glucose group had a significance value of 0.514 ($p > 0.05$), indicating that the variances across the groups were equal. The normality test, using the Kolmogorov-Smirnov test, showed significance values of 0.647 for both the normal and high blood glucose groups ($p > 0.05$), suggesting that the data in all groups followed a normal distribution. Thus, the assumptions for the F-test and t-test were met. The differences in blood glucose measurements obtained using the chemistry analyzer, glucometer, and spectrophotometer were then analyzed using F-tests and t-tests.

Table 2. Comparison of Blood Glucose Levels Measured Using Chemistry Analyzer, Glucometer, and Spectrophotometer for Normal Participants

Variable	F(%)	Normal Mean ±SD	Pvalue
Chemistry Analyzer	25(100)	90.52±11.529	0.001
Glucometer	25(100)	95.88±14.397	0.001
Spectrophotometer	25(100)	93.00±12.659	0.001

In the normal group, the average blood glucose measurements were 90.52 ± 11.529 mg/dL using the chemistry analyzer, 95.88 ± 14.397 mg/dL using the glucometer, and 93.00 ± 12.659 mg/dL using the spectrophotometer.

Table 3. Comparison of Blood Glucose Levels Measured Using Chemistry Analyzer, Glucometer, and Spectrophotometer for High Participants

Variable	F(%)	Normal Mean ±SD	Pvalue
Chemistry Analyzer	25(100)	272.04±30.814	0.001
Glucometer	25(100)	278.44±30.271	0.001
Spectrophotometer	25(100)	275.48±30.574	0.001

In the high blood glucose group, the average measurements were 272.04 ± 30.814 mg/dL with the chemistry analyzer, 278.44 ± 30.271 mg/dL with the glucometer, and 275.48 ± 30.574 mg/dL with the spectrophotometer.

Discussion

This research conducted at Kuta Alam Health Center, Banda Aceh City, on 50 samples, examined blood glucose levels using chemistry analyzer, glucometer, and spectrophotometer. The sample population consisted of 38 women (76.0%) and 12 men (24.0%) with an average age of 57.8 years. In the normal glucose group, the lowest and highest blood glucose measurements were 72 mg/dL and 116 mg/dL, respectively, with an average of 90.52 ± 11.529 mg/dL using the chemistry analyzer; 75 mg/dL and 129 mg/dL, with an average of 95.88 ± 14.397 mg/dL using the glucometer; and 74 mg/dL and 120 mg/dL, with an average of 93.00 ± 12.659 mg/dL using the spectrophotometer. In the high blood glucose group, measurements ranged from 195 mg/dL to 342 mg/dL, with an average of 272.04 ± 30.814 mg/dL using the chemistry analyzer; 200 mg/dL to 358 mg/dL, with an average of 278.44 ± 30.271 mg/dL using the glucometer; and 199 mg/dL to 354 mg/dL, with an average of 275.48 ± 30.574 mg/dL using the spectrophotometer.

Statistical analysis using the F-test and t-test yielded a p-value of 0.001 ($p < 0.05$), leading to the acceptance of H1 and the rejection of H0. This indicates a significant difference in blood glucose levels measured using the chemistry analyzer, glucometer, and spectrophotometer. The observed differences in blood glucose measurements across the three methods may be attributed to variations in the sample types used. Although all samples were venous blood, the chemistry analyzer and spectrophotometer utilized blood serum, while the glucometer used whole blood. Venous blood, which carries a higher concentration of carbon dioxide as it returns from tissues to the lungs, may contribute to discrepancies in measurement outcomes.

Interfering factors that can lead to errors in glucometer readings are categorized into two groups: substances that may cause cross-reactions and those that affect enzyme activity in the test strip. Substances such as maltose, galactose, and xylose, which are structurally similar to glucose, can interfere with glucose measurements. Additionally, factors such as oxygen, acetaminophen, ascorbic acid, bilirubin, hematocrit levels, and low blood pressure can impact the accuracy of blood glucose testing. Another substance that may cause erroneous readings is the extraperitoneal dialysis solution containing 7.5% icodextrin. Icodextrin is metabolized into maltose, which is absorbed into the peritoneum, and this maltose, along with galactose and xylose, can lead to falsely elevated glucose readings when using glucometers that employ the glucose dehydrogenase (GDH)-pyrroloquinoline quinone (PQQ) method [16]. However, the glucose oxidase method, commonly used for glucose testing, is specific to glucose and is not affected by these other sugars. In the glucose oxidase method,

oxygen and acetaminophen can cause falsely high glucose readings, while ascorbic acid may result in falsely low glucose measurements [17]

CONCLUSION

From this study, it can be concluded that blood glucose levels are measured more precisely and accurately by the chemistry analyzer compared to the glucometer and spectrophotometer. Moreover, the variability in results among these tools must be carefully considered when making medical decisions related to blood glucose managementThis study concludes that blood glucose levels are measured more accurately and precisely using a chemistry analyzer compared to a glucometer or spectrophotometer. Additionally, the variability in results among these devices should be carefully considered when making medical decisions related to blood glucose management..

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