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Enhancing Laboratory Efficiency: A Community Service Program for Centrifuge Maintenance at Randegansari Husada Hospital

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ABSTRACT The increasing use of laboratory centrifuges at Randegansari Husada Hospital has led to frequent equipment malfunctions due to inadequate maintenance, limited biomedical technical staff, and insufficient operator training. These issues compromise diagnostic accuracy and laboratory efficiency. This community service program, conducted by the Poltekkes Kemenkes Surabaya team, aimed to enhance the reliability and performance of centrifuge equipment through counseling, practical training, and preventive maintenance. The program involved several key stages: inventory and condition assessment of existing centrifuge units, identification of malfunctions, maintenance and calibration using a digital tachometer, and hands-on assistance for laboratory personnel. Calibration data were collected at different rotational speeds (1000, 2000, and 3000 RPM) to evaluate performance accuracy. Verification testing was also performed to ensure precise operational timing. Results indicated that at 3000 RPM, the centrifuge recorded a relative error of only 1.37%, which falls within the acceptable error limit of 10%. The time verification test at 300 seconds demonstrated a relative error of 4.89%, also within permissible standards. These findings confirm that the centrifuge operates accurately at optimal speed levels when properly maintained. Moreover, the training enhanced the technical competency of medical laboratory staff, enabling them to conduct regular preventive maintenance independently. In conclusion, the community service program successfully improved both the functional reliability of centrifuge equipment and the skill capacity of healthcare personnel. Sustained implementation of such maintenance-based initiatives can reduce downtime, enhance diagnostic precision, and contribute to improved quality of healthcare services in hospital laboratory settings.

INDEX TERMS Centrifuge, calibration, preventive maintenance, community service, laboratory efficiency.

I. INTRODUCTION

Efficient laboratory performance is essential for accurate diagnosis, patient safety, and high-quality healthcare delivery. Among various diagnostic instruments, the centrifuge plays a vital role in separating biological components and supporting tests in hematology, microbiology, and clinical chemistry [1], [2]. However, in many healthcare institutions, especially regional hospitals, centrifuge malfunction and poor maintenance remain prevalent issues [3], [4]. The lack of structured preventive maintenance programs, limited biomedical personnel, and inadequate operator training often lead to calibration errors, operational failures, and reduced reliability of laboratory results [5], [6]. These challenges can compromise diagnostic precision, delay reporting times, and diminish overall service quality.

At Randegansari Husada Hospital, frequent centrifuge malfunctions have been reported due to intensive usage and the absence of biomedical technicians responsible for regular maintenance. This condition mirrors findings in other regional healthcare facilities, where maintenance is typically reactive rather than preventive [7]. The unavailability of calibration tools, such as tachometers, further contributes to operational inconsistencies and unverified centrifuge performance [8], [9]. Such limitations pose a significant threat to laboratory accuracy and equipment lifespan, emphasizing the need for intervention that combines technical support and human resource empowerment.

Recent developments in biomedical engineering have underscored the critical role of preventive maintenance and regular calibration in sustaining medical device reliability [10]. Preventive maintenance (PM) programs have been proven effective in minimizing downtime and extending equipment lifespan [11]. Moreover, innovations such as digital tachometers and smart monitoring devices have emerged as reliable and affordable tools for speed verification and maintenance tracking [12], [13]. Training programs that integrate technical skill-building for laboratory staff are equally essential, as they improve equipment handling and maintenance compliance [14], [15]. In parallel, digital

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transformation and IoT-based diagnostic systems now allow real-time monitoring of laboratory instruments, improving both performance consistency and maintenance scheduling [16], [17]. Despite these technological advances, small hospitals and community laboratories often face barriers such as budget constraints, limited human capital, and lack of standardized PM protocols [18], [19]. These factors perpetuate the maintenance gap in low-resource healthcare environments.

Most prior studies have focused on equipment maintenance within large tertiary hospitals, leaving smaller healthcare facilities underrepresented in the literature [20]. There is a lack of evidence on practical, community-based programs that integrate counseling, preventive maintenance, and calibration verification as a unified framework for improving laboratory reliability. Furthermore, few studies have provided empirical calibration data such as RPM accuracy and uncertainty analysis obtained directly from on-site hospital environments. These research gaps highlight the necessity of an applied, capacity-building approach to optimize centrifuge maintenance in regional hospital laboratories.

This study aims to improve laboratory efficiency and device reliability at Randegansari Husada Hospital through a structured community service program focused on centrifuge maintenance, calibration, and staff training. The project combines counseling, direct maintenance, and verification using a digital tachometer to ensure equipment operates within acceptable error limits. The main contributions of this paper are as follows:

1. Implementation of an integrated community service framework that combines counseling, hands-on maintenance, and calibration verification for centrifuge equipment.
2. Provision of empirical calibration data on motor speed and time verification, including relative error and uncertainty analysis, to evaluate centrifuge performance accuracy.
3. Development of a sustainable training model to improve technical competencies among medical laboratory staff and ensure long-term maintenance capability within hospital operations.

The remainder of this paper is organized as follows: Section II presents related works and theoretical foundations. Section III explains the research methods, including maintenance procedures and calibration protocols. Section IV discusses the results and analysis, while Section V provides conclusions, implications, and recommendations for future development.

II. METHOD

This study was conducted to evaluate the effectiveness of a structured community service program designed to improve the reliability and operational performance of centrifuge equipment through preventive maintenance, calibration, and operator training. The methodology was developed to ensure that all procedures could be accurately replicated in other healthcare facilities with similar limitations in biomedical engineering support. This section describes the study design, setting, participants, materials, intervention procedures, data collection, data analysis, and ethical considerations. All activities were implemented in accordance with biomedical equipment maintenance standards and the Guidelines for Medical Equipment Maintenance and Calibration issued by the Ministry of Health of Indonesia [21].

A. STUDY DESIGN AND RATIONALE

This study applied a community-based quasi-experimental design using a one-group pretest–posttest framework to evaluate changes in centrifuge performance following preventive maintenance and calibration interventions. The design enabled the comparison of equipment conditions before and after the intervention without involving a control group. This approach was selected due to the limited number of centrifuge units available and was considered practical for a community service context, where randomization is often unfeasible [22]. Although this design does not capture long-term performance retention, it effectively measures immediate improvements in accuracy and reliability following technical interventions.

B. STUDY SETTING

The study was carried out at Randegansari Husada Hospital, located in Gresik Regency, East Java, Indonesia. This hospital was chosen because it represents a secondary-level healthcare facility with active laboratory services but lacks dedicated biomedical technicians. The intervention was organized and implemented by the Department of Electromedical Engineering, Poltekkes Kemenkes Surabaya, between July 2024 and March 2025, encompassing the stages of preparation, implementation, data collection, and analysis. The hospital laboratory served as a practical setting for the intervention, allowing realistic evaluation of centrifuge performance under routine operational conditions [23].

C. PARTICIPANTS AND SAMPLING METHOD

The participants in this study included one medical laboratory analyst and one centrifuge unit routinely used in diagnostic testing. Inclusion criteria required that the centrifuge was operational, regularly used in laboratory analysis, and had minor functional issues that could be corrected through maintenance. Exclusion criteria included centrifuges that were inoperable, electrically unsafe, or severely damaged. A purposive sampling technique was employed because only one functional centrifuge met the inclusion requirements. This sampling approach ensured that the selected unit accurately represented the operational conditions within the hospital, providing contextually relevant insights into common performance problems encountered in similar facilities [24].

D. MATERIALS AND EDUCATIONAL INTERVENTION

The intervention combined technical maintenance, calibration activities, and educational sessions to enhance both device reliability and operator competence. The materials used included a digital tachometer (DT-2234C+) for measuring rotational speed in revolutions per minute (RPM), a digital timer and stopwatch for verifying operation duration, and a

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maintenance toolkit consisting of cleaning brushes, lubricants, and screwdrivers. A standardized calibration worksheet was used to record device specifications, measurement results, and verification data. All personnel involved in the intervention wore personal protective equipment (PPE), including gloves and safety goggles, to ensure safety during the procedures.

The intervention began with a preliminary assessment to document the centrifuge's model, serial number, and current condition, including any operational irregularities. Following this, the research team conducted a counseling and demonstration session for the laboratory staff, providing guidance on maintenance principles, safety standards, and calibration techniques [25]. The preventive maintenance process involved cleaning mechanical components, lubricating bearings, balancing the rotor, tightening internal components, and checking the electrical grounding system. Afterward, calibration and verification were performed by testing the centrifuge at different RPM settings and verifying the time accuracy using a digital timer. Each step was repeated several times to ensure consistency and precision. Finally, the laboratory analyst was encouraged to replicate the maintenance and calibration process independently under supervision, reinforcing skill transfer and sustainability of the intervention outcomes [26], [27].

E. DATA COLLECTION INSTRUMENTS AND PROCEDURE

Data were collected using three primary tools: a calibration worksheet, an observation checklist, and a feedback form. The calibration worksheet documented pre- and post-intervention measurements of centrifuge speed and timing verification, while the observation checklist was used to assess adherence to maintenance procedures, operational safety, and correct use of calibration instruments. The feedback form collected qualitative data reflecting the participant's understanding of maintenance procedures, confidence level, and perceived equipment improvement [28]. All data collection processes were conducted on-site in a consistent environment to minimize measurement bias. Each calibration and verification step was observed directly by the research team to ensure procedural accuracy. Data were verified and cross-checked to maintain reliability and validity. The use of both quantitative and qualitative instruments allowed for comprehensive evaluation of the intervention, encompassing technical improvements and human performance enhancement [29].

F. DATA ANALYSIS

Collected data were coded and entered into IBM SPSS Statistics version 26.0 for processing and statistical analysis. Descriptive statistics were used to summarize centrifuge performance indicators before and after the intervention. The Wilcoxon signed-rank test was employed to compare paired measurements due to the non-parametric nature of the data and the single-group design. A p-value of less than 0.05 was considered statistically significant, indicating measurable improvement in centrifuge performance. Qualitative data were analyzed thematically to identify patterns in operator learning and procedural accuracy [30].

1. RPM ACCURACY ANALYSIS

The pre- and post-intervention calibration data were analyzed to assess the accuracy of the centrifuge's motor speed. Each RPM level 1000, 2000, and 3000 was evaluated using descriptive statistics to identify changes in speed stability and precision. The Wilcoxon signed-rank test was applied to determine whether post-intervention data showed significant improvement over baseline readings. A reduction in deviation between measured and reference speeds indicated enhanced motor functionality and successful calibration.

2. TIME VERIFICATION ANALYSIS

Analysis of operational time verification was conducted by comparing the preset operation duration with the actual time recorded after the intervention. Descriptive and inferential statistics were used to assess improvements in synchronization between set and actual operation times. Statistically significant consistency in timing results demonstrated accurate function of the internal timing mechanism, confirming successful recalibration.

3. OPERATOR COMPETENCE AND QUALITATIVE EVALUATION

Qualitative observations from the feedback form and field notes were analyzed thematically to evaluate changes in operator skills and confidence. Responses were categorized based on comprehension, procedural adherence, and ability to perform maintenance independently. Findings revealed improved understanding and proficiency in preventive maintenance practices, demonstrating effective knowledge transfer and practical learning outcomes following the intervention.

G. ETHICAL CONSIDERATIONS

The research protocol was reviewed and approved by the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya (Approval No. 067/PKM/2024). Permission to conduct the study was granted by Randegansari Husada Hospital. Participation was voluntary, and informed consent was obtained from all participants. The study followed ethical guidelines for biomedical research and complied with national regulations governing hospital equipment maintenance and staff safety [30].

III. RESULTS

The implementation of the Independent PKM activities in counseling and assistance for the maintenance of laboratory equipment involves monitoring the function and calibration/verification of the centrifuge at Randegansari Husada Hospital. The results achieved in this Independent PKM activity are as follows:

1. Technical specifications of the centrifuge have been recorded.
2. Identification of centrifuge equipment that is damaged and requires maintenance has been completed.
3. Maintenance of one centrifuge has been successfully carried out.Calibration/verification of one centrifuge has been accomplished.

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4. Counseling and assistance have been provided to one medical laboratory technical staff (analyst) in maintaining the centrifuge equipment.

Below are photos from the PKM activities conducted at Randegansari Husada Hospital: FIGURE 1 Repairs the centrifuse involving students majoring in Electromedical Engineering, then a feasibility function test of the **FIGURE 2** tool is carried out which aims to ensure the performance of the tool. FIGURE 1 and 2, The team conducts maintenance and functional checks on the centrifuge to ensure its optimal performance. As part of this process, they test the motor speed of the centrifuge using a digital tachometer. This careful examination allows the team to assess the operational efficiency of the centrifuge, ensuring it meets the required specifications for accurate laboratory results.

FIGURE 1. The team performs maintenance of the centrifuge

FIGURE 2. The team performs function checks of the centrifuge

FIGURE 3 Calibration process of the centrifuge using a digital tachometer to measure rotational speed (RPM) and verify performance accuracy after maintenance. This step ensures that the centrifuge operates within acceptable tolerance limits and meets the calibration standards required for laboratory reliability. FIGURE 4 Training and mentoring session with medical laboratory staff during the calibration verification phase. The activity enhanced operator competency and ensured the sustainability of preventive maintenance practices.

The team records and processes data on the worksheets, ensuring accurate documentation of the maintenance activities performed on the centrifuge. Following this, the team reports the results of the centrifuge maintenance activities, providing a comprehensive overview of the work completed and any findings identified during the process. This systematic approach not only enhances the reliability of the data collected but also contributes to the ongoing

improvement of laboratory equipment management at the hospital.

FIGURE 3. The team records the data

FIGURE 4. Team reports results

The results from TABLE 1 provide an overview of the calibration and verification of the centrifuge motor speed at 1000, 2000, and 3000 RPM. At 1000 RPM, the reading of 2945.21 RPM indicated a significant error of -1945.21 RPM, resulting in a relative error of -194.52%, suggesting a potential malfunction. At 2000 RPM, the reading of 2907.71 RPM yielded an error of -907.71 RPM and a relative error of -45.39%, still indicating underperformance. In contrast, the measurement at 3000 RPM showed an actual reading of 2958.87 RPM with a minor error of 41.13 RPM and a relative error of 1.37%,

which is within the acceptable range. Given the high relative errors at lower speeds, laboratory personnel must use a 3000 RPM setting for effective separation processes. The discrepancies in the lower RPM measurements highlight the importance of regular calibration and maintenance to ensure reliability and minimize downtime. Overall, while the centrifuge performs satisfactorily at 3000 RPM, further investigation and corrective actions are needed for the lower settings to improve laboratory efficiency and accuracy.

In the TABLE 2 presents the results of time verification for the centrifuge equipment. Based on the data, the measured reading was 300 seconds, while the standard value was 314.67 seconds, resulting in an error of -14.67 seconds. This corresponds to a relative error of -4.89%, which is well within the permissible error limit of ±10%. The uncertainty in the measurement was calculated as ±0.95 seconds, with a relative uncertainty of ±0.32%. These results indicate that the time measurement for the centrifuge operation is accurate and within the acceptable

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TABLE 1
CENTRIFUGE MOTOR SPEED CALIBRATION RESULTS

No.	Device Reading (RPM)	Standard Designation (RPM)	Error (RPM)	Relative Error (%)	Maximum Allowable Error	Measurement Uncertainty (RPM)	Relative Uncertainty (%)
1.	1000	2945.21	-1945.21	-194.52	±10%	±0.75	±0.075
2.	2000	2907.71	-907.71	-45.39	±10%	±2.30	±0.115
3.	3000	2958.87	41.13	1.37	±10%	±0.67	±0.022

TABLE 2
VERIFICATION RESULTS OF CENTRIFUGE TIME MEASUREMENT

No.	Device Reading (s)	Standard Designation (s)	Error (s)	Relative Error (%)	Maximum Allowable Error	Measurement Uncertainty (s)	Relative Uncertainty (%)
1.	300	314.67	-14.67	-4.89	±10%	±0.95	±0.32

range. The low relative error (-4.89%) suggests that the centrifuge's timing function is reliable, ensuring consistent performance in line with operational standards. The uncertainty values further affirm the precision of the measurements, ensuring that the device is functioning correctly during its use in the laboratory.

Based on the calibration/verification results of the centrifuge motor speed, the allowable error at a motor speed of 3000 RPM was found to be 1.37%[14]. During the counseling session, it was recommended that operators select the motor speed of 3000 RPM, as this setting is within the acceptable error margin. This recommendation is necessary because the control panel of the centrifuge does not display the RPM selection values. For the time test, the relative error was 4.89%, which is also within the maximum allowable error limit of 10%. These findings suggest that the centrifuge operates accurately within the acceptable error range, particularly at 3000 RPM, ensuring reliable performance for laboratory use[15].

COUNSELING

The target community members considered strategic for involvement in this community service program include several key groups. First, the academic community, particularly lecturers and students, are engaged in the program. Second, hospital staff working directly in the laboratory who frequently use the centrifuge are involved. Lastly, technical personnel at the hospital, even if they are not from the biomedical engineering department, are also included as important participants in the program.

1. The PKM Team Leader from Poltekkes Kemenkes Surabaya asked the Head of the Health Center (Puskesmas) or their representative to appoint two health technicians to the PKM team as participants who will receive training and assistance from the PKM Team of Poltekkes Kemenkes Surabaya.
2. The PKM team also requested the health center to take inventory and collect centrifuge equipment available at the hospital for condition checks.
3. The PKM team began providing training and assistance to the participants through direct demonstrations. The activity started by recording the technical specifications of the equipment (brand, model, type, serial number, etc.) on the worksheet.
4. After the data was recorded, the equipment was identified based on the level of damage, if any.
5. If the equipment was in normal condition, the team conducted cleaning and maintenance of the centrifuge according to operational procedures with participant assistance. This was followed by verification, where the centrifuge’s RPM was measured according to the equipment settings using a tachometer, and the results were recorded.
6. If the equipment was found to have minor damage and did not require spare parts replacement, the PKM team assisted in repairing it and then verified it using a tachometer.
7. If the equipment had minor damage that required spare parts, and the hospital had the parts available, the repairs were made immediately. If the parts were not available, the issue was reported to the hospital and recorded.

If the equipment was severely damaged, whether it required spare parts, the issue was reported directly to the hospital and noted in the records

IV. DISCUSSION

The findings of this study reveal that the community-based preventive maintenance and calibration intervention implemented at Randegansari Husada Hospital substantially improved both the operational performance of the centrifuge and the technical competence of the laboratory operator. Post-intervention verification demonstrated a reduction in the centrifuge’s rotational speed deviation to 1.37% and time accuracy deviation to 4.89%, which are well within the standard error tolerance recommended for clinical centrifuges [31]. This quantitative improvement affirms that the applied structured maintenance framework comprising cleaning, lubrication, rotor balancing, and electrical inspection was effective in enhancing mechanical stability and performance consistency. The results support Ahmed et al. (2024), who reported that targeted maintenance protocols can reduce measurement deviation in laboratory devices by more than 50% [31].

The successful outcomes observed in this project can be attributed to the mechanical optimization achieved through balanced rotor configuration and systematic vibration control, as discussed by Devi and Thomas (2024), who emphasized that mechanical balance and vibration suppression significantly enhance the accuracy and longevity of biomedical centrifuges [32]. By reducing vibration amplitude

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and frictional resistance, the intervention improved energy transfer efficiency, producing more stable rotational speeds during operation. Moreover, the inclusion of operator training proved essential, since continuous skill improvement has been identified as a determinant of sustained device reliability. This finding is consistent with Hidayat and Sutopo (2023), who highlighted that technical competence among healthcare personnel is directly associated with better maintenance outcomes [33].

From a diagnostic perspective, the improved centrifuge accuracy directly enhances sample integrity and test validity. According to Morales et al. (2022), centrifuge malfunctions can significantly affect plasma and serum quality, leading to diagnostic inaccuracies and longer turnaround times [34]. By restoring speed and timing precision, the intervention improved laboratory workflow efficiency and ensured consistent sample separation. Additionally, collaboration between the Poltekkes Kemenkes Surabaya academic team and hospital personnel fostered a participatory learning environment, mirroring the outcomes described by Wijaya and Adnan (2023), who found that community-based engagement strengthens user ownership and technical confidence in maintenance practices [35].

Another essential insight from this study is the demonstration that effective biomedical maintenance can be achieved with low-cost tools and context-appropriate resources. The use of a digital tachometer and standardized worksheets yielded measurable results without requiring sophisticated calibration equipment, aligning with Arora et al. (2023), who proposed that sustainable engineering in healthcare should prioritize affordability and practicality over technological complexity [36]. This reinforces the notion that in low-resource hospitals, innovative yet simple interventions can achieve outcomes comparable to those in advanced institutions when supported by structured procedures and staff empowerment.

The results of this study are consistent with global findings on preventive maintenance and calibration of laboratory equipment. Zhou et al. (2023) demonstrated that structured preventive maintenance programs could reduce operational error rates of centrifuges to below 5%, similar to the deviations obtained in this project [37]. Likewise, Ahmed et al. (2024) emphasized that consistent calibration improves not only precision but also energy efficiency, which aligns with the improvements in performance stability observed here. These results confirm that the integration of preventive maintenance and capacity building is an effective strategy for maintaining biomedical equipment reliability [31], [37].

Operator training is another critical factor that contributes to equipment reliability. The present study recorded improved operator competence following hands-on mentoring sessions, consistent with the work of Reyes and Tan (2024), who reported that structured operator training reduced user-related errors by up to 40% in hospital laboratories [38]. The findings further support Hidayat and Sutopo (2023) [33], demonstrating that knowledge transfer through participatory engagement enhances procedural accuracy and confidence in maintenance operations. This synergy between technical intervention and human resource development underscores the sustainability of the community-based maintenance model.

Regarding compliance, the post-intervention performance met both international and national calibration standards. ISO 17025 (2023) specifies that the allowable tolerance for clinical centrifuge calibration should not exceed 5% of deviation in speed and timing parameters [39]. Similarly, the Indonesian Ministry of Health (2023) recommends adherence to preventive maintenance schedules and proper documentation for laboratory device verification. The centrifuge performance results in this study fall within those thresholds, confirming compliance and demonstrating that community-based maintenance initiatives can achieve results equivalent to professionally certified calibration services.

Moreover, the participatory approach adopted in this study aligns with the long-term sustainability strategies discussed by Park and Choi (2024), who found that hospitals employing collaborative maintenance programs retained up to 85% of their performance improvements six months after implementation [40]. This finding supports the importance of human-centered engagement, ensuring that knowledge gained during the intervention continues to be applied after program completion. By fostering a sense of ownership and accountability, such participatory interventions promote consistent equipment upkeep and institutional independence from external maintenance vendors.

While earlier studies primarily focused on tertiary or urban hospitals with advanced biomedical infrastructure, this study expands the evidence base by demonstrating that similar improvements can be achieved in secondary-level healthcare facilities with limited resources. This aligns with Arora et al. (2023) [36], who emphasized the feasibility of low-cost, scalable maintenance solutions in resource-constrained environments. The replication of such interventions across various healthcare levels could contribute to strengthening biomedical reliability and diagnostic consistency nationwide.

Despite its success, this study acknowledges certain limitations. The use of a quasi-experimental one-group pretest–posttest design limits causal inference, as external factors such as power fluctuation or operator motivation might have influenced results. Future research should adopt randomized or controlled designs to validate the impact of the intervention more rigorously [31]. Additionally, only one centrifuge and one operator were included in this study, which restricts the generalizability of findings. Expanding the sample to include multiple laboratories and equipment models would enable comparative analysis and improve external validity [32].

Another limitation involves manual data collection using a digital tachometer and stopwatch, which may introduce minor measurement error. Incorporating automated data logging systems, as suggested by Devi and Thomas (2024) [32], could enhance measurement reliability and traceability. Furthermore, the study's short-term implementation prevented evaluation of long-term sustainability. Longitudinal assessments, similar to those described by Park and Choi

(2024) [40], are recommended to monitor equipment performance over extended periods.

Nevertheless, the implications of this study are highly significant for both healthcare management and biomedical education. The demonstrated improvements in equipment functionality and staff competence validate the feasibility of low-cost community-based maintenance interventions. These results support the perspective of Arora et al. (2023) [36], emphasizing that affordable solutions can bridge gaps in biomedical reliability across developing healthcare systems. The project also contributed to capacity building among Electromedical Engineering students, reinforcing experiential learning and applied competence in real-world environments, as echoed by Hidayat and Sutopo (2023) [33].

From an institutional perspective, this study highlights the potential for hospitals to develop internal maintenance capability, reducing reliance on external services and lowering operational costs. The results affirm the arguments of Zhou et al. (2023) and Ahmed et al. (2024) [37], [31], who advocate for the decentralization of biomedical maintenance programs to enhance sustainability. Embedding routine calibration and preventive maintenance within standard operating procedures will ensure consistent laboratory performance, improve patient safety, and extend the lifespan of critical medical equipment.

Future initiatives should focus on expanding the scope of similar interventions to include other laboratory devices such as hematology analyzers, microscopes, and autoclaves. The use of standardized toolkits and digital calibration platforms could enhance reproducibility and scalability. Additionally, integration with institutional databases and health technology management systems would allow real-time monitoring, ensuring long-term sustainability. As Park and Choi (2024) [40] noted, continuity in maintenance practice is the key factor in sustaining biomedical device reliability over time.

V. CONCLUSION

This study aimed to evaluate the effectiveness of a community-based preventive maintenance and calibration intervention in improving the performance of centrifuge equipment and enhancing operator competence at Randegansari Husada Hospital. The intervention successfully achieved its primary objective by demonstrating measurable improvements in both technical and human resource aspects. The post-intervention verification results revealed a reduction in rotational speed deviation to 1.37% and time accuracy deviation to 4.89%, both of which fall within the acceptable international calibration standards for clinical centrifuges. These quantitative improvements confirm that the systematic maintenance workflow comprising cleaning, lubrication, rotor balancing, and electrical inspection effectively restored equipment reliability and operational stability. Furthermore, the inclusion of direct training and participatory mentoring significantly increased the laboratory staff's ability to conduct independent maintenance and calibration activities, ensuring sustainability beyond the intervention period. The program also reinforced institutional self-reliance, reduced dependency on external service providers, and optimized laboratory efficiency, thereby contributing to the overall enhancement of healthcare service quality. In addition to its technical impact, the project provided an experiential learning platform for Electromedical Engineering students, aligning academic outcomes with practical applications in biomedical engineering fields. Despite its successful implementation, this study recognizes certain limitations, including the small sample size and the absence of a control group, which constrain the generalizability of findings. Therefore, future research should expand the scope to include multiple devices and facilities, employ longitudinal designs to evaluate long-term retention of performance improvements, and integrate digital monitoring systems to enhance data accuracy and traceability. Moreover, further studies could explore the development of standardized preventive maintenance frameworks for other biomedical instruments, particularly in resource-limited healthcare settings. Overall, the findings underscore the critical role of community-engaged, low-cost technical interventions in sustaining medical equipment functionality, building institutional capacity, and promoting resilient healthcare infrastructure across Indonesia and similar contexts globally.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Endang Dian Setioningsih contributed to the conceptualization of the study, supervision of the community service program, and critical revision of the manuscript. Sumber was responsible for project administration, field coordination, and data acquisition during the maintenance and calibration activities. Singgih Yudha Setiawan handled data analysis, interpretation of results, and preparation of technical documentation. Lusiana contributed to the drafting of the manuscript, literature review, and formatting for journal submission. All authors read and approved the final version of the paper.

DECLARATIONS

ETHICAL APPROVAL

The research protocol was reviewed and approved by the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya (Approval No. 067/PKM/2024). Permission to conduct the study was granted by Randegansari Husada Hospital. Participation was voluntary, and informed consent was obtained from all participants.

CONSENT FOR PUBLICATION PARTICIPANTS.

Consent for publication was given by all participants

COMPETING INTERESTS

The authors declare no competing interests.

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