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ORIGINAL

Longitudinal Assessment of Competency Development in Post-Mortem Examination Training for Medical Students

Evaluación longitudinal del desarrollo de competencias en la formación de estudiantes de medicina en exámenes post mortem

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ABSTRACT

Post-mortem examinations were vital in forensic science, helped to determine the cause of death and offered essential insights for medico-legal investigations. Proper training in autopsy procedures was crucial for medical students pursuing careers in forensic pathology. However, little was known about how competency in this area develops over time. Research aims to assess how medical students' competency in performing post-mortem examinations evolves throughout their training and to identify factors that influence skill development. A total of 183 medical students participated, with their competency evaluated at various stages of training. During assessments, participants demonstrated their technical competence as well as diagnostic abilities and procedural expertise. IBM SPSS software version 29 has been utilized in the research. ANOVA, Chi-square tests and T-tests formed the basis for performance assessment, as these methods revealed periodic performance differences and competency reinforcement variables. Student skills significantly improved due to the training curriculum used during the educational journey. Students achieved notable advancement in the technical capabilities together with improvement in precise medical diagnosis. Education combined with repeated practice developed essential skills significantly as early training focused on distinct abilities compared to later stages of training. Post-mortem examination training programs helped students achieve marked progress in the competence development. Systematic assessment methods proved essential for forensic pathology education, as they helped medical students achieve professional-level skill development, according to the data results.

Keywords: Post-Mortem Examination; Medical Education; Skill Progression; Technical Skills; Diagnostic Accuracy; Procedural Knowledge.

RESUMEN

Los exámenes post mortem eran vitales en la ciencia forense, ayudaban a determinar la causa de la muerte y ofrecían perspectivas esenciales para las investigaciones médico-legales. Una formación adecuada en los procedimientos de autopsia era crucial para los estudiantes de medicina que querían dedicarse a la patología forense. Sin embargo, poco se sabía sobre cómo se desarrolla la competencia en esta área con el paso del tiempo. El objetivo de la investigación es evaluar cómo evoluciona la competencia de los estudiantes de medicina en la realización de exámenes post-mortem a lo largo de su formación e identificar los factores que influyen en el desarrollo de habilidades. Participaron 183 estudiantes de medicina, cuya competencia

se evaluó en distintas fases de la formación. Durante las evaluaciones, los participantes demostraron su competencia técnica, así como su capacidad de diagnóstico y su pericia en los procedimientos. En la investigación se ha utilizado el programa informático IBM SPSS versión 29. ANOVA, pruebas Chi-cuadrado y pruebas T constituyeron la base de la evaluación del rendimiento, ya que estos métodos revelaron diferencias periódicas de rendimiento y variables de refuerzo de la competencia. Las competencias de los estudiantes mejoraron significativamente gracias al plan de formación utilizado durante el itinerario educativo. Los estudiantes lograron un notable avance en las capacidades técnicas junto con una mejora en el diagnóstico médico preciso. La formación combinada con la práctica repetida desarrolló las habilidades esenciales de forma significativa, ya que la formación temprana se centró en habilidades distintas en comparación con las etapas posteriores de la formación. Los programas de formación en exámenes post mortem ayudaron a los estudiantes a lograr notables avances en el desarrollo de competencias. Los métodos de evaluación sistemática resultaron esenciales para la formación en patología forense, ya que ayudaron a los estudiantes de medicina a alcanzar un desarrollo de competencias de nivel profesional, según los resultados de los datos.

Palabras clave: Examen Post Mortem; Educación Médica; Progresión de Competencias; Habilidades Técnicas; Precisión Diagnóstica; Conocimientos Procedimentales.

INTRODUCTION

Medical education depends on post-mortem examination because it delivers three essential educational benefits: disease Pathophysiology understanding and human anatomical knowledge development alongside improved diagnostic abilities for students. The procedure enables students to examine death causes, thereby helping their formation of complete clinical understanding.[1] The educational tool provides learners with a special capability to link examination notes from living patients to autopsy data for a better understanding of medical diagnosis and care protocols. Post-mortem examinations help students master important forensic medicine skills by training to understand death-related ethics and rules as well as the medical-legal system of death.[2] Through autopsy exposure, medical students enhance their thinking ability through assessment of clinical diagnosis variations with actual post-mortem death causes. Students gain thorough knowledge about human biology by studying post-mortem disease manifestations of various organ systems during this experience.[3] Medical education programs can include post-mortem training, because this training enhances future doctors' competencies when addressing death cases and supporting end-of-life care and helps to achieve better clinical diagnoses. The valuable training obtained by practical learning students leads to higher medical school productivity and improved skills in handling medical complications that occur during clinical practice.[4,5] Forensic medical services provide essential functions to medical investigations through post-mortem evaluations. The whole process functions as an essential tool that aids in death because identification helps to reveal criminal activities and generates vital investigation information necessary for legal cases. Current medical curricula provide limited education about forensic medicine, particularly regarding post-mortem examination methods, even though the subject proves fundamental for this field.[6] Insufficient education provided to students produces professional difficulties regarding essential skills necessary for performing autopsies as future medical professionals in clinical and legal settings. Forensic medical knowledge development remains vital because it ensures proper post-mortem results together with preserving proper standards when dealing with sensitive cases.[7] To conduct a post-mortem examination one can have a deep understanding of anatomy and pathology along with full knowledge of legal, regulations that determine. Students who receive insufficient training show reduced capacity to operate autopsy tools correctly along with diminished and understanding that results in poor advancement of their career. The inclusion of forensic medicine education in medical curricula becomes essential because this creates graduates who understand properly how to conduct post-mortem examinations with confidence coupled with necessary competence and ethical awareness.[8] The foundation helps forensic investigations achieve higher quality levels through reliable information needed for legal proceedings. Medical institutions use advanced educational methods alongside technological resources to advance training methods for post-mortem examination skills in their medical programs. Medical schools adopt mixed autopsy teaching methods by combining traditional supervised cadaver dissection with virtual autopsy instruments, such as 3D imaging and digital dissection tools.[9] Modern post-mortem examination software lets students investigate human body anatomy and pathology while selecting their learning sequence freely. Modern training methods based on simulation have become essential, as medical students practice post-mortem procedures under controlled scenarios before performing examinations on actual deceased individuals.[10] Progress in post-mortem examination education has not eliminated several training inadequacies. Medical schools face obstacles in ensuring sufficient realistic autopsy training, as lack both deceased bodies suitable for student practice and enough trained forensic pathologists to guide students. Under these conditions, students fail to gain the essential skills and self-assurance required to conduct an autopsy competently.[11]

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The integration of post-mortem examination training remains deficient inside medical curricula as institutions direct their emphasis on clinical abilities and theoretical knowledge. Competency Activity-based training in forensic medicine appears to prevent students from gaining a complete grasp of the importance of autopsy for clinical practice and legal cases.[12] A limitation of competency development in post-mortem examination training for medical students is the potential bias introduced by limited sample size and institutional setting, so the research considered a larger sample size and employed ANOVA, T-Test, and Chi-square tests to evaluate the competency development in post-mortem examination training through assessments measured, such as technical skills, diagnostic accuracy, and procedural knowledge.

Post-mortem examination training had been provided with the use of actors and simulated mannequins. Participants gave positive rating to the training, which was conducted in small groups of no more than five. Research indicate that introduction and continuance could boost confidence in day-to-day practice and enhanced the quality of external post-mortem examinations.[13] Intensive training employed contemporary learning techniques could improve the caliber of medical external post-mortem exams. Although there were deficiencies in several courses, two stations in Halle, Germany, in 2016 demonstrated positive results. This could result in better instruction.[14] General practitioner post-graduate trainees' attitudes, knowledge, and abilities about external post-mortem examination (EPME) were examined. 33 % of the 380 trainees were regular sections and less than 18 % are confident in their ability to distinguish between natural and unnatural causes.[15] Students' perceptions of comprehension and learning experience were much improved by the inclusion. Positive motifs about patient empathy, realism, and visual learning were identified in the qualitative results. It concludes that using images provides students with a realistic learning experience and a virtual tour of the human body.[16] Issues include mistrust of donations, insufficient safeguards for children, information complexity, and excessive costs for research institutes to standardize the informed consent structure and promote public involvement.[17] The knowledge of pertinent laws was inconsistent in at least one case for 54 % of the respondents. According to the study, just because someone feels qualified doesn't necessarily mean that they can conduct external postmortem examinations. The system is undermined by inconsistent actions and beliefs.[18] Students' feedback on an online course in applied forensic medicine and pathology highlights the impact of the COVID-19 pandemic on the transition to remote learning. Despite the shift, students remained actively engaged and recognized the relevance of forensic medicine for their future clinical careers. The online course received positive reviews and favorably compared to previous blended learning formats.[19] In 2020, the Italian Parliament passed legislation aiming to strengthen body donation by guaranteeing respect for the dignity of the departed. Anatomical dissection is a vital medical activity that helps students comprehend human organs and fosters respect for death.[20]

METHOD

Medical student development regarding post-mortem procedure competency during educational progression was observed in the research. The assessment evaluates technical abilities in addition to diagnostic accuracies and procedural mastery among medical students across their academic progression. The research investigates performance factors to prove that continuous training programs can exist for forensic pathology. Figure 1 represents the schematic diagram of the methodology flow.

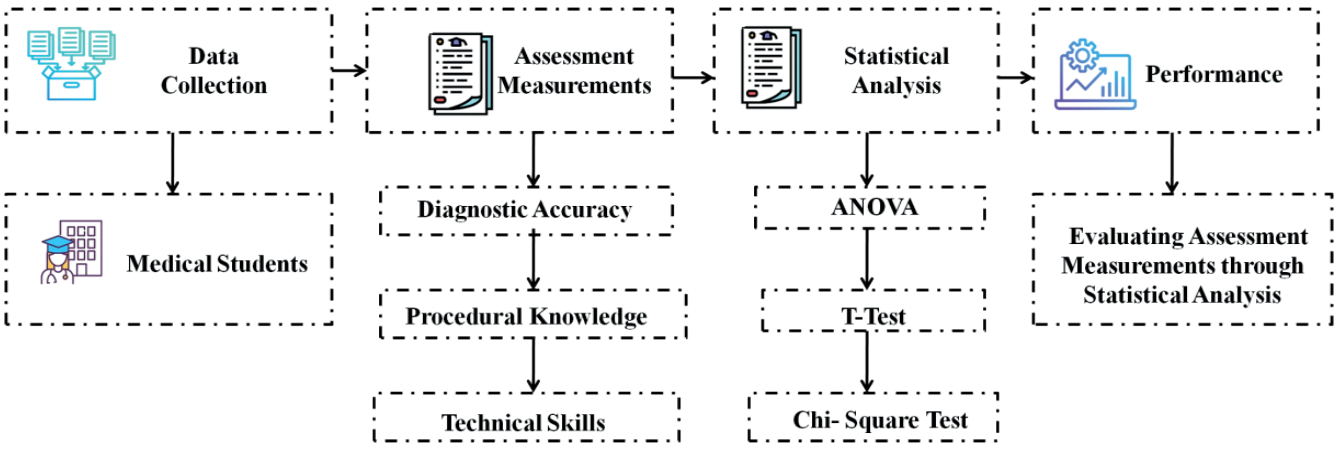

Figure 1. Schematic diagram of methodology flow

Data collection

There are 183 medical students whose enrollment covered different academic years from the first through the graduation year who were included in the research. The evaluation system for post-mortem examination competency served the research to evaluate student proficiency growth patterns during training. Assessments

administered at set intervals allowed researchers to conduct comprehensive evaluations of trainees' technical skills, diagnostic precision and procedural skills. The evaluation method delivered important information about how students in forensic pathology programs develop their medical skills and affects their educational advancement.

Assessment measurement

A total of 183 medical students received evaluation through an assessment of their technical competence and their diagnostic ability, along with their understanding of post-mortem procedures. Students were assessed through multiple evaluation methods to determine their capabilities in whole-body post-mortem procedures. Tracking competency growth during training happened through several evaluation points, so the process revealed the most impactful areas for improvement.

Technical skills

The education of medical students about post-mortem evaluations serves as an essential aspect of their forensic pathology training before they can build their technical competencies. To perform accurate autopsies medical professionals need various technical skills, which include performing precise dissection procedures as well as gathering tissue samples and locating body organs inside the body. The procedures need careful detail focus because any minor mistakes can lead to wrong findings. Through their education students learn to enhance their medical capability, which allow them to conduct complex procedures with excellent precision. The slow development of such skills remains essential because it helps students achieve proficiency in dealing with complex medical situations that yield trustworthy outcomes. Students need the seamless integration of diagnostic ability and technical expertise to become competent forensic pathologists in their future careers. The expert level of a medical professional depends on their dedication to precise death cause determination and decision-making in medico-legal situations.

Diagnostic accuracy

Post-mortem examination training programs require precise case diagnosis as an essential factor for developing student competence. The educational journey for medical students develops their ability to detect death causes and concealed medical conditions. Post-mortem examinations achieve more accurate results when diagnoses are correct and such accuracy adds crucial value to legal autopsy investigations. The training sectors of educators benefit through diagnostic accuracy monitoring because evaluation data shows student progress in accurate diagnosis formation, which leads to their development as forensic pathologists skilled in evidence-based conclusions.

Procedural knowledge

The main focus of medical students' post-mortem examination education centers on teaching them procedural knowledge acquisition methods. Standard autopsy protocols require learners to master dead body handling techniques together with tool preparation methods and observation recording practices during autopsies. Student expertise in procedures allows them to conduct examinations in a self-assured manner while maintaining ethical and legal compliance and maintaining operational consistency. Students' comprehension of forensic tools and procedures becomes more sophisticated during training because it enhances their capability development to perform accurate post-mortem assessments in forensic pathology.

Statistical assessment

The IBM SPSS software version 29 has been utilized in the research. The research employed ANOVA and T-Test together with Chi-square tests to measure changes in post-mortem examination abilities over time through statistical assessments of student performance development. ANOVA determined training competency variations among different stages to detect whether important skill improvements existed between training start and completion. The T-tests demonstrated how students' scores evolved between specific time points by performing individual pair-wise tests of scores. Categorical variables were analyzed through the Chi-square test to establish if prior experience or year of study had any significant influence on competency development. Multiple assessment methodologies combined to deliver a strong understanding of elements that affect students' learning of skills and their proficiency development.

Performance analysis

The evaluation process consisted of measuring essential competencies, which included technical abilities together with diagnostic precision and procedural knowledge. ANOVA and T-tests together with Chi-square tests analyzed performance variations and competency growth factors through statistical methods. The post-mortem examination training program produced observable skill development among students, especially in technical proficiency together with diagnostic accuracy improvement.

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Demographic characteristics

The examination of the participant population evaluates participant population groups to provide insights into how various student populations advance through their post-mortem training experience. Performance evaluation of different groups enables researchers to find particular competency development patterns that reveals factors that affect learning results. The method reveals the diverse ways, where the students learn new skills due to their background knowledge and training effort together with their adoption of technical aids. The assessment system allows specific changes to be made in the training process so that each trainee gets the support they need to fulfill post-mortem competency requirements. Table 1 depicts the demographic characteristics of medical students. Figure 2 presents the demographic characteristics of medical students (a) gender and (b) year of study.

Table 1. Demographic characteristics of medical students

Categories	Group's	Count (n=183)	Percentage (%)
Gender	Male	99	54,1
	Female	84	45,9
Age Range	18-22	123	67,2
	23-27	48	26,2
	28+	12	6,6
Year of Study	Year 1	45	24,6
	Year 2	50	27,3
	Year 3	43	23,5
	Year 4	30	16,4
	Year 5+	15	8,2
Geographical Location	Urban	105	57,4
	Rural	78	42,6
Prior Autopsy experience	Yes	55	30,1
	No	128	69,9

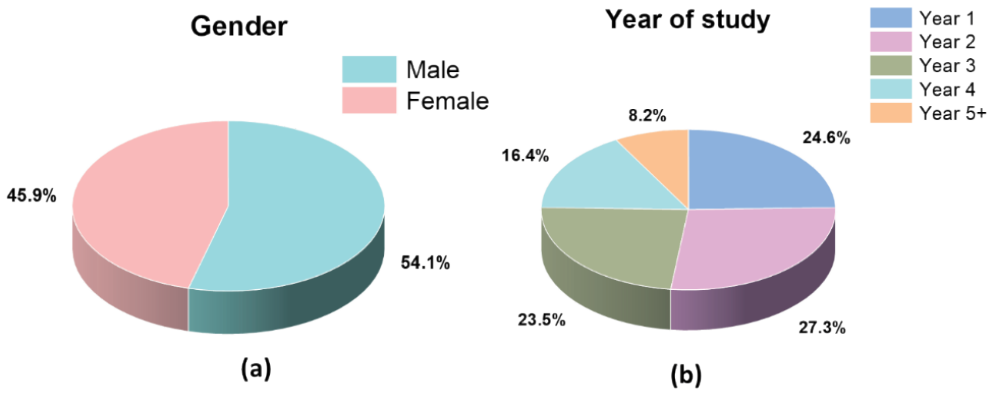

Figure 2. Graphical representation of (a) Gender and (b) Year of study

ANOVA

ANOVA determined the variations in competency growth between successive stages of post-mortem examination instruction for medical students. ANOVA revealed performance changes among students through mean comparison at different training stages to determine if their skills improved with time. This statistical approach demonstrated that students became more capable in their post-mortem examination skills through consistent practice and education by measuring their progress. The results show significant differences in technical skills (p = 0,015), diagnostic accuracy (p = 0,002), and procedural knowledge (p = 0,005), indicating that competency development improved over time. Table 2 presents the quantitative values of ANOVA. The source of variation in between groups and within groups is as shown in equation (1).

$$F = \frac{\text{Between-group variance}}{\text{Within-group variance}} = \frac{MT_{between}}{MT_{within}} \qquad (1)$$

Table 2. Quantitative values of ANOVA

Source of Variation	ss	df	MS	F-statistic	P-value
Between Groups (Technical skills)	45,50	3	15,17	3,50	0,015
Between Groups (Diagnostic accuracy)	53,45	3	17,82	5,30	0,002
Between Groups (Procedural Knowledge)	51,90	3	17,30	4,60	0,005
Within Groups	215,67	179	1,20	-	-
Total	366,02	182		-	-

Note: Sum of squares (ss), Degrees of Freedom (df), Mean Squares (MS)

T-Test

Medical students' post-mortem examination training competency scores were analyzed using the T-Test for different stages of their education. This statistical evaluation tool determined if student performance changed significantly during multiple points of training by assessing three key competencies. Evaluation through the T-Test revealed student skill progress by comparing the mean scores across different groups, demonstrating patterns of expertise growth. Forensic pathology education improved its precision in identifying development benchmarks; the t-values for technical skills, diagnostic accuracy, and procedural knowledge indicate statistically significant improvements, with p-values less than 0,001. Table 3 illustrates the quantitative values of the T-Test and figure 3. Means of the T-test are calculated on the basis of equation (2).

$$s = \sqrt{\frac{}{}} \qquad (2)$$

Table 3. Quantitative values of T-Test

Factors	Mean (Early stage)	Mean (Late stage)	t-value	df	P-value
Technical skills	65,4	85,2	8,32	182	<0,001
Diagnostic accuracy	70,1	88,4	7,91	182	<0,001
Procedural knowledge	60,5	80,3	6,77	182	<0,001

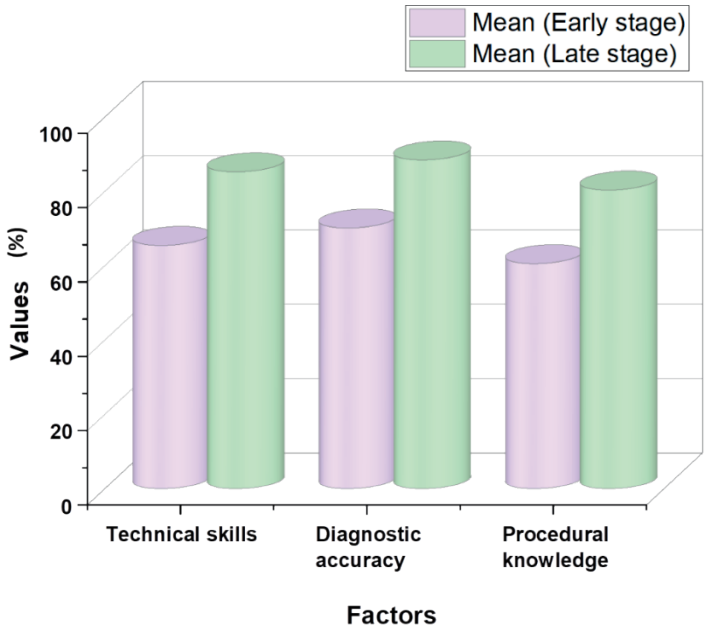

Figure 3. Graphical representation of early and late-stage

Chi-square test

An evaluation of post-mortem examination training competency dependence on various factors utilized Chi-square procedures. The statistical method helped to recognize competence variations during different training durations, including both the start and finish periods. The Chi-square tests evaluated student technical proficiency diagnostic accuracy and procedural knowledge development through the analysis of demographic variables and other data points, including prior experience and year of study. The Chi-square tests revealed that there was a significant improvement in technical skills ($p < 0,05$) and procedural knowledge ($p < 0,05$) between the early and late stages of training. However, the difference in diagnostic accuracy was not significant ($p > 0,05$) and the formula of Chi-square test is described in the equation (3). Tables 4, 5, and 6 present the values of the chi-square test in technical skills, diagnostic accuracy, and procedural knowledge.

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \qquad (3)$$

Table 4. Quantitative Values of Technical Skills

Training stage	Early-stage Technical Skills	Late-stage technical sills	Good technical skills	Chi-square value	P-value
Early	40	100	43	12,35	<0,05

Table 5. Quantitative Values of Diagnostic Accuracy

Training stage	Early-stage Diagnostic Accuracy	Late-stage Diagnostic accuracy	Good Diagnostic accuracy	Chi-square value	P-value
Early	60	90	33	10,47	>0,05
Late	6	14	163	-	-

Table 6. Quantitative values of Procedural knowledge

Training stage	Early-stage Procedural knowledge	Late-stage Procedural knowledge	Good procedural knowledge	Chi-square value	P-value
Early	55	85	43	14,25	<0,05
Late	5	25	153	-	-

Significant Improvement in Performance over Time

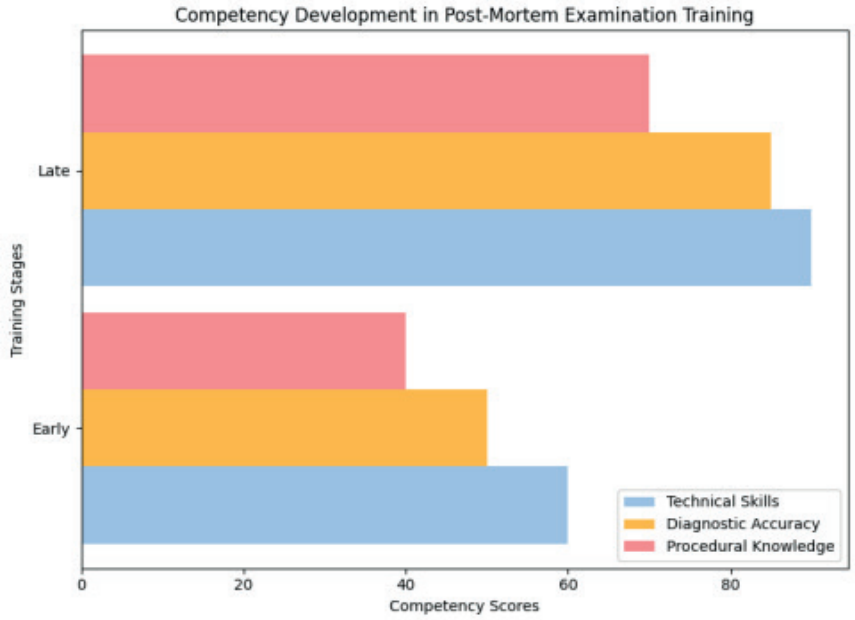

Figure 4. Graphical representation of significant improvement in performance over time

As student training in post-mortem examination procedures progressed; the technical abilities together with diagnostic accuracy steadily improved. Student performance testing demonstrated weak initial autopsy abilities, which improved substantially as their training progressed through time. Educational and practice continuance strongly impacted student performance because it became more expert at difficult procedures and completed better diagnoses. The regular advancement in technical abilities together with diagnostic capabilities leads to improve proficiency in forensic pathology practice, as shown in figure 4.

CONCLUSIONS

Post-mortem examination training assessment over time demonstrated medical students strengthened their technical competencies together with diagnostic proficiency and procedural understanding. All the evaluated domains demonstrated significant improvement based on ANOVA, T-tests and Chi-square test results. Technical skills showed increased development ($p = 0,015$) through ANOVA and statistical signs of enhancement ($p < 0,001$) through T-tests ($p < 0,05$) through Chi-square tests. Similarly, diagnostic accuracy developed through ANOVA ($p = 0,002$) and T-tests ($p < 0,001$). Procedural knowledge also grew significantly, measured by ANOVA ($p = 0,005$) T-tests ($p < 0,001$) Medical students require educational experiences combined with practical work and assessment protocols to build competencies in forensic pathology, which results in reliable post-mortem examination ability. The research examined students from a single medical institution, it cannot reflect medical education systems across the world, so future research requires expanding its sample base to multiple education programs nationwide.

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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