Volume **100** **e202603015**
ORIGINAL 20 pages
Received: **9/8/2025** Accepted: **2/24/2026** Published: **3/10/2026**
ONLINE VERSION

Evaluation of certification courses on causes of death to physicians in specialty training

Evaluación de los cursos de certificación de las causas de la defunción para médicos en formación de la especialidad

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FUNDING

There was no funding.

SUGGESTED CITATION

Cirera Suárez L, Maeso Martínez S, Fernández-Somoano A, Salmerón Martínez D. Evaluation of certification courses on causes of death to physicians in specialty training. Rev Esp Salud Pública. 2026; 100: March 10th e202603015.

AUTHORSHIP CONTRIBUTIONS

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ETHICAL CONSIDERATIONS

Due to the characteristics of this study, it was not necessary to obtain approval from the Ethics Committee. The courses on certification of causes of death for physicians in specialty training were anonymous (with respect to name, age, sex, medical specialty, etc.). The courses were a defined item of the *Transversal and Complementary Residency Program*, common to all medical specialties. The case evaluation form for the courses only included place and date for administrative indexing. Evaluation is an inherent part of the Specialist Physician Training Residency.

Authors declare that there is no conflict of interests

ABSTRACT

BACKGROUND // The causes of death are the pathologies that physicians fill on death certificates. The causes of death quality is a mandatory requirement for useful mortality statistics. To train physicians is essential for the correct fulfillment of death causes. The objective of this paper was to evaluate the efficacy of courses on causes of death certification to all physicians in specialty training.

METHODS // A descriptive observational epidemiological study was conducted to evaluate the efficacy of medical death certification in eighteen in-person courses using a quasi-experimental pre- and posttest design aimed to all physicians during their specialty training in Spain. We assessed: legible handwriting; logical sequence; absence of abbreviations and acronyms; causal sequence, no added causes, no omitted causes; immediate, intermediate, fundamental causes, other conditions, and underlying cause. *Correct* toll was the achievement of 2/3 of the maximum score; and *Suitable*, the achievement of the correct score in logical and causal sequences, without added or omitted causes, and the three underlying causes of initial and final paired cases. We applied bivariate statistics to paired/unpaired indicators between individual/grouped pre-posttests, and multivariate statistics adjusting for evaluator and course.

RESULTS // 96% of cases were included, and the 85% paired pre-posttests. The individual indicators grouped into *Form*, *Concept*, *Result*, and *Total*, improved significantly from the pretest. The paired and adjusted analysis showed a 26% to 80% increase of Suitable physicians in specialty training.

CONCLUSIONS // The efficacy of the courses on medical certification is assessed. Systematic courses on certification of causes of death for all physicians in specialty training should be implemented.

KEYWORDS // Medical education; Death certificates; Cause of death; Data quality; Vital statistics; Spain.

RESUMEN

FUNDAMENTOS // Las causas de defunción son las patologías que el personal médico consigna en los certificados médicos de defunción. La calidad de las causas de defunción es un requisito necesario para la utilidad de la estadística de mortalidad. Es fundamental formar en la correcta cumplimentación médica de las causas de defunción. El objetivo de este trabajo fue evaluar la eficacia de los cursos de certificación de las causas de la defunción a todo médico especialista en formación (MIR).

MÉTODOS // Se realizó un estudio epidemiológico observacional descriptivo de la eficacia del aprendizaje en certificación médica mediante dieciocho cursos presenciales evaluados con diseño cuasiexperimental pre y postest, dirigidos a todo MIR y especialidad en España. Evaluamos: escritura legible; secuencia lógica; ausencia de abreviaturas y acrónimos; secuencia causal, sin causas añadidas o no omitidas; y causas inmediata, intermedia, fundamental, otros procesos y causa básica. Se consideró *Correcto* obtener dos tercios de la puntuación máxima; y *Apto*, obtener la puntuación correcta en secuencias lógica y causal, sin causas añadidas u omitidas, y las tres causas básicas de los casos iniciales y finales. Se aplicaron técnicas estadísticas bivariantes para indicadores no/emparejados entre pre-postest individuales/agrupados, y multivariantes ajustando por evaluadora y curso.

RESULTADOS // Se incluyeron el 96% de casos y el 85% de indicadores emparejados. Los indicadores grupales *Forma*, *Concepto*, *Resultado* y *Total* mejoraron significativamente. Los análisis ajustados de los casos emparejados pre-postest aumentaron los MIR aptos del 26% al 80%.

CONCLUSIONES // Los cursos de certificación MIR de la defunción evidencian eficacia. Se deberían implementar cursos sistemáticos MIR de certificación de las causas de la defunción.

PALABRAS CLAVE // Educación médica; Certificado de defunción; Causa de muerte; Calidad de datos; Estadísticas de mortalidad; España.

ACKNOWLEDGMENTS

Thanks to María Milagros Montesinos, Mercedes Expósito, Bárbara María Arana and María Victoria Uroz for their collaboration.

RESP

INTRODUCTION

Understanding the health status of the population is a fundamental responsibility of Public Health, including the mortality monitoring. Mortality statistics are a primary indicator of population health status. Ensuring the quality of causes of death in mortality statistics is essential for a National Health System. The quality of cause-of-death data depends on the accuracy of the medical death certificate, which constitutes the main source of mortality statistics. High-quality statistical information enables comparability over time and across populations **(1)**.

Causes of death are the pathologies recorded by physicians on the medical death certificates. The quality of cause-of-death data in mortality statistics has been evaluated in scientific publications as well as in official health statistics reports **(1-6)**. The quality of mortality statistics varies across geographic territories. In Western Europe, Spain holds an intermediate position in terms of quality based on Chapter XVIII (ill-defined causes of mortality) of the International Classification of Diseases-10th Revision (ICD-10) of the World Health Organization (WHO) **(7)**. Inadequate quality of cause-of-death data in mortality statistics implies a dual problem of reliability and validity, both in terms of magnitude and random distribution across causes of death **(8-11)**.

The WHO has also classified the cause-of-death statistics of several high-income Western European countries (including Germany, Austria, Belgium, Denmark, and France, all regulated by universal health insurance systems) as being of intermediate quality **(12)**. Furthermore, in the current decade and worldwide, six high-income countries have reported between 9% and 31% of impossible and ill-defined causes of death **(13)**. Some studies have highlighted physicians' inability to accurately complete death certificates **(14-16)**. Other studies have linked insufficient academic training in medical death certification to reduced reliability of mortality statistics **(17)**.

Furthermore, training courses aimed at improving medical certification of causes of death have been developed using different approaches, diverse methodologies, and targeting various groups of medical professionals **(13,17-21)**.

Some of these training programs are delivered through new educational technologies, such as mobile phone applications **(17)**, websites, or online learning platforms **(15-19)**.

The aim of this study was to evaluate the efficacy of training courses on medical certification of causes of death delivered to physicians in specialty training (PST).

SUBJECTS AND METHODS

A descriptive observational epidemiological study with a quasi-experimental pre-post design

was conducted to evaluate the efficacy of 18 in-person courses on cause-of-death certification delivered to all physicians in specialty training (PST) (n=289) during their second year of residency across all medical specialties in the Region of Murcia (Spain).

Training Intervention. The courses were a mandatory component of the *Transversal and Complementary Training Program* for all PST specialties. The sessions covered the history of mortality statistics, relevant legislation, and the usefulness of accurate certification for the Health Administration, in accordance with the World Health Organization (WHO)-ICD-10 standards. Following the theoretical presentation by the professors, participants individually and anonymously completed a set of case scenarios, which were subsequently reviewed and discussed with the professors **(22)**. The courses were delivered by a physician specialist in Legal and Forensic Medicine and another specialized in Preventive Medicine and Public Health. Each course lasted around 120 minutes.

Evaluation. At the beginning of each course, every PST participant individually completed three certification case scenarios, which were repeated at the end of the course. The cases were extracted from real death certificates through expert selection **(22)**. Approval from a Research Ethics Committee was not sought, as this was neither a biomedical study nor did it involve clinical health data; the cases were provided in anonymized form. The selected cases were of progressively increasing difficulty in terms of causes of death and their interconnections, based on ICD-10 coding rules and the algorithms of the international automated coding system Iris.

Selection of Death Causes and the Underlying Cause of Death. The medical death certificate includes, in Part 1, the *Immediate Cause* (the disease or pathological condition directly leading to death); the *Intermediate Causes* (the causal chain of events leading to the Immediate Cause); and the *Underlying Cause* (the disease initiating the chain of events resulting in all subsequent conditions listed above it). In Part 2, labeled *Other Conditions*, are the relevant contributing conditions to death, but not directly related to the causal sequence **[Annex I]**.

By applying the WHO ICD-10 coding rules to the causes listed on the certificate, the *Underlying Cause* was selected, which constitutes the single source for international mortality statistics. Ideally, each cause should be accompanied by its time of onset, expressed in days, months, or years. If one cause is pathophysiologic responsible for the remaining causes listed on the certificate, that condition is considered the underlying cause of death..

- **Case #1.** This was considered the baseline case. The only applicable ICD-10 coding rule is that of a single cause listed on the certificate: *acute myocardial infarction, unspecified*, with a reported time of onset of two hours, compatible with a fatal outcome. Therefore, the underlying cause of death is acute myocardial infarction, unspecified (ICD-10 code I21.9). In the Iris multiple-cause coding system, the ICD-10 code assigned was I21.9 **[Annex I]**.

- **Case #2.** *Chronic obstructive pulmonary disease* (COPD) caused the other conditions listed in Part 1 of the certificate, namely *pneumonia and acute respiratory failure* (following the first WHO ICD-10 coding rule). The combination of unspecified COPD and pneumonia results in COPD with acute lower respiratory infection (second coding rule). With a time of onset of 3 hours for acute respiratory failure and 10 years for COPD, both were compatible with the proposed outcome. Smoking, included under *Other conditions*, with a duration of 10 years, was also compatible with the outcome. Therefore, the underlying cause of death is *COPD with acute lower respiratory infection* (J44.0). In the Iris multiple-cause coding system, the code assigned was: J96.0/J18.9/J44.9*F17.2 **[Annex I]**.

- **Case #3.** According to the first coding rule, *acute appendicitis* caused the other conditions in Part 1, *peritonitis* and *sepsis*. According to the second coding rule, the combination of acute appendicitis and peritonitis results in acute appendicitis with localized peritonitis. The time of onset -1 day for sepsis and peritonitis, and 3 days for appendicitis- was compatible with the outcome. Malignant hypertension, hypertensive heart disease, and chronic renal failure, included under *Other conditions*, with a duration of 10 years, were also compatible with the outcome. The underlying cause of death was therefore *acute appendicitis with localized peritonitis* (K35.3). In the Iris multiple-cause coding system, the code assigned was: A41.9/K65.0/K35.8*I10/I11.9/N18.9 **[Annex I]**.

Learning Indicators. Learning assessment indicators were defined at both the individual and group level. Individual indicators (*Legible Writing, Logical Sequence, and Absence of Abbreviations and Acronyms*) were combined into the group-level indicator *Format*. Logical Sequence was considered correct when there were no blank lines between causes.

Causal Sequence, No Added Causes, and *No Omitted Causes* were combined into the group-level indicator *Concept*. Causal Sequence was defined as the correct physiological and temporal concatenation of the causes listed.

Immediate Cause, Intermediate Cause, Underlying Cause, and *Other Conditions* were combined into the group-level indicator *Outcome*. The underlying cause of death was determined according to WHO standards.

A *Total* indicator was added as the sum of the evaluation scores for *Format, Concept,* and *Outcome*.

Efficacy Evaluation of Learning Indicators. For each case and each indicator, scoring was dichotomous: 1=correct, 0=incorrect. Two expert nurse coders and one PST evaluated the cases and scored the indicators. A medical nosologist supervised their evaluations and resolved any discrepancies. For individual indicators and for group-level indicators of individual cases (denoted as 1, 2, 3) and grouped cases (denoted as 1–3), the sum of scores was calculated. An indicator was considered *Correct* when at least two-thirds of the maximum possible score was achieved. A PST was considered *Suitable* when the score was *correct* for both logical and causal sequences, with no added or omitted causes, and all underlying causes correctly identified in the grouped

cases 1–3 (that is, at least 10 out of 15 possible points) **[Annex II]**.

Statistical Analysis. All cases with valid values were included. One course was excluded from the analysis due to missing final cases.

Descriptive statistical analyses were conducted for both unadjusted and adjusted indicators. Course characteristics were summarized using counts, percentages, and means, as appropriate.

In the subgroup with paired measurements, the McNemar test was used to evaluate intra-individual change. In addition, mixed-effects models were fitted using Restricted Maximum Likelihood (REML) to evaluate individual and group indicators between baseline and final cases, model intra-individual correlation, and utilize all available observations, adjusting for assessor and course date. The covariance structure of the repeated measurements in the REML model was specified as autoregressive with a lag of 1. Along with the REML model, logistic regression was applied to evaluate the association between suitable / not suitable PST and learning outcomes (percentage of passes, score, and grade) between initial cases 1-3 and final grouped and matched cases, adjusting for evaluator and course date. Statistical significance was set at a two-sided $p<0.05$. Analyses were performed using *SPSS*, version 27 (IBM Corp., Armonk, NY, EE. UU.) with *Python* integration.

RESULTS

A total of 289 PST participated in the study, with course participation ranging from 8 to 26 students per session. In total, 1,604 case scenarios were analyzed. For each case, 11 individual indicators were assessed, resulting in a total of 17,644 indicators. After pairing, 737 pairs were available out of 867 possible pairs, distributed as 245 pairs (85%) for cases 1 and 2, and 247 pairs (86%) for case 3 **[Table 1]**.

Individual Indicators. Improvements in individual indicators across cases 1, 2, and 3 ranged from approximately 1% for *Legible Writing* in case 3 to 57% for *No Added Causes* in case 1 **[Figure 1]**. Before pairing, 25% of individual indicators were initially correct, increasing to 90% in the final cases. In all cases, correct certification of the underlying cause of death improved by at least 18 percentage points **[Annex III]**.

When analyzing grouped final cases 1–3, all individual indicators showed statistically significant increases, except for *Legible Writing*. The underlying cause of death increased from 74% in the initial cases to 98% in the final cases **[Annex III]**.

For paired cases 1, 2, and 3, all individual indicators showed statistically significant improvement ($p<0.001$), except for *Legible Writing* in cases 1 and 3 and *Logical Sequence* in case 3 **[Table 2]**. Considering grouped cases 1–3, *Legible Writing* remained non-significant **[Table 2]**.

Group-Level Indicators. Group-level indicators showed improvements ranging from 3% in *Format* for case 3 to 55% in *Outcome* for case 1 **[Figure 2]**. Unpaired cases 1, 2, and 3 demonstrated statistically significant differences in all indicators except *Format* in case 3. When analyzing grouped unpaired cases 1–3, statistically significant improvements were observed in all group-level indicators **[Annex III]**.

Table 1
Course characterization(*) according to date, number of Physicians in Specialty Training, number of cases performed at the beginning and repeated at the end of the course, and evaluator's cases(**). PST certification courses on causes of death.

Course	Physicians		Total initial cases	Subtotal initial cases			Total final cases	Subtotal final cases			Total matched cases	Subtotal matched cases			Evaluator
	n	%		*Case 1*	*Case 2*	*Case 3*		*Case 1*	*Case 2*	*Case 3*		*Case 1*	*Case 2*	*Case 3*	
30-V-12	19	6.6	57/57	19/19	19/19	19/19	57/57	19/19	19/19	19/19	57/57	19/19	19/19	19/19	1
31-V-12	19	6.6	48/57	16/19	16/19	16/19	57/57	19/19	19/19	19/19	48/57	16/19	16/19	16/19	1
08-X-12	8	2.8	24/24	8/8	8/8	8/8	24/24	8/8	8/8	8/8	24/24	8/8	8/8	8/8	2
10-X-12	13	4.5	30/39	10/13	10/13	10/13	39/39	13/13	13/13	13/13	30/39	10/13	10/13	10/13	2
22-X-12	17	5.9	48/51	16/17	16/17	16/17	39/51	13/17	13/17	13/17	36/51	12/17	12/17	12/17	2
30-X-12	17	5.9	51/51	17/17	17/17	17/17	51/51	17/17	17/17	17/17	51/51	17/17	17/17	17/17	1
18-XII-12	14	4.8	42/42	14/14	14/14	14/14	42/42	14/14	14/14	14/14	42/42	14/14	14/14	14/14	1
19-XII-12	26	9.0	70/78	23/26	23/26	24/26	78/78	26/26	26/26	26/26	70/78	23/26	23/26	24/26	1
02-V-13	15	5.2	45/45	15/15	15/15	15/15	45/45	15/15	15/15	15/15	45/45	15/15	15/15	15/15	2
28-V-13	13	4.5	36/39	12/13	12/13	12/13	36/39	12/13	12/13	12/13	33/39	11/13	11/13	11/13	2
29-V-13	20	6.9	57/60	19/20	19/20	19/20	54/60	18/20	18/20	18/20	51/60	17/20	17/20	17/20	2
30-V-13	18	6.2	54/54	18/18	18/18	18/18	45/54	15/18	15/18	15/18	45/54	15/18	15/18	15/18	2
03-VI-13	11	3.8	33/33	11/11	11/11	11/11	33/33	11/11	11/11	11/11	33/33	11/11	11/11	11/11	3
30-IX-13	13	4.5	39/39	13/13	13/13	13/13	39/39	13/13	13/13	13/13	39/39	13/13	13/13	13/13	3
02-X-13	19	6.6	57/57	19/19	19/19	19/19	0/57	0/19	0/19	0/19	0/57	0/19	0/19	0/19	3
03-X-13	14	4.8	42/42	14/14	14/14	14/14	39/42	13/14	13/14	13/14	39/42	13/14	13/14	13/14	3
08-X-13	18	6.2	54/54	18/18	18/18	18/18	51/54	17/18	17/18	17/18	51/54	17/18	17/18	17/18	3
10-X-13	15	5.2	43/45	14/15	14/15	15/15	45/45	15/15	15/15	15/15	43/45	14/15	14/15	15/15	3

PST=Physicians in Specialty Training. **(*)** Teaching staff: a forensic and a preventive & Public Health physician. **(**)** Two coding nurses & a Physician in Specialty Training.

Figure 1
Correct individual indicators (in %) of initial and final cases 1, 2 & 3 according to the learning assessment. Certification courses on causes of death to Physicians in Specialty Training.

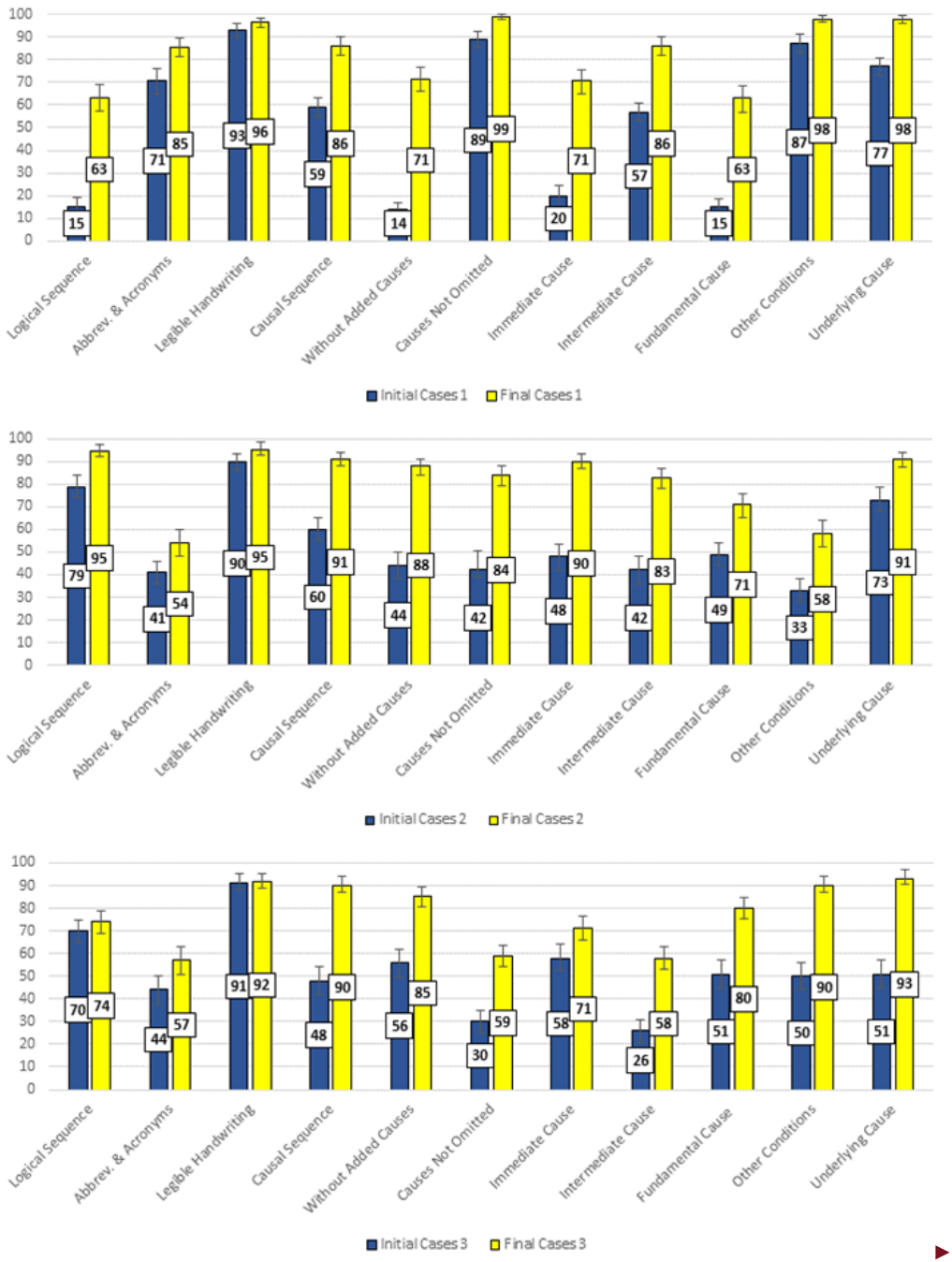
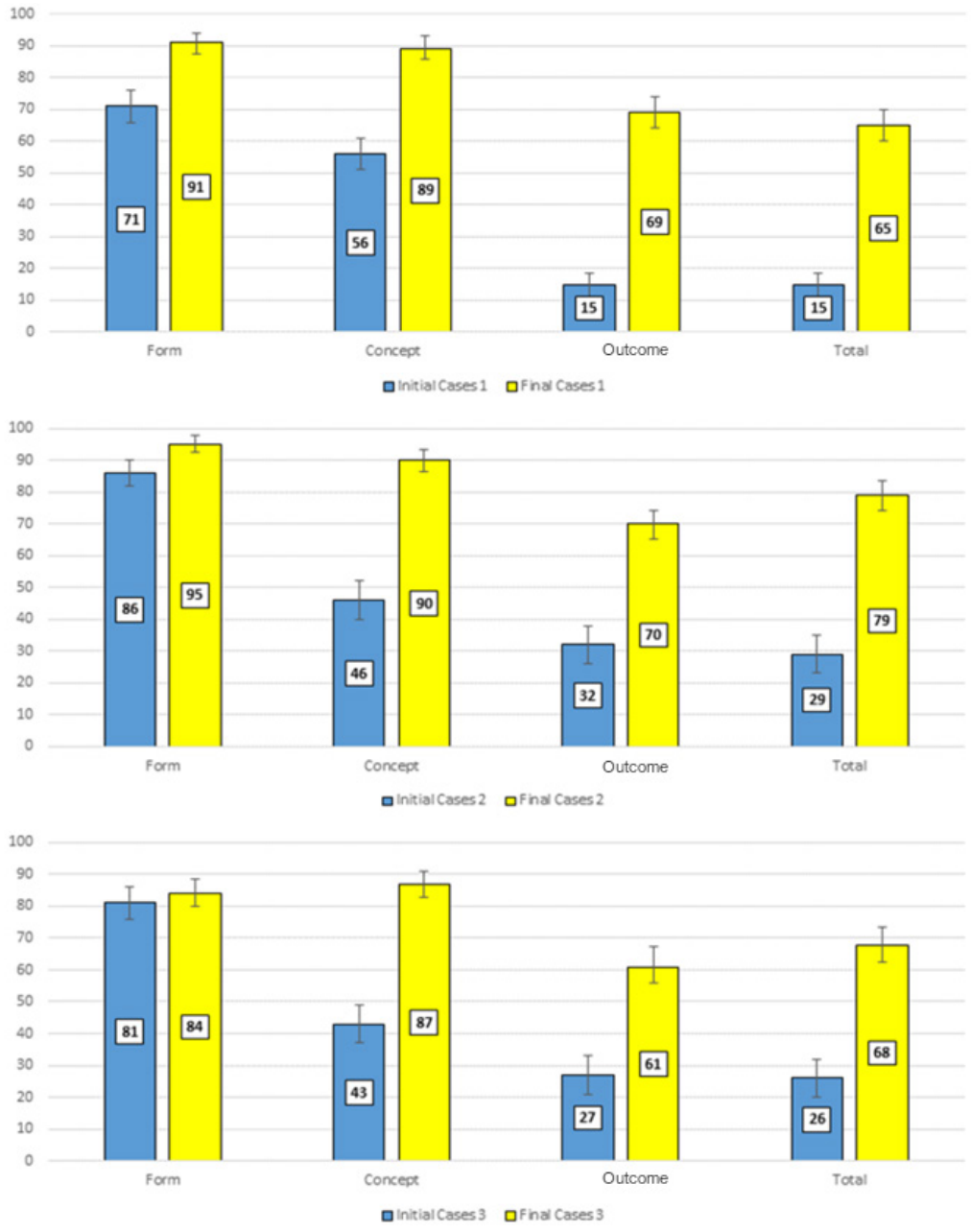


Table 2
Correct & total cases count (n/N) of the learning assessment indicators in the initial and final paired cases. PST certification courses on death causes.

	Indicators	Case 1			Case 2			Case 3			Cases 1-3 together(**)		
		Initial	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)
Individual indicators	Legible Handwriting	228/245	236/245	0.096	220/245	231/245	<0.001	223/247	229/247	0.210	227/245	234/245	0.092
	Logical Sequence	37/244	154/244	<0.001	193/245	232/245	<0.001	169/247	180/247	0.278	163/244	210/244	<0.001
	Abbreviations & Acronyms	171/245	209/245	<0.001	90/245	135/245	<0.001	111/247	142/247	0.002	119/245	166/245	<0.001
	Causal Sequence	155/245	211/245	<0.001	143/244	224/244	<0.001	115/247	221/247	<0.001	137/244	233/244	<0.001
	Without Added Causes	38/245	175/245	<0.001	108/245	217/245	<0.001	139/247	210/247	<0.001	94/245	220/245	<0.001
	Causes Not Omitted	218/245	242/245	<0.001	96/244	206/244	<0.001	66/246	148/246	<0.001	119/243	219/243	<0.001
	Immediate Cause	176/245	148/245	<0.001	118/245	224/245	0.006	143/247	175/247	0.001	115/245	214/245	<0.001
	Antecedent Causes	148/245	213/245	<0.001	100/245	205/245	<0.001	57/247	141/247	<0.001	84/245	213/245	<0.001
	Fundamental Cause	39/244	155/244	<0.001	114/245	176/245	<0.001	123/247	197/247	<0.001	81/244	201/244	<0.001
	Other Conditions	214/245	240/245	<0.001	77/245	142/245	<0.001	118/247	221/247	<0.001	133/245	230/245	<0.001
	Underlying Cause	196/245	240/245	<0.001	177/243	222/243	<0.001	124/247	228/247	<0.001	181/243	240/243	<0.001
Group indicators(**)	Form	168/244	223/244	<0.001	206/245	232/245	<0.001	198/247	207/247	0.314	147/244	202/244	<0.001
	Concept	148/245	217/245	<0.001	108/244	220/244	<0.001	102/246	214/246	<0.001	71/243	219/243	<0.001
	Result	38/244	171/244	<0.001	72/243	170/243	<0.001	60/247	149/247	<0.001	59/242	209/242	<0.001
	Total	38/244	178/244	<0.001	65/243	192/243	<0.001	58/246	167/246	<0.001	59/242	217/242	<0.001

PST=Physicians in Specialty Training.
(*) p= statistical significance by McNemar test. **(**)** If individual indicators sum ≥2/3 of total points, then the group indicator score as correct, otherwise incorrect score.

Figure 2
Correct group indicators (in %) of initial and final cases 1, 2 & 3 according to the learning assessment. Certification courses on causes of death to Physicians in Specialty Training.



Paired Analyses. In paired analyses, all group-level indicators showed statistically significant improvements, except for the *Format* indicator in case 3. When grouped cases 1–3 was considered, all indicators reached statistical significance **[Table 2]**.

Adjusted Analyses by Evaluator and Course. After adjusting for evaluator and course, statistically significant improvements were observed between initial and final cases for individual indicators including *Absence of Abbreviations and Acronyms, Causal Sequence, No Added Causes, No Omitted Causes, Immediate Cause, Intermediate Cause, Underlying Cause, Other Conditions*, and *Underlying Cause of Death*. Exceptions were *Legible Writing* in cases 1 and 3, and *Logical Sequence* in case 3. Similarly, differences in individual and group-level indicators for grouped cases 1–3 were statistically significant ($p<0.001$) **[Table 3, Annex IV]**.

Learning Efficacy Indicators. Among PST who correctly completed paired cases 1–3, the proportion classified as suitable increased from 25.7% to 79.6%. The mean score for these cases increased from 11.4 to 13.5 points out of a maximum of 15, while the mean grade increased from 7.6 to 8.9 out of 10. All learning efficacy indicators reached statistical significance ($p<0.001$) **[Table 4, Annex V]**.

DISCUSSION

The courses improved accurate certification regarding *abbreviations and acronyms, causal sequence, and the correct identification of immediate, intermediate, underlying, and underlying cause of death*. They also enhanced the group-level indicators of *Format*, *Concept*, *Outcome*, and *Total* in both paired and unpaired initial and final cases. Moreover, the courses tripled the certification efficacy of PST in the most demanding indicators.

Potential limitations related to missing cases could suggest a selection bias against the null hypothesis. However, the number of missing initial cases was small (n=13/289), distributed among a maximum of three participants per course. PST with missing final cases affected only one course of 19 participants, which was subsequently excluded. The courses were entirely anonymous, with attendance as the only control. A slightly higher proportion of female participants and a small component of newly nationalized residents were noted, with a demand for PST medical specialties at least comparable to the national average.

Regarding the quasi-experimental epidemiological design without a control group, the courses demonstrated external validity through replication of results in other similar courses conducted at different times, geographic and cultural contexts, and with diverse learners, including medical students and practicing physicians **(18)**. Likewise, the external validity of the courses suggests effectiveness, with almost no *laboratory* control conditions, and no more than the obligation to attend the course in some cases.

The three cases in our course did not include deaths from external causes or stillbirths, as these are reported in documents other than the medical death certificate used in the courses. It is known that deaths from external causes and judicial deaths generally suffer from reliability and validity

Table 3
Correct & total cases count (n/N) according of the learning assessment indicators in initial and final paired cases adjusted by evaluator and course date. PST certification courses on causes of death.

	Indicators	Case 1			Case 2			Case 3			Cases together 1-3(**)		
		Initial	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)
Individual indicators	Legible Handwriting	257/276	247/258	0.050	248/276	244/258	0.005	253/278	238/258	0.142	256/276	245/258	0.044
	Logical Sequence	42/275	163/258	<0.001	217/276	244/258	<0.001	193/278	190/258	0.254	184/275	233/258	<0.001
	Abbreviations & Acronyms	197/276	219/258	<0.001	112/276	140/258	<0.001	122/278	147/258	0.001	142/276	172/258	<0.001
	Causal Sequence	163/276	224/258	<0.001	166/276	234/257	<0.001	133/278	232/258	<0.001	157/276	146/257	<0.001
	Without Added Causes	38/276	182/258	<0.001	121/276	227/258	<0.001	156/278	218/258	<0.001	103/276	231/258	<0.001
	Causes Not Omitted	245/276	255/258	<0.001	116/276	215/257	<0.001	82/278	152/257	<0.001	144/276	229/256	<0.001
	Immediate Cause	55/276	184/258	<0.001	133/276	234/258	<0.001	161/278	182/258	<0.001	128/276	225/258	<0.001
	Antecedent Causes	158/276	223/258	<0.001	117/276	214/258	<0.001	73/278	150/258	<0.001	99/276	223/258	<0.001
	Fundamental Cause	41/275	164/258	<0.001	136/276	184/258	<0.001	141/278	207/258	<0.001	98/275	212/258	<0.001
	Other Conditions	240/276	253/258	<0.001	92/276	150/258	<0.001	140/278	232/258	<0.001	154/276	242/257	<0.001
	Underlying Cause	213/276	252/258	<0.001	201/276	232/256	<0.001	143/278	239/258	<0.001	203/276	252/256	<0.001
Group indicators(**)	Form	194/275	234/258	<0.001	236/276	244/258	<0.001	224/278	217/258	0.226	169/275	212/258	<0.001
	Concept	155/276	230/258	<0.001	127/276	230/257	<0.001	120/278	223/257	<0.001	79/276	229/256	<0.001
	Result	41/275	179/258	<0.001	88/276	178/255	<0.001	74/278	158/258	<0.001	69/275	220/256	<0.001
	Total	41/274	188/258	<0.001	81/276	202/255	<0.001	73/278	175/257	<0.001	69/274	229/255	<0.001

PST=Physicians in Specialty Training.
(*) Mixed model adjusted to evaluator, course date and random PST effect. **(**)** If individual indicators sum ≥2/3 of total points, then the group indicator score as correct, otherwise incorrect score.

Table 4
Count, percentage (%), score, and grade of suitable(*) Physicians in Specialty Training of all initial and final paired cases adjusted by evaluator and course date.

Cases	n	N	%	p(**)	Score	p(***)	Grade	p(***)
Initial Cases 1-3 together	71	276	25.7	<0.001	11.4	<0.001	7.6	<0.001
Final Cases 1-3 together	203	255	79.6		13.5		8.9	

(*) Suitable=Physicians in Specialty Training, who obtains at least 10 (2/3) points of the maximum 15 points from the sum of 3 correct underlined causes of death (3 points) plus the points of logical sequence+causal sequence+no added causes+causes not omitted.
(**) Logistic model adjusted to evaluator and course date.
(***) Mixed model adjusted to evaluator, course date and random PST effect.

PST=Physicians in Specialty Training; n=Number of suitable Physicians in Specialty Training. Score=Adjusted mean of the sum of points; Grade=Adjusted mean of the proportion of points over the total. The maximum grade level is 10.

issues **(4)**. Similarly, stillbirths are reported on separate documents, which at the time were not incorporated into the Iris automated coding system in Spain.

Among the strengths of this study, we highlight the novelty of the participants studied, the sample size, the inclusion of three cases with a gradient of complexity, the comprehensiveness and innovation of the indicators, the pre-post pairing of cases, and the appropriate statistical treatment. All these aspects allow replication in other contexts.

Regarding the number of death certificates, some studies included three or fewer certificates **(15)**. while others included more certificates **(23-25)** and evaluated them through audit processes **(26-28)**.

The observed learner typology included medical students **(23)**, physicians in specialty training **(15,27)**, specialist physicians **(14,16,23)**, physicians in specialty training together with specialist physicians **(20,21)**, and a combination of medical students, physicians in specialty training, and specialist physicians **(19,29)**.

Concerning the number of participants in the educational intervention, most studies recruited fewer learners **(12,17,23,25)**. In our study, 289 participants were recruited, a number similar to another Spanish study **(24)**, though one foreign study included more physicians **(28)**.

The efficacy of our courses demonstrated an increase of 54% in suitable PST, based on an evaluation designed with rigorous criteria. However, improvements were smaller in several other studies **(15,23,25)**.

A previous study in our region **(30)** reported similar performance in the *Concept* and *Outcome* indicators. The underlying cause of death improved by 14% among practicing physicians, whereas in the present study it improved by 19% among PST.

Significant differences exist between death certificates and the corresponding medical records **(16)**. Given that the WHO medical death certificate format is universally applicable, our results may have external validity and be generalizable. Similarly, evidence exists showing improvement in death certificate com-

pletion six months after training in 30% of physicians in the Philippines **(28)**.

Further studies are needed to evaluate the medium- and long-term impact of medical training courses on the quality of mortality statistics. At the same time, we recommend implementing systematic courses on cause-of-death certification for all medical specialties, delivered by specialists in Preventive Medicine and Public Health and in Legal and Forensic Medicine. In this regard, medical training on causes of death should be a mandatory workshop for all PST in specialty training in Spain.

In conclusion, cause-of-death certification courses for physicians in specialty training have demonstrated their efficacy. Final case assessments showed substantial improvement compared to initial results following course participation.

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Annex I
Cases 1, 2 and 3 & their correct filling-in on WHO death certificate form adapted to Spain.

Case 1. A 47-year-old man suffers an acute myocardial infarction, from which he dies in 2 hours.

Frame A: Medical data: Part 1 and 2				
1 ***Inmediate Cause*** Report disease or condition directly leading to death on line a ***Intermediate Cause*** Report chain of events in due to order (if applicable) ***Fundamental Cause*** State the underlying cause on the lowest used line			**Cause of death**	**Time interval from onset to death**
		a	*Acute myocardial infarction*	*2 Hours*
		b		
		c		
		d		
2 Other significant conditions contributing to death (time intervals can be included in brackets after the condition)				

Case 2. A 75-year-old man with a 30-year history of smoking, who presents with the criteria for Chronic Obstructive Pulmonary Disease of 10 years' duration. He was seen at home for pneumonia. He was treated with broad-spectrum antibiotics, but in the last 3 hours his respiratory function progressively worsens, resulting in his death.

Frame A: Medical data: Part 1 and 2				
1 ***Inmediate Cause*** Report disease or condition directly leading to death on line a ***Intermediate Cause*** Report chain of events in due to order (if applicable) ***Fundamental Cause*** State the underlying cause on the lowest used line			**Cause of death**	**Time interval from onset to death**
		a	*Acute respiratory failure*	*3 Hours*
		b	*Pneumonia*	
		c		
		d	*Chronic obstructive pulmonary disease*	*10 Years*
2 Other significant conditions contributing to death (time intervals can be included in brackets after the condition)			*Smoking (10 Years)*	

Case 3. A 63-year-old woman, who had suffered from malignant hypertension for 10 years, manifesting as hypertensive heart disease and chronic renal failure. She was admitted to the hospital with abdominal pain labelled as acute appendicitis. Three days after the appendectomy, she developed signs of peritonitis and sepsis, as a result of which she died.

Frame A: Medical data: Part 1 and 2				
1 ***Inmediate Cause*** Report disease or condition directly leading to death on line a ***Intermediate Cause*** Report chain of events in due to order (if applicable) ***Fundamental Cause*** State the underlying cause on the lowest used line			**Cause of death**	**Time interval from onset to death**
		a	*Sepsis*	*1 Day*
		b	*Peritonitis*	*1 Day*
		c		
		d	*Acute appendicitis*	*3 Days*
2 Other significant conditions contributing to death (time intervals can be included in brackets after the condition)			*Malignant hypertension, hypertensive heart disease, chronic renal failure(10 years)*	

Annex II
Indicators and scoring to assess learning in certification cases. Certification courses on causes of death to Physicians in Specialty Training.

	Indicators	Case 1/2/3		Cases 1-3	
		Score	*Incorrect*	*Score*	*Correct*(*)
Individual Indicators	Legible Handwriting	1	0	0-3	2
	Logical Sequence	1	0	0-3	2
	Abbreviations and Acronyms	1	0	0-3	2
	Causal Sequence	1	0	0-3	2
	Without Added Causes	1	0	0-3	2
	Causes Not Omitted	1	0	0-3	2
	Immediate Cause / 1a	1	0	0-3	2
	Intermediate Causes / 1b-1c	1	0	0-3	2
	Fundamental Cause / 1d	1	0	0-3	2
	Other Conditions / 2	1	0	0-3	2
	Underlying Cause	1	0	0-3	2
	Indicators	**Case 1/2/3**		**Cases 1-3**	
		Score	*Correct*(*)	*Score*	*Correct*(*)
Group Indicators(**)	Forma	0-3	2	0-9	6
	Concepto	0-3	2	0-9	6
	Resultado	0-5	3.3	0-15	10
	Total	0-11	7.3	0-33	22

(*) Correct ≥2/3 of the maximum score.

Suitable=Physicians in specialty training who obtains at least 10 (2/3) points of the maximum 15 points from the sum of 3 correct underlying causes of death (3 points) plus the points of logical sequence+causal sequence+no added causes+causes not omitted.

1, 2, a, b-c point to part 1 & 2 of causes location on WHO certificate of death.

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Annex III
Percentage (%) and counts of correct cases (n) of the learning assessment indicators in the initial and final cases without pairing. Certification courses on causes of death to Physicians in Specialty Training.

	Indicators	Case 1			Case 2			Case 3			Cases 1-3(**)		
		Initial	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)	*Initial*	*Final*	*p*(*)
Individual indicators	Legible Handwriting	93.1 (257)	95.7 (247)	0.19	89.9 (248)	94.6 (244)	0.04	91.0 (253)	92.2 (238)	0.61	92.8 (256)	95.0 (245)	0.29
	Logical Sequence	15.3 (42)	63.2 (163)	<0.001	78.6 (217)	94.6 (244)	<0.001	69.4 (193)	73.6 (190)	0.28	66.9 (184)	90.3 (233)	<0.001
	Abbreviations and Acronyms	71.4 (197)	84.9 (219)	<0.001	40.6 (112)	54.3 (140)	<0.001	43.9 (122)	57.0 (147)	0.00	51.5 (142)	66.6 (172)	<0.001
	Causal Sequence	59.1 (163)	86.8 (224)	<0.001	60.1 (166)	91.1 (234)	<0.001	47.8 (133)	89.9 (232)	<0.001	56.9 (157)	86.8 (146)	<0.001
	Without Added Causes	13.8 (38)	70.5 (182)	<0.001	43.8 (121)	88.0 (227)	<0.001	56.1 (156)	84.5 (218)	<0.001	37.3 (103)	89.5 (239)	<0.001
	Causes Not Omitted	88.8 (245)	98.8 (255)	<0.001	42.0 (116)	83.7 (215)	<0.001	29.5 (82)	59.1 (152)	<0.001	52.2 (144)	89.5 (229)	<0.001
	Immediate Cause	19.9 (55)	71.3 (184)	<0.001	48.2 (133)	90.1 (234)	<0.001	57.9 (161)	70.5 (182)	<0.001	46.4 (128)	87.2 (225)	<0.001
	Intermediate Cause	57.2 (158)	86.4 (223)	<0.001	42.4 (117)	82.9 (214)	<0.001	26.3 (73)	58.1 (150)	<0.001	35.9 (99)	86.4 (223)	<0.001
	Fundamental Cause	14.9 (41)	63.6 (164)	<0.001	49.3 (136)	71.3 (184)	<0.001	50.7 (141)	80.2 (207)	<0.001	35.6 (98)	82.2 (212)	<0.001
	Other Conditions	87.0 (240)	98.1 (253)	<0.001	33.3 (92)	58.1 (150)	<0.001	50.4 (140)	89.9 (232)	<0.001	55.8 (154)	94.2 (257)	<0.001
	Underlying Cause	77.2 (213)	97.7 (252)	<0.001	72.8 (201)	90.6 (232)	<0.001	51.4 (143)	92.6 (239)	<0.001	73.6 (203)	98.4 (252)	<0.001
Group indicators(**)	Form	70.5 (194)	90.7 (234)	<0.001	85.5 (236)	94.6 (244)	<0.001	80.6 (224)	84.1 (217)	0.29	61.5 (169)	82.2 (212)	<0.001
	Concept	56.2 (155)	89.1 (230)	<0.001	46.0 (127)	89.5 (230)	<0.001	43.2 (120)	86.8 (223)	<0.001	28.6 (79)	89.5 (229)	<0.001
	Result	14.9 (41)	69.4 (179)	<0.001	31.9 (88)	69.8 (178)	<0.001	26.6 (74)	61.2 (158)	<0.001	25.1 (69)	85.9 (220)	<0.001
	Total	15.0 (41)	65.1 (188)	<0.001	29.3 (81)	79.2 (202)	<0.001	26.3 (73)	68.1 (175)	<0.001	25.2 (69)	89.8 (229)	<0.001

(*) p=statistical significance using Chi-square test. **(**)** If individual indicators sum ≥2/3 of total points, then the group indicator score as correct, otherwise incorrect score.

Annex IV

Indicators and estimates of the change in the number of correct cases in the final cases compared to the initial unmatched cases, adjusted by assessor and course date. Certification courses on causes of death to Physicians in Specialty Training.

	Indicators	Case 1			Case 2			Case 3			Cases 1-3(**)		
		Beta	*CI95%*	*p*(*)	*Beta*	*CI95%*	*p*(*)	*Beta*	*CI95%*	*p*(*)	*Beta*	*CI95%*	*p*(*)
Individual indicators	Legible Handwriting	0.34	-1.51x10^{-5}-0.07	0.05	0.05	0.02-0.09	0.005	0.02	-0.06	0.142	0.03	0.001-0.06	0.044
	Logical Sequence	0.47	0.41-0.54	<0.001	0.15	0.10-0.21	<0.001	0.04	-0.14	0.254	0.18	0.12-0.25	<0.001
	Abbreviations and Acronyms	0.15	0.09-0.21	<0.001	0.17	0.11-0.24	<0.001	0.12	0.05-0.20	0.001	0.18	0.11-0.25	<0.001
	Causal Sequence	0.24	0.18-0.29	<0.001	0.32	0.25-0.39	<0.001	0.44	0.37-0.51	<0.001	0.39	0.33-0.46	<0.001
	Without Added Causes	0.56	0.50-0.62	<0.001	0.44	0.37-0.51	<0.001	0.29	0.22-0.36	<0.001	0.52	0.45-0.58	<0.001
	Causes Not Omitted	0.1	0.07-0.14	<0.001	0.43	0.36-0.50	<0.001	0.33	0.26-0.40	<0.001	0.4	0.33-0.46	<0.001
	Immediate Cause	0.52	0.45-0.59	<0.001	0.43	0.37-0.50	<0.001	0.14	0.07-0.21	<0.001	0.41	0.34-0.48	<0.001
	Intermediate Cause	0.26	0.19-0.33	<0.001	0.43	0.35-0.50	<0.001	0.35	0.29-0.41	<0.001	0.52	0.45-0.59	<0.001
	Fundamental Cause	0.48	0.41-0.55	<0.001	0.24	0.16-0.32	<0.001	0.31	0.24-0.38	<0.001	0.49	0.42-0.56	<0.001
	Other Conditions	0.11	0.07-0.15	<0.001	0.29	0.20-0.37	<0.001	0.42	0.36-0.49	<0.001	0.41	0.34-0.47	<0.001
	Underlying Cause	0.19	0.14-0.24	<0.001	0.18	0.11-0.25	<0.001	0.43	0.36-0.49	<0.001	0.25	0.19-0.31	<0.001
Group indicators(**)	Form	0.22	0.16-0.28	<0.001	0.1	0.05-0.15	<0.001	0.04	-0.12	0.226	0.22	0.16-0.29	<0.001
	Concept	0.29	0.24-0.35	<0.001	0.45	0.38-0.51	<0.001	0.46	0.39-0.53	<0.001	0.61	0.55-0.67	<0.001
	Result	0.54	0.48-0.61	<0.001	0.4	0.33-0.48	<0.001	0.37	0.30-0.44	<0.001	0.62	0.55-0.69	<0.001
	Total	0.58	0.51-0.64	<0.001	0.52	0.45-0.59	<0.001	0.45	0.38-0.52	<0.001	0.66	0.59-0.72	<0.001

(*) Mixed model adjusted for evaluator, course date, and random MIR effect. **(**)** If the sum of the individual indicators is ≥2/3 of the total points, then the group indicator is correct; otherwise, it is incorrect.

Annex V

Indicators and estimates of the change in the number of those who passed, in the score and in the grade in the final cases compared to the initial cases, matched and adjusted by assessor and course date. Certification courses on causes of death to Physicians in Specialty Training.

Cases	Suitable(*)			Score			Grade		
	Beta	*CI95%*	*p*(**)	*Beta*	*CI95%*	*p*(***)	*Beta*	*CI95%*	*p*(***)
Initial Cases 1-3 together	Ref.	-	<0.001	Ref.	-	<0.001	Ref.	-	<0.001
Final Cases 1-3 together	0.54	0.47-0.61		2.02	1.66-2.39		1.35	1.11-1.59	

(*) Suitable=physicians in specialty training who obtain at least 2/3 of the points (≥10 out of a possible 15 points) for the sum of causal sequence+no added causes+no omitted causes, and with all basic causes correct.
(**) Logistic model adjusted for assessor and course date.
(***) Mixed model adjusted for assessor, course date, and random MIR effect.

Score=adjusted mean of the sum of points; Grade=adjusted mean of the proportion of points out of the total. The maximum grade is 10.