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EFFECTS OF SEQUENTIAL CLINICAL SIMULATION THROUGHOUT A DEGREE IN MEDICINE ON STUDENTS' CLINICAL COMPETENCY PROFILE ON GRADUATION

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ABSTRACT – *Objective:* Medical students at Francisco de Vitoria University undergo simulation training as part of their clinical reasoning education, including technical and non-technical skills.

Our goal is to demonstrate that, in fourth- and fifth-year students, simulation-based learning favors motivation towards the active acquisition of knowledge and its application in the clinical environment, in the cross-curricular skills of medical history, physical examination, and communication.

Materials and Methods: The students carry out eight simulation scenarios per academic year. In the academic year 2022-2023, the 3rd, 6th, and 8th simulations of all fourth- and fifth-year students were analyzed. After watching the simulations, a questionnaire was completed in which the cross-curricular competencies acquired in medical history, physical examination, and communication were assessed.

Results: After analyzing the results, it was found that there were significant differences in the overall assessment and evolution of learning between the three scenarios assessed in both year groups, with a greater improvement in the fifth year than in the fourth year.

The scores for the items assessed in medical history, physical examination, and communication became increasingly higher as the students progressed through the scenarios and the academic year.

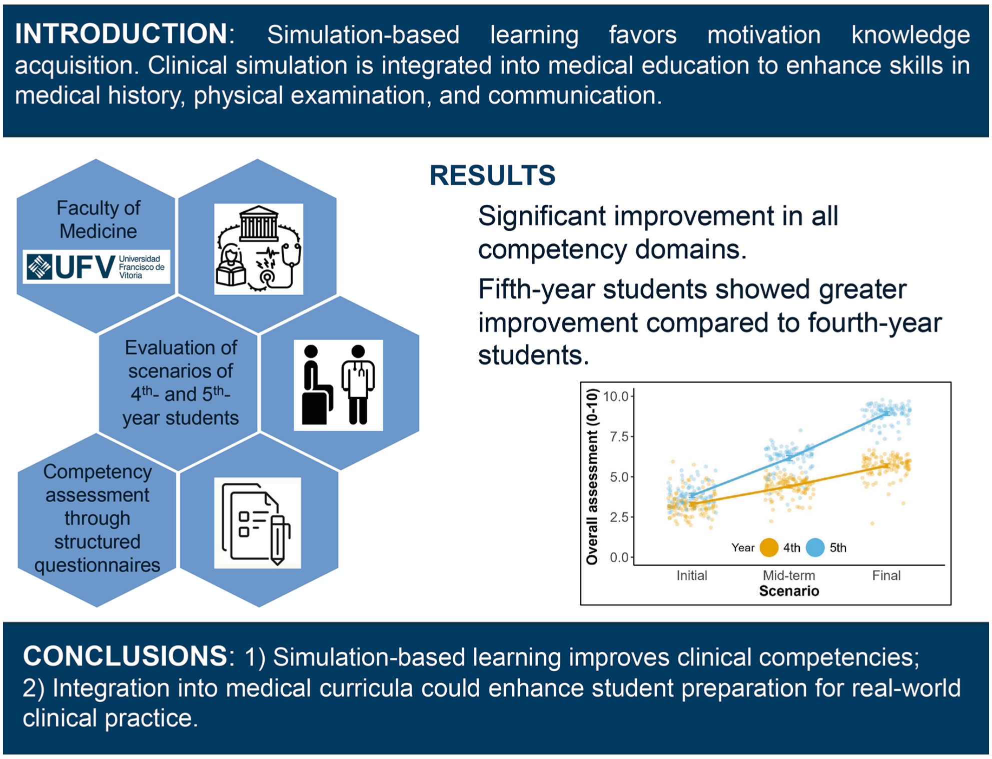
Conclusions: The results demonstrate that simulation teaching improves the acquired competencies of fourth- and fifth-year medical students in the domains of medical history, physical examination, and communication. Further studies supporting this theory are necessary to initiate its implementation in the training curriculum of undergraduate students.

KEYWORDS: Simulation, Learning, Competence domains, Medical degree.

INTRODUCTION

The development of health professionals is constantly changing, and this is associated with a permanent re-evaluation of concepts that allow for better medical practice. These changes have impacted educational institutions, which seek to generate new tools that allow students at different levels of training to acquire and apply basic knowledge and thereby contribute to the environment, standardizing quality processes in a hospital setting that is safe for patients.

Learning through simulation in the different areas of medicine has been a hot topic for some



Graphical Abstract. Graphical representation of the impact of simulation-based learning on clinical competencies in medical education.

years now, based on the recreation of a clinical event or the training of a technique in the most reliable way possible[1].

The teaching is active, as students conduct the simulation through their actions and decisions. It also ensures 'safe teaching', since the actions are not performed on patients but on more or less sophisticated mannequins or actors[2].

There are currently few studies involving undergraduate students where their competence development is objectively assessed with the help of simulation techniques.

Traditionally, the training of medical students is based on the learning model centered on the classroom and the subsequent completion of internships in hospitals with real patients. Currently, the evaluation methods for medical students are primarily based on assessing the theoretical knowledge acquired during classes, typically through multiple-choice, written, or oral exams. These types of exams only evaluate theoretical knowledge acquired but not the practical performance or the integration of theoretical and practical knowledge.

The introduction of simulation helps to evaluate practical performance with simulated cases or patients, just like the Objective Structured Clinical Examination (OSCE), which evaluates clinical competencies through stations that simulate real situations[3].

Simulation-based teaching has been part of the educational curriculum in some Health Sciences Universities for years, including the Francisco de Vitoria University, where the study was conducted.

Gaba, the father of simulation, defines it not as technology but rather as a teaching technique that evokes real experiences with guided interactive experiences[4].

As a technique, simulation has many advantages for student learning, one of the most important of which is that it provides a safe environment for the student and patient, and the scenarios are adapted to the training needs as the courses progress[5].

The development of health professionals is in constant change, associated with a permanent re-evaluation of concepts that allow for better medical practice. These changes have had an impact on educational institutions, which seek to generate new tools that allow students at different levels of training to acquire and apply basic knowledge, and thereby contribute to the environment, standardizing quality processes in a hospital setting that is safe for patients.

Clinical simulation, understood as processes directed by expert staff towards medical students with previous knowledge, has allowed the creation of new competences through scenarios that permit students to engage in a clinical context similar to reality[2].

The usefulness of these techniques has been demonstrated, not only in terms of the ease of learning clinical practices and shortening the time it takes to learn skills, but also by reducing the stress linked to learning.

We found that this methodology, despite its cost, promotes the formation of a reproducible scenario that allows the acquisition of experiences and skills that will later be used appropriately with patients[6].

There are currently few studies involving undergraduate students where their competence development is objectively assessed with the help of simulation techniques. Innovative research into this topic is the only way to improve what is needed and make this process the next step forward in teaching in medical schools around the world.

The fourth- and fifth-year medical students experience 8 simulation scenarios throughout the academic year.

The aim of this study is to assess the degree to which undergraduate students master the aspects developed in practical clinical simulations; specifically, evaluate enhancements of 1) the ability to develop comprehensive medical histories that include all relevant patient information, 2) clinical examination skills tailored to the patient's presenting pathology and 3) effective interpersonal communication skills, enabling efficient and empathetic interaction with patients, their families, and healthcare professionals.

MATERIALS AND METHODS

Study design

This was a descriptive, observational, prospective and longitudinal study. A randomized design was not available as simulation sessions are integrated in the overall curriculum.

Participants

Students from fourth- and fifth-year medical students at the Francisco de Vitoria University; a total of 113 students were in their fourth year and 96 students in their fifth year.

Intervention

Over the academic year, the students carried out 8 simulation sessions. These simulation sessions were part of a simulation training program running from the first to the last year of the degree course, aimed at empowering students in their acquisition of clinical competences.

Data collection

Data was collected for the 2022-2023 academic year, between September 2022 and May 2023.

For this research, the researchers watched three scenarios corresponding to the 3rd, 5th and 8th simulation scenarios in each course and completed a questionnaire designed by the simulation trainers. Reliability between researchers was previously evaluated by Kappa Index, with values over 0.8 for all the items from the questionnaire.

This questionnaire is based on the items assessed in the annual Objective Structured Clinical Examination as well as the subjects "Clinical Methods" and "Clinical Scenarios". It has three main domains: medical history, physical examination, and communication, each with secondary items (Table I). These main domains were cross-curricular competences common to all settings and all medical graduates.

The variables collected in the questionnaire are qualitative with two possible answers:

1. A score of 0 if not completed, 1 if partially completed, 2 if fully completed.
2. YES/NO, if completed or not completed.

For each domain, the average of the responses was weighted on a scale of 0 to 10; the average of the three domains assessed was used for the overall rating.

The questionnaire was completed electronically, and the data was stored securely on the Qualtrics platform.

Statistical analysis

The qualitative variables were described as absolute frequencies (n) and relative frequencies (%) and the quantitative variables as mean ± standard deviation. To assess the temporal evolution of the different variables, the Friedman test was performed, calculating the effect size with Kendall's W. A linear mixed model was also used to determine the influence of the academic year and the scenario over the course of the year as fixed effects, including each student as a random effect. To calculate the effect size, the Estimated Marginal Means (EMMs) method and the Conover test were used as post-hoc analysis. The statistical analysis was performed with R v. 4.2 software. Significant differences were considered to exist when the *p*-value was lower than 0.05.

Ethical principles

The study protocol received approval from the regulatory Ethics Committee (Universidad Francisco de Vitoria, Madrid, Spain) with the code 31/2022. It adhered to the ethical principles of the Declaration of Helsinki. Informed consent to review videos from simulation scenarios were previously obtained from the participants.

Table I. Validation questionnaire.

<table>
<tr><th>I</th><th>Obtain and compile a medical record that contains all the relevant information</th><th>0</th><th>1</th><th>2</th></tr>
<tr><td>1</td><td>Asks openly about the main reason for the visit and records this in the medical record (1 pt if they do one of the two, 2 pts if they do both)</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Takes a history of the current disease<table><tr><th></th><th>Yes</th><th>No</th></tr><tr><td>Since when?</td><td></td><td></td></tr><tr><td>Localisation and irradiation</td><td></td><td></td></tr><tr><td>Time pattern</td><td></td><td></td></tr><tr><td>Aggravating/attenuating factors</td><td></td><td></td></tr><tr><td>Accompanying symptoms</td><td></td><td></td></tr><tr><td>Functional limitation</td><td></td><td></td></tr><tr><td>Associated with something?</td><td></td><td></td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Explores the patient’s perspectives on the health problem (ideas, fears, expectations, etc.)</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Generates a list of personal history in the medical record<table><tr><th></th><th>Yes</th><th>No</th></tr><tr><td>Drug allergies</td><td></td><td></td></tr><tr><td>Medical history</td><td></td><td></td></tr><tr><td>Surgical history</td><td></td><td></td></tr><tr><td>Substance use</td><td></td><td></td></tr><tr><td>Usual medication</td><td></td><td></td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Takes a family, social and employment history<table><tr><th></th><th>Yes</th><th>No</th></tr><tr><td>Family history</td><td></td><td></td></tr><tr><td>Work activity</td><td></td><td></td></tr><tr><td>Family environment</td><td></td><td></td></tr><tr><td>Baseline situation (IADL/DADL)</td><td></td><td></td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Takes the medical history by organs and apparatus, appropriate to the case<table><tr><th></th><th>Yes</th><th>No</th></tr><tr><td>Systemic symptoms (fever, asthenia, anorexia, weight loss)</td><td></td><td></td></tr><tr><td>Neurological symptoms</td><td></td><td></td></tr><tr><td>Respiratory symptoms</td><td></td><td></td></tr><tr><td>Cardio-circulatory symptoms</td><td></td><td></td></tr><tr><td>Digestive symptoms</td><td></td><td></td></tr><tr><td>Genito-urinary symptoms</td><td></td><td></td></tr><tr><td>Musculoskeletal/skin symptoms</td><td></td><td></td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>II</td><td>Conduct a physical examination</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Explains to the patient what examination is going to be performed, why it is necessary, and where the patient should be positioned</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Washes hands before and after the physical examination (1 pt if they do one of the two, 2 pts if they wash both times)</td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Checks vital signs (heart rate, respiratory rate, blood pressure, temperature, etc.), appropriate to the case</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Performs a physical examination appropriate to the clinical problem</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>Examines the patient thoroughly, following a systematic approach (by organs and apparatus, etc.), completing the inspection, palpation, percussion and auscultation, when appropriate</td><td></td><td></td><td></td></tr>
<tr><td>III</td><td>Establish good interpersonal communication skills enabling efficient and empathetic communication with patients, relatives and other professionals</td><td></td><td></td><td></td></tr>
<tr><td>12</td><td>Introduces themselves at the beginning of the scenario, asks the patient’s name</td><td></td><td></td><td></td></tr>
<tr><td>13</td><td>Asks about the patient’s concerns and needs</td><td></td><td></td><td></td></tr>
<tr><td>14</td><td>Maintains an assertive attitude while conveying information in terms understandable to the patient</td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>Action plan</td><td></td><td></td><td></td></tr>
<tr><td>16</td><td>Appropriate farewell</td><td></td><td></td><td></td></tr>
</table>

IADL: Independent for activities of daily living. DADL: Dependent for activities of daily living.

Table II. Measurement of overall assessment over time by academic year.

	Initial[1]	Mid-term[1]	Final[1]	*p*-value[2]	Effect size[3]	Magnitude
4th year (n=113)	3.30 ± 0.73	4.40 ± 0.56	5.68 ± 0.66	**<0.001**	0.851	Large
5th year (n=96)	3.83 ± 0.66	6.15 ± 0.79	8.92 ± 0.55	**<0.001**	0.960	Large

[1]Mean ± SD = standard deviation. [2]Friedman rank sum test. [3]Kendall W.

Table III. Results of the linear mixed model and effect size on overall evaluation.

Linear mixed model

Term	*p*-value
Time point	**<0.001**
Year	**<0.001**
Interaction Time point: Year	**<0.001**

Effect	EMMeans[1]	95% CI (Lower)	95% CI (Upper)	*p*-value[2]	Effect size[3]
Initial 4th - Mid-term 4th	-1.09	-1.33	-0.85	**<0.001**	-1.74
Mid-term 4th - Final 4th	-1.28	-1.52	-1.04	**<0.001**	-2.04
Initial 5th - Mid-term 5th	-2.32	-2.58	-2.06	**<0.001**	-3.7
Mid-term 5th - Final 5th	-2.77	-3.03	-2.51	**<0.001**	-4.42

Effect	EMMeans[1]	95% CI (Lower)	95% CI (Upper)	*p*-value[2]	Effect size[3]
Initial 4th - Initial 5th	-0.53	-0.79	-0.26	**<0.001**	-0.84
Mid-term 4th - Mid-term 5th	-1.76	-2.02	-1.49	**<0.001**	-2.8
Final 4th - Final 5th	-3.24	-3.51	-2.98	**<0.001**	-5.17

[1]Estimated marginal means. [2]Conover test. [3]Population SD/equivalent degrees of freedom. CI: Confidence interval; SD: Standard deviation.

RESULTS

209 students (113 in the fourth year and 96 in the fifth year) participated in the study. Questionnaires were collected for all three simulation scenarios (initial, mid-term and final). In terms of sex, there were 18 male students (15.9%) in the fourth year and 18 male students (18.7%) in the fifth year.

We first wanted to determine whether the students' overall rating (calculated as the average, from 0 to 10, of each of the items included in the questionnaire) improved over the course of the year. In both the fourth and fifth years there were significant differences between the scenarios, with a large effect size (Kendall's W: 0.851 for the fourth year and 0.960 for the fifth year) (Table II).

To determine whether both the time-point and the academic year influenced the overall rating, a linear mixed model was used, with the student being the random effect of the model and Year and Time-point being the fixed effects. Both Time-point (passage of time) and Year were significant variables for explaining the observed variability in the outcome measure "Global Rating"; furthermore, the Year-Time-point interaction was also significant for explaining the observed variability (Figure 1).

Using the Estimated Marginal Means (EMMs) method and Conover's test as a post-hoc analysis, the effect size of the passage of time between the initial and mid-term scenarios and between the mid-term and final scenarios was determined for both the fourth- and fifth-year students, with the effect size being objectively larger in the fifth year than in the fourth year. The effect size of the variable "Year" was also assessed, i.e., whether the students obtained different overall ratings in the initial, mid-term or final scenarios because they were in different years; the effect size was greater (Conover's test) in the final scenario than in the mid-term scenario, and this, in turn, was greater than the effect size obtained in the initial scenario (Table III).

Evaluation by domains

To check whether the origin of these differences was due to any of the domains assessed, the same analysis was carried out using the scores obtained in each of the 3 competency domains assessed: medical history, exploration and communication.

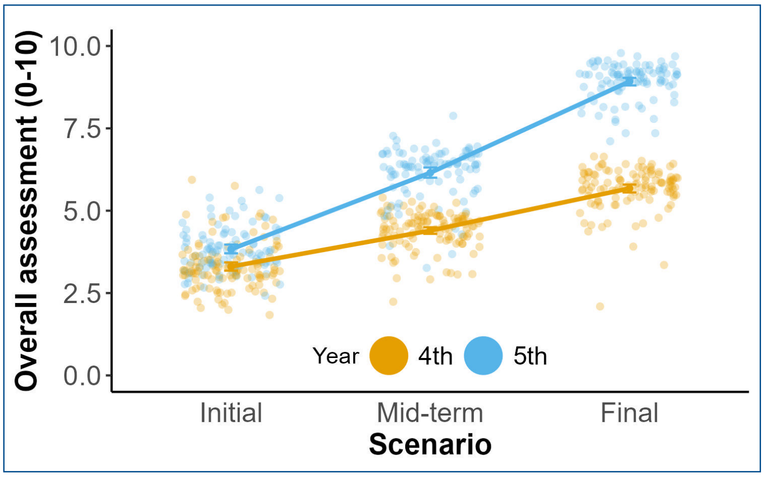


Figure 1. Progression of overall assessment scores across three clinical scenarios (Initial, Mid-term, Final) for fourth- (orange) and fifth-year (blue) medical students. Each dot represents an individual student's score, with lines indicating the mean trend.

Again, for the 3 domains, there were significant assessment differences between the 3 scenarios evaluated in the two years (Friedman's test *p*-value <0.001). Although the effect size (Kendall's W) was large in both years, it was larger in the fifth year than in the fourth year (Table IV). This result led us to assess whether there was a relationship between improvement over time and academic year; we therefore used a linear mixed model to evaluate this.

Both the Time-point (passage of time) and the academic year were significant variables for explaining the variability observed in the variable "Global assessment", as well as the possible interaction between the two variables. On this occasion, for Medical History, the effect size was greater between the initial and mid-term scenarios, but for Exploration and Communication, the effect size was greater between the mid-term and final scenarios; and this was the case for the fourth and fifth years.

The effect size of the variable "Year" was assessed, i.e., whether the students scored differently in the domains in the initial, mid-term or final scenarios because they were in different years; as with the overall score, the effect size was greater (Conover's test) in the final scenario than in the mid-term scenario, and this, in turn, was greater than the effect size obtained for the initial scenario (Table V).

DISCUSSION

According to our results, students improved their performance across the eight simulation scenarios developed during the fourth and fifth academic years of the medical degree at Francisco de Vitoria University, with a progressive increase in competence levels (anamnesis, physical examination, and communication) from the first scenario to the final one assessed. Learning increases as the students move through the simulation scenarios and this is greater in fifth-year students than in fourth-year students.

These results seem to indicate that the progress made in the fifth year is greater than in the fourth year. This finding might be a consequence

Table IV. Measurement of assessment by domains over time by academic year.

		Initial[1]	Mid-term[1]	Final[1]	*p*-value[2]	Effect size[3]	Magnitude
4th year	**Medical history**	3.67 ± 0.84	5.18 ± 0.63	6.50 ± 0.85	**<0.001**	0.805	Large
	Exploration	2.97 ± 0.83	3.77 ± 0.58	5.05 ± 0.84	**<0.001**	0.723	Large
	Communication	3.19 ± 0.99	4.09 ± 0.87	5.32 ± 0.82	**<0.001**	0.650	Large
5th year	**Medical history**	4.20 ± 0.84	7.00 ± 1.07	9.03 ± 0.54	**<0.001**	0.964	Large
	Exploration	3.53 ± 1.07	5.59 ± 0.98	8.76 ± 0.91	**<0.001**	0.939	Large
	Communication	3.69 ± 1.09	5.69 ± 0.73	8.95 ± 1.08	**<0.001**	0.935	Large

[1]Mean ± SD = standard deviation. [2]Friedman rank sum test. [3]Kendall W.

Table V. Effect size in the domain assessment.

	Effect	EMMeans[1]	95% CI (Lower)	95% CI (Upper)	*p*-value[2]	Effect size[3]
Medical history	Initial 4th - Mid-term 4th	-1.51	-1.81	-1.21	**<0.001**	-1.91
	Mid-term 4th - Final 4th	-1.32	-1.62	-1.02	**<0.001**	-1.67
	Initial 5th - Mid-term 5th	-2.81	-3.13	-2.48	**<0.001**	-3.55
	Mid-term 5th - Final 5th	-2.03	-2.36	-1.7	**<0.001**	-2.57
	Initial 4th - Initial 5th	-0.53	-0.85	-0.21	**<0.001**	-0.67
	Mid-term 4th - Mid-term 5th	-1.83	-2.15	-1.51	**<0.001**	-2.31
	Final 4th - Final 5th	-2.54	-2.86	-2.22	**<0.001**	-3.21
Exploration	Initial 4th - Mid-term 4th	-0.8	-1.12	-0.47	**<0.001**	-0.93
	Mid-term 4th - Final 4th	-1.28	-1.61	-0.96	**<0.001**	-1.49
	Initial 5th - Mid-term 5th	-2.06	-2.42	-1.71	**<0.001**	-2.4
	Mid-term 5th - Final 5th	-3.17	-3.52	-2.81	**<0.001**	-3.68
	Initial 4th - Initial 5th	-0.56	-0.9	-0.21	**<0.001**	-0.65
	Mid-term 4th - Mid-term 5th	-1.82	-2.17	-1.48	**<0.001**	-2.12
	Final 4th - Final 5th	-3.71	-4.05	-3.36	**<0.001**	-4.31
Communication	Initial 4th - Mid-term 4th	-0.89	-1.23	-0.55	**<0.001**	-1.00
	Mid-term 4th - Final 4th	-1.23	-1.57	-0.89	**<0.001**	-1.38
	Initial 5th - Mid-term 5th	-2.00	-2.37	-1.63	**<0.001**	-2.24
	Mid-term 5th - Final 5th	-3.26	-3.63	-2.89	**<0.001**	-3.65
	Initial 4th - Initial 5th	-0.49	-0.86	-0.12	**0.002**	-0.55
	Mid-term 4th - Mid-term 5th	-1.6	-1.97	-1.23	**<0.001**	-1.79
	Final 4th - Final 5th	-3.63	-4.00	-3.26	**<0.001**	-4.06

[1]Estimated marginal means. [2]Conover test. [3]Population SD/equivalent degrees of freedom. CI: Confidence interval; SD: Standard deviation.

of the fact that the students in the fifth year have completed more simulation scenarios, as they have accumulated the scenarios of the entire academic year as well as those from previous years.

Consequently, the variables academic year and passage of time (scenarios) interact to boost the improvement of learning. It is difficult to find scientific literature supporting these specific results limited to simulation scenarios. Students in a higher year, naturally, experience a greater progression in their abilities. This may be due to several factors, the first being that, at the end of the fifth year of medical studies, the students have already acquired competences that make them more educated from a general perspective as well as, more specifically, in the items studied. Evidently, time spent in healthcare centers also plays a very important role in the acquisition of these competences. On the other hand, and this is one of the limitations of the study, the behavior of our results may be limited to these two groups of students in particular, and when repeated with different students, different patterns may be observed.

In Spanish hospitals, for the vast majority of the time, students are limited to the role of simple observers, and it is difficult for them to become actively involved in diagnostic and therapeutic decision-making. When they do practical training and collaborate in taking medical histories or examining patients, they are not usually directly responsible for their management, so it is very positive for their training to be the key player in the simulation and to actively participate in therapeutic decision-making in a quasi-realistic environment.

The study proved useful for the instructors, as it allowed us to observe small groups directly at work, identify gaps in training, and analyze the teamwork of the students. It is very important to analyze these non-technical factors during debriefing because we know that human factors are the cause of more than 70% of complications in healthcare[7].

From our perspective, some of the objectives of undergraduate simulation activities that were developed during the simulation scenarios were[8]:

Students were able to identify and handle serious and common situations that required immediate attention;

Simulation facilitated the retention of knowledge and skills through their practical application;

Students were able to experiment, reflect and, consequently, better manage stress to optimize decision-making in serious situations;

They were able to develop skills for cooperative work in crisis situations.

To achieve these objectives, it is necessary for the student to repeat simulation scenarios several times; students who develop simulation scenarios seem to acquire the necessary skills in shorter periods of time than those who are exposed only to routine clinical situations with real patients[9]; therefore, there is a relationship between the total time of exposure to simulation activities and learning outcomes[9].

Our experience leads us to believe that simulation training is possible and satisfactory for undergraduate medical students.

CONCLUSIONS

The results of this study show that it is both feasible and positive to use clinical simulation to teach medical undergraduates, from which we can infer that simulation tends to favor their motivation towards the active learning of knowledge and its application in the clinical environment.

Clinical simulation training can be an excellent complement to hospital internships, and we believe that this could be integrated into the educational curricula of medical schools.

We are beginning to obtain our own data, as other authors have shown that the transfer of skills acquired in simulation increases the learning retention rate compared to traditional teaching methods[1].

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article. The authors also have no relevant financial or non-financial interests to disclose.

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Authors' Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by EMB, FN. The first draft of the manuscript was written by EMB and all authors commented on previous versions of the manuscript. All authors read and approved the original manuscript as well as the reviewed version.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due giving ethical and privacy considerations but are available from the corresponding author on reasonable request.

Ethics Approval and Informed Consent

This study was approved by the Ethics Committee at Francisco de Vitoria University with ID number 31/2022 on July 27th, 2022. All the participants completed the informed consent form for research purposes provided by the UFV Clinical Simulation Centre.

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