

# How Much do We Know About Pulse Oximeters Used in Every Field from Home Care to Critical Care? A Descriptive Study

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## Abstract

**BACKGROUND/AIMS:** Aim of this study was to evaluate the knowledge and actions of nurses regarding the use of pulse oximeters. The measurement of oxygen saturation is considered as an additional indicator for measuring vital signs. The measurement of oxygen saturation by pulse oximeters is a part of nursing care in terms of the rapid evaluation of patients. The literature suggests that errors made in taking measurements influence the reliability of these measurement even though it is easy to use pulse oximeters.

**MATERIALS AND METHODS:** Sample selection was not carried out in this descriptive study, all of the nurses (n=588) in the population were included in this study; however, the sample of this study consisted of 393 nurses who agreed to participate. This study was conducted with nurses working at a university hospital in Ankara province in Türkiye. In order to assess the knowledge and attitudes of nurses about the use of pulse oximetry, research data and nursing identifying characteristics were collected through a questionnaire developed according to the literature.

**RESULTS:** In order to evaluate the data, the pulse oximeter knowledge mean scores of nurses were calculated from the answers given to 28 statements. The knowledge levels of the nurses working in both clinical fields and services on the use of pulse oximeter were observed to not be at the desired level.

**CONCLUSION:** The fact that nurses know how to correctly use of all technological devices in the units where they work is essential for patient outcomes to be reliable and for patients to receive efficient care. The fact that hospital management regulates in-service training intermittently for the nurses employed is considered to be effective in eliminating these deficiencies.

**Keywords:** Knowledge, nursing, oximetry

## INTRODUCTION

Respiration, the most basic physiological human need, is based on oxygen (O<sub>2</sub>) reaching the body's cells and the removal of carbon dioxide from cells.<sup>1</sup> Since it cannot meet the metabolic requirements, O<sub>2</sub> binds to hemoglobin (Hb) and enters circulation as oxyhemoglobin. The binding rate of O<sub>2</sub> to Hb is defined as "O<sub>2</sub> saturation" and expressed as a percentage. While arterial O<sub>2</sub> saturation is shown as

"SaO<sub>2</sub>", peripheral O<sub>2</sub> saturation is shown as "SpO<sub>2</sub>".<sup>2,3</sup> SaO<sub>2</sub> refers to the O<sub>2</sub> saturation of Hb in erythrocytes. The normal O<sub>2</sub> saturation value is between 90-100%.<sup>4,6</sup>

Monitoring the SpO<sub>2</sub> levels of patients in the assessment of the respiratory process and the vital functions of the patient and for the early detection and intervention of hypoxic conditions is one of the fundamental duties of the nurse. This level is measured and evaluated

**To cite this article:** Ketı EP, Ünlüsoy Dinçer N. How Much do We Know About Pulse Oximeters Used in Every Field from Home Care to Critical Care? A Descriptive Study. Cyprus J Med Sci 2023;8(1):74-82

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**Received:** 06.02.2021  
**Accepted:** 13.02.2022



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by nurses through analysis of an invasive arterial blood gas sample or by using a pulse oximeter device non-invasively.<sup>7</sup>

Pulse oximeters entering into the health care scene for the first time in 1850 with Sechenov's experiments<sup>8</sup> and have now reached the ability to follow up patients from home by becoming android-based mobile devices enabling them to be used easily in non-clinical environments with today's technology.<sup>9</sup> Pulse oximeters consist of a probe and a monitor.<sup>10</sup> There is a photo-transmitter with light emitting diodes emitting infrared rays (at 940 nm wave width) and red light (at 660 nm wave width) on one side of the pulse oximeter probe and a photodetector receiving these light wave lengths on the other side. In the monitor section, the absorption degree of these wavelengths is determined and the O<sub>2</sub> saturation value and the heart rate are displayed on the screen as a wave sample.<sup>11</sup> The types of pulse oximeter devices are desktop, finger, portable and those which can be connected to bedside monitors.<sup>12</sup> There are forehead, ear, nose, and finger probes which can be connected to pulse oximeter devices. These probes are either detachable clip-on or adhere to the skin.<sup>6</sup>

Pulse oximeters are easy-to-use and painless<sup>10,11</sup> devices which have the capability to measure arterial blood O<sub>2</sub> saturation, do not require calibration, have a high accuracy rate and widespread usage in the medical world. Pulse oximeters are used in patients with impaired respiratory and circulatory system, operating rooms, intensive care units, emergency departments, clinics, when transferring patients and during patient follow-up at home.<sup>6</sup> In addition, pulse oximeters have a great importance in determining silent hypoxia during the coronavirus disease 19 pandemic period in the current situation.<sup>13</sup> The use of pulse oximeters which provide information on the patient's immediate status quickly and with low cost is advantageous since they are portable and rechargeable. Since the measurements are performed with a non-invasive method, they do not have any complications such as damaging veins. However, burns arising from not replacing the pulse oximeter probes at proper intervals, allergies to sticky probes, and tissue ischemia risk are some of the disadvantages in their use.<sup>6,14,15</sup>

The reliability of the SpO<sub>2</sub> value is affected by having a clean and dry area, skin color, nail varnish and henna, perfusion insufficiency, excessive movement, ambient light, proper placement of the probe and appropriate probe selection. The fact that nurses know the working mechanism of pulse oximeters, how to use them and what affects O<sub>2</sub> saturation reduces measurement errors.<sup>7,16</sup> Knowing the factors affecting the use of pulse oximeters and the reliability of the SpO<sub>2</sub> values measured in pulse oximetry and following up the patient's oxygenation are important in terms of medical treatment and nursing care. The fact that nurses evaluate SpO<sub>2</sub> correctly and prepare a nursing care plan concerning any problems in this regard increases the efficiency of the care given to the patients.

Studies have revealed that nurses have a lack of knowledge about the use of pulse oximeter. For example, in their study, Kiekkas et al.<sup>17</sup> stated that the knowledge mean scores of the nurses on a total of 21 information evaluation questions were  $\bar{x}=12.8\pm 3.2$ . In this study, it was seen that the lack of knowledge was mostly related to the working principles of pulse oximeters. In a study which was similar to the present study in terms of methodology conducted by Yıldız et al.<sup>18</sup> on intensive care nurses in a university hospital in Türkiye, it was observed that the knowledge mean score was 14.52 out of a total of 26 statements for the use and the principles of pulse oximeters. The results of this research

show that nurses do not have enough knowledge about first aid for hypoxic patients. Apart from these, from the late 90s to the present day, we have come across several studies investigating the level of nurses' knowledge about the use pulse oximeters in many different countries.<sup>19</sup> Studies have shown that there was a lack of knowledge about the use of pulse oximeters, and at this point, training should be organized regarding both the use of pulse oximeters and their working principles. The study of Stathoulis et al.<sup>20</sup> showed the effect of training on the level of knowledge of health care personnel.

Pulse oximeters, which are known to be widely used in critical areas, have become tools which can be used in daily life from home care to critical areas, and even in mobile devices. In terms of patient care and safety, it is very important that nurses, responsible for caregiving and patient education, have sufficient knowledge and experience about pulse oximetry. For these reasons, our research was implemented in all units of a university hospital in Türkiye in order to assess the theoretical information and the behavior of the nurses regarding pulse oximetry.

## MATERIALS AND METHODS

### Study Design and Participants

This descriptive study was conducted in a university hospital located within the boundaries of Ankara province. The population of the study consisted of all the nurses (n=588) working in the university hospital located within the boundaries of Ankara province. This research was conducted with a total of 393 nurses who volunteered to participate in this study and were not off duty or on sick leave at the time of this study. The rate of participation in this research was 66.8%.

### Data Collection

The data were collected by using a questionnaire developed by the researcher. The questionnaire consisted of three parts. In the first part, there were 15 questions about the descriptive characteristics of nurses and the use of pulse oximeters. The second part included an information test which identifies the pulse oximeter device and consists of correct or incorrect statements (a total of 28 statements) about which situations can affect the value read in pulse oximeter devices. The second part was developed specifically for this study because no instrument which captured the relevant content with measured reliability and validity was available after a literature review. There are 12 statements which assess the possible situations where nurses use pulse oximeters in the last part of the questionnaire. The nurses were asked to mark the appropriate answers from the options of "always", "occasionally" or "never" for the frequency of use of pulse oximeters.

In order to ensure the content validity of the questionnaire in this study, the opinions of three experts in the nursing field and an expert in the field of assessment and evaluation in education were obtained. Whether or not each item in the questionnaire was appropriate for the assessment instrument was evaluated by these experts at the content validity phase. The necessary modifications were made in line with the suggestions received from the experts. A preliminary application was carried out by obtaining the written consent of 20 nurses using a face-to-face interview technique through pre-scheduled appointments. Those nurses who were interviewed in the pre-practice were excluded from the final sample. The questionnaire was evaluated in accordance with the feedback received from the preliminary application and it was reassessed and arranged in terms of its flow order, function, and quality.

This study was conducted between the 15<sup>th</sup> of March and the 15<sup>th</sup> of June, 2014. The nurses who signed the informed consent form were asked to respond to demographic questions and to mark as “correct” or “incorrect” options for the knowledge expressions and to mark as “always”, “occasionally” or “never” for the behavior expressions. It took approximately 20 minutes to complete the questionnaire.

### Statistical Analysis

Statistical Package for the Social Sciences (SPSS) version 21.0 (IBM SPSS Corp.; Armonk, NY, USA) was used for statistical analyses. The demographic data were analyzed in percentages. We eliminated 3 questionnaire forms as they were not completely filled out. Thus, the data obtained from 393 questionnaires were analyzed. One point was given for each correct answer of the respondents to the statements, and then, the total score was calculated. Mean, standard deviation, minimum, and maximum values were used to indicate the knowledge scores of the nurses. While the normality of numerical variables was examined by the Shapiro-Wilk test, the homogeneity of variances were investigated by Levene’s test. Since the parametric test conditions were not met, the Mann-Whitney U test was used to examine whether or not there was a difference between the knowledge mean scores and status of using pulse oximeter of the nurses. Kruskal-Wallis and Siegel-Castellan tests were used for the multiple group comparisons. Statistical significance was set at  $p < 0.05$ .

### Ethics Committee Approval

The study protocol was officially approved and ethics committee approval was obtained from Ankara University Ethics Committee (approval number: 160/961, date: 19.12.2013). We obtained written permission from the medical directors of the hospitals and written informed consent from the nurses who agreed to participate in this study.

## RESULTS

Table 1 shows the descriptive characteristics of the nurses participating in this study. The average age of the nurses was  $33.15 \pm 7.39$  years and 39.7% were in the age group of 28-36 years. It was observed that the nurses participating in this study received different nursing education, and more than half of the nurses (58.5%) had a bachelor’s degree in nursing, and 4.6% had postgraduate education in nursing. One out of five nurses participating in this study (20.4%) stated that they had been working as a nurse for 1-5 years; and another one out of five (20.9%) stated they had been working as a nurse for 6-10 years. 33.6% of the nurses were working in critical units, 22.4% were working in surgical units, and 21.9% were working in internal medicine units.

More than half of the nurses (62.6%) followed up their patients by using a pulse oximeter. While patient follow-up pulse oximeter use was highest for those cases requiring emergency intervention (43.3%), the rate of pulse oximeter use was 21.1% in routine/all patient follow-up. When the distribution of the body parts measured by the pulse oximeter was examined, on the finger was highest with a rate of 73.4% and on the toe was in second place with a rate of 15.7%; whereas, only one person was taking measurements from the nose (0.3%) (Table 1).

It was determined that 49.5% of the nurses received their information about pulse oximeter at school during their nursing education and 39.2% received this information in the hospital via in-service training.

The rate of receiving information from journals and articles was only 4.9% among the information sources regarding pulse oximeters (Table 1).

Table 2 shows the distribution of responses given by the nurses to the pulse oximeter related statements. The “Failure to properly place the pulse oximeter probe affects the pulse oximeter value” statement was given correct answers at the highest rate (83.5%) from all the statements. The nurses gave correct answers with the highest rate (81.7%) for the statement about the measurement made on the finger among the statements about the correct placement of the light source of the pulse oximeter probe. The most incorrectly answered statements about the placement of the light source of the pulse oximeter probe were those statements about the correct measurement parts of the pulse oximeter on the forehead (89.1%), nose (78.4%) and ears (76.1%). 74.6% of the nurses gave the correct answer to the statement about the limit of the value read from the pulse oximeter and 69.2% gave the correct answer to the statement on what the pulse oximeter measures.

The nurses gave correct answers for the statements about the factors affecting the value read from pulse oximeter mostly for the proper placement of the pulse oximeter probe (83.5%), for shivering and tremors (73.5%), and for the humidity of the measurement area (71.8%). 75.6% of the nurses responded incorrectly to the effect of surgical lights on the values given by pulse oximeters (Table 2).

The knowledge mean score of the nurses to the total of 28 statements was  $\bar{x} = 15.06 \pm 6.0$ . This result indicated that 53.8% of the statements were known correctly by the nurses. There was no nurse who responded to all of the statements correctly.

There was no statistically significant difference between the average ages of the nurses and their knowledge mean scores ( $p > 0.05$ ). The difference between the knowledge mean scores and educational levels, working periods and the units of the nurses was found to be significant ( $p < 0.05$ ). When their educational levels were examined, it was observed that the knowledge mean scores of those nurses with a bachelor’s degree were significantly higher than the knowledge mean scores of those nurses with an associate’s degree in nursing and vocational health school education in advanced statistical analysis. In the pairwise comparison related to the working period, it was determined that the difference between the groups was between those nurses working for 20 years or more and those nurses working for 1-5 years and the knowledge mean scores of those nurses having a working period of 20 years or more were significantly lower. The knowledge mean scores of the nurses working in the critical units were observed to be higher than that of those working in the other units ( $p < 0.05$ ). The difference between the nurses’ status of using pulse oximeter and their knowledge mean scores was determined to be significant ( $p < 0.05$ ) (Table 3).

Table 4 examines the frequency of nurses’ actions of using pulse oximeters in certain possible situations. It was determined that the nurses “always” used pulse oximeter for following up patients with respiratory problems (79.4%), for following up patients using mechanical ventilators (75.1%) and for following up patients after a surgical operation (67.4%).

## DISCUSSION

Pulse oximeters are very important devices for detecting hypoxic events which are considered as an additional indicator in assessing vital signs which are not visible in various situations.<sup>21</sup> Nurses are responsible

for knowing how patients' O<sub>2</sub> saturation values are measured and the correct measurement techniques in order to follow-up the patient's saturation. Therefore, the nurses' knowledge about pulse oximeters is very important in terms of the correct evaluation of the patient.

In our study, the mean score for the knowledge of nurses regarding the total of 28 statements including pulse oximeter knowledge statements

was 15.06±6.0. In this study, it was observed that the knowledge mean score of the nurses was not at the expected level when considering that more than half of the nurses participating in the present study used pulse oximeter in their units and about half of the nurses were working in the critical units. This situation revealed that the nurses were conducting measurements without knowing the details of the technological device they were using. When similar studies were

**Table 1. Descriptive characteristics of the nurses (n=393)**

Descriptive characteristics	n	%
<b>Age groups</b>		
19-27	111	28.2
28-36	156	39.7
37-45	101	25.7
46+	25	6.4
<b>Average age mean score (± SD): 33.15±7.39, minimum: 19, maximum: 53</b>		
<b>Educational level/graduation</b>		
Vocational health school	77	19.6
Associate degree	68	17.3
Bachelor's degree	230	58.5
Postgraduate degree	18	4.6
<b>Clinical experience (in years)</b>		
<1	43	10.8
1-5	80	20.4
6-10	82	20.9
11-15	58	14.8
16-20	53	13.5
>20	77	19.6
<b>Department</b>		
Critical units	132	33.6
Surgical units	88	22.4
Internal units	86	21.9
Outpatient clinic	56	14.2
Mixed units	14	3.6
Special branch nursing	12	3.1
Management	5	1.2
<b>Nurses' use of pulse oximeter in the units (n=393)</b>		
Using	246	62.6
Not using	147	37.4
<b>Body parts measured by pulse oximeter (n=331)<sup>†</sup></b>		
Finger	246	74.3
Toe	53	16.0
Earlobe	31	9.4
Nose	1	0.3
<b>Place where the training/information on pulse oximeter was received (n=416)<sup>†</sup></b>		
At school during nursing education	163	49.5
In the hospital with in-service training	129	39.2
Experience, learning from other occupational members	68	17.3
The internet	37	11.2
Related journals and articles	16	4.9
Conferences, courses, seminars	3	0.8

<sup>†</sup>Since the nurses responded to more than one option, "n" is multiplied, SD: Standard deviation, min: Minimum, max: Maximum

examined,<sup>17,18,22-24</sup> we came across several studies, the results of which are compatible with the results of our research. In the study of Yıldız et al.<sup>18</sup> that was conducted with nurses of an intensive care unit at a university hospital in Türkiye, it was observed that nurses had relatively low averages on their knowledge scores for the use of pulse oximeters. In their study, the insufficiency of the knowledge score average was explained by the fact that most of the participants gained their first experience on pulse oximeter use during their clinical practices and they did not receive sufficient formal education on pulse oximetry. In the study of Nimbalkar et al.<sup>22</sup> from India, it was noted that the average knowledge score for the use of pulse oximeter was below expectations and the average knowledge scores of the nurses with formal education were higher for theoretical knowledge questions. The study of Milutinovic et al.<sup>23</sup> from Serbia stated that the average knowledge scores were low mainly for those questions regarding the principles of pulse oximeter use and an increase in the level of knowledge for this is a situation which can be achieved with formal education, not through experience. On the other hand, Kiekkas et al.<sup>17</sup> stated that knowledge is

mostly obtained with clinical experience rather than formal education with regards to low levels of pulse oximeter knowledge score averages. Seeley et al.<sup>24</sup> stated that there were considerable deficiencies regarding the theoretical factors affecting the practice and interpretation of pulse oximeters in their study with fresh graduates who had some clinical experience. The findings of their study are similar to the knowledge score average in our study. In our study, half of the participants had received information about pulse oximeter at school during their formal education, and nearly half of them had received in-service training. The low number of those who had received formal education and those who had received in-service training after graduation may explain the result that the knowledge point average was not at the expected level. In addition, the research conducted by Elliot and Williamson<sup>25</sup> in 2020 offers a new perspective on the lack of knowledge of nurses on the use of pulse oximeters. Elliot and Williamson<sup>25</sup> examined the lecture notes about pulse oximetry in 32 current nursing books used by undergraduate students and concluded that superficial and variable information may be one of the factors associated with this lack of

**Table 2. Distribution of nurses' responses to statements about pulse oximetry (n=393)**

No	Statements	Those who gave the correct answers	
		n	%
1.	Pulse oximeters are an invasive assessment tool	269	68.4
2.	The adhesive pulse oximetry sensors are disposable <sup>†</sup>	165	42.0
3.	Heart rate is assessed by pulse oximeters <sup>†</sup>	245	62.3
4.	Respiratory rate is measured by pulse oximeters	245	62.3
5.	Partial oxygen pressure is measured by pulse oximeters	100	25.4
6.	Pulse oximeters measure the amount of oxygen carried by hemoglobin <sup>†</sup>	272	69.2
7.	When measuring from the finger, the light source of the pulse oximeter should be on the nail <sup>†</sup>	321	81.7
8.	The location of the pulse oximeter probe should be changed every 8 hours	80	20.4
9.	Pulse oximeter probes may cause burns if they remain in the same area for a long time <sup>†</sup>	101	25.7
10.	In the forehead measurement, the light source of pulse oximeter should be placed just above the eyebrows by centering the iris <sup>†</sup>	43	10.9
11.	If the value read from the pulse oximeter is 80, then the patient does not need oxygen support	293	74.6
12.	The region in which the pulse oximeter probe is placed should be evaluated for allergic reactions <sup>†</sup>	196	49.9
13.	In measurements on the ears, the light source of the pulse oximeter should be on the tragus	94	23.9
14.	In measurements on the nose, the light source of the pulse oximeter should be on the nose wing <sup>†</sup>	85	21.6
15.	The pulse oximeter value is affected by the humidity of the measurement area of pulse oximeter <sup>†</sup>	282	71.8
16.	Dried liquid or blood on the pulse oximeter probe does not affect the pulse oximeter value	266	67.7
17.	Failure to place the pulse oximeter probe properly affects the pulse oximeter value <sup>†</sup>	328	83.5
18.	Surgical lights on the pulse oximeter probe do not affect the pulse oximeter value	96	24.4
19.	Hypothermic state affects the reading time of the pulse oximeter device <sup>†</sup>	275	70.0
20.	Carbon monoxide poisoning does not affect pulse oximeter values	252	64.1
21.	Dark nail polishes affects pulse oximeter values <sup>†</sup>	265	67.4
22.	Fake nails affect pulse oximeter values <sup>†</sup>	267	67.9
23.	The presence of anemia does not affect pulse oximeter values	201	51.1
24.	Excessive movement of the probe-inserted extremity affects shivering and tremor pulse oximeter value <sup>†</sup>	289	73.5
25.	Hypotension affects pulse oximeter values <sup>†</sup>	184	46.8
26.	The probe attached to the extremity where the patient follow-up instruments are located does not affect pulse oximeter values	244	62.1
27.	Peripheral vascular disease affects pulse oximeter values <sup>†</sup>	271	69.0
28.	A tight connection of the pulse oximeter probe does not affect pulse oximeter values	191	48.6

<sup>†</sup>Correct statements

knowledge. When the contents of the books were examined, it was determined that there was not enough information on how the pulse oximeter works, what the pulse oximeter measures and how O<sub>2</sub> enters the tissues, and there was no correlation between those resources in terms of conveying the information completely.<sup>25</sup>

Unlike these studies, it was seen in the study of Raza et al.,<sup>26</sup> (USA, 2019) that the knowledge score average of the participants was higher

than ours and the other studies we discussed above. It is thought that this difference arises from the differences in the nursing curriculums between countries.<sup>26</sup> As in the countries where these studies were conducted,<sup>17,18,22-24</sup> there is no examination for this field after undergraduate graduation in Türkiye. However, U.S. nursing candidates must pass the national NCLEX exam upon successful completion of their nursing school to be eligible to work as a Registered Nurse.<sup>26</sup> This exam covers a variety of basics, including information on the respiratory

**Table 3. Distribution of the knowledge mean scores on pulse oximetry according to the descriptive characteristics of the nurses (n=393)**

Demographical variables	Knowledge mean score (for 28 statements)				
	Number	Mean ± SD	Min.	Max.	Pair-wise comparison
<b>Age groups</b>					
19-27	111	16.51±4.2	2	25	-
28-36	156	15.47±5.5	0	25	
37-45	101	13.35±7.2	0	26	
46+	25	13.00±8.5	0	24	
<b>Evaluation<sup>†</sup></b>	<b>KW=7.623; p&gt;0.05</b>				
<b>Educational level/graduation</b>					
1. Vocational health school	77	13.66±6.3	0	24	2-3
2. Associate degree	68	10.43±8.0	0	22	2-4
3. Bachelor's degree	230	16.73±4.1	1	26	1-3
4. Postgraduate degree	18	17.33±5.7	6	25	-
<b>Evaluation<sup>‡</sup></b>	<b>KW=39.636; p&lt;0.001</b>				
<b>Clinical experience (in years)</b>					
1. <1	43	15.37±4.1	2	22	2-6
2. 1-5	80	16.94±3.7	7	25	
3. 6-10	82	15.82±5.6	0	25	
4. 11-15	58	15.07±5.3	0	23	
5. 16-20	53	14.72±6.7	0	25	
6. >20	77	12.38±7.9	0	26	
<b>Evaluation<sup>‡</sup></b>	<b>KW=13.308; p&lt;0.05</b>				
<b>Unit</b>					
1. Critical units	132	16.70±4.5	2	25	1-4
2. Surgical units	88	15.10±5.3	0	22	
3. Internal units	86	15.49±5.2	0	23	
4. Outpatient clinic	56	10.82±8.7	0	24	
5. Mixed units	14	15.29±5.4	0	21	
6. Special branch nursing	12	13.00±8.25	1	26	
7. Management	5	15.90±3.9	11	21	
<b>Evaluation<sup>‡</sup></b>	<b>KW=17.837; p&lt;0.05</b>				
<b>Use of pulse oximeters in units by nurses</b>					
Using	246	16.98±4.0	0	25	-
Not using	147	11.86±7.2	0	26	
Total	393	15.06±6.0	0	26	
<b>Evaluation<sup>†</sup></b>	<b>Z=-6.920; p&lt;0.001</b>				
<b>In-service training on the use of pulse oximeter</b>					
Trained	129	16.86±4.1	0	25	-
Not trained	200	16.20±4.7	0	26	
Total	329	16.46±4.5	0	26	
<b>Evaluation<sup>†</sup></b>	<b>Z=-1.120 p&gt;0.05</b>				

<sup>†</sup>Kruskal-Wallis test was conducted. <sup>‡</sup>Kruskal-Wallis and Siegel Castellan tests were conducted. SD: Standard deviation, Min.: Minimum, Max.: Maximum



system, such as pulse oximetry. For this reason, students who are preparing for this exam are encouraged to have sufficient knowledge about pulse oximetry. Thus, the knowledge of the student remains up to date after graduation; the high knowledge scores of the nurses participating in the U.S. study can be explained by this situation.<sup>26</sup>

It was observed that the knowledge mean scores of those nurses who had higher education, received in-service training, had a working period of 1-5 years, and were working in critical units were higher. This can be explained by the fact that the education of newly graduated nurses is more up-to-date compared to those nurses who have been working for 6 years or more, and these new graduates are employed more often in critical units in our country and they use technology more effectively. The fact that technological devices are used more frequently in critical areas indicates that the knowledge levels of the nurses working in these units are higher. In addition, this situation reveals the effect of in-service training on the importance of updating information. Stathoulis et al.<sup>20</sup> emphasize the effectiveness and importance of training related to the use of pulse oximeters in their research which was carried out with 78 nurses in Greece. It was stated in their research that the average knowledge score increased significantly after training. Thus, it can be concluded that in-service training increases the knowledge levels of nurses. Unlike the results of our study, it was reported that the knowledge point averages of those nurses with a working period of more than 10 years were found to be higher in the study of Kiekkas et al.<sup>17</sup> In the results of Nimbalkar's<sup>22</sup> study conducted in a tertiary hospital in India, no significant difference was found among the pulse oximeter knowledge scores between those nurses working for less than one year and for those working for more than one year, and between those nurses working in the intensive care unit and those working in other units.

When the distribution of the responses given by the nurses to the statement "what pulse oximetry measures" was examined, it was observed that they generally did not have exact knowledge on what a pulse oximeter measures. It was observed that the nurses knew that O<sub>2</sub> saturation is measured by pulse oximeters but they did not know the connection between O<sub>2</sub> saturation and PaO<sub>2</sub>. This makes us

think that nurses only superficially use these medical devices in the clinical setting. When the studies conducted in different countries were examined,<sup>18,22,27</sup> their results were found to be compatible with the results of the present study. In the study conducted by Yıldız et al.<sup>18</sup> with 72 intensive care nurses in Türkiye, it was stated that "Pulse oximetry measures partial O<sub>2</sub> pressure" was the most frequently given wrong answer among the information propositions regarding pulse oximetry. In the study conducted by Bader in Saudi Arabia<sup>27</sup> which had similar features in terms of the method performed, it was stated that only 22% of the participants among 66 pediatric nurses gave the correct answer to "what the pulse oximeter measures". In Bader's study, it was stated that while 33% of the nurses knew the measurement value of the O<sub>2</sub> saturation read in the pulse oximeter, only 12% of them answered the measurement percentage of PaO<sub>2</sub> correctly. In the study of Milutinovic et al.<sup>23</sup> in Serbia, it was seen that there was a lack of knowledge on the meaning of pulse oximeter values and how to interpret them.

It can be asserted that there is a general lack of theoretical knowledge about the use of pulse oximeters by nurses, even when the education differences between countries were considered. In addition, these findings suggest that nurses access information from other professional members through a master-apprentice relationship without obtaining information from a guide or source on the subject and they gain experience without establishing a cause-effect relationship.

It was observed that more than half of the nurses gave the correct answer to the statement about the measurement made on the finger from the statements including the correct placement areas of the pulse oximeter probe on the body regions measured and they responded to the other statements at low rates. This is thought to be associated with the fact that measurements are performed mostly on the finger in the hospital where the study was conducted.

Correct answers were given mostly to those statements of proper placement of the pulse oximeter probe, and shivering and tremor among those factors affecting the value given by pulse oximeters. When considering that nearly half of the nurses participating in the present study were working as critical field nurses, the high level of response to this statement was a positive result. Conditions due to perfusion failure

**Table 4. Nurses' status of evaluating the frequency of behavior related to the use of pulse oximeter in certain possible situations (n=393)**

No	Behavior/action statements	Always		Sometimes		Never	
		No	(%)	No	(%)	No	(%)
1	I use a pulse oximeter during transfers between clinics.	100	25.4	189	48.1	104	26.5
2	I use a pulse oximeter in the follow-up of patients taking vasodilators and sedative drugs.	201	51.1	104	26.5	88	22.4
3	I use a pulse oximeter in the follow-up of patients taking inotropic drugs.	179	45.5	94	23.9	120	30.5
4	In addition to blood pressure, pulse rate, respiratory rate, and the body temperature, I measure and record the values read on the pulse oximeter on the first admission of patients to the clinic.	181	46.1	120	30.5	92	23.4
5	I use a pulse oximeter in the follow-up of patients connected to mechanical ventilators.	295	75.1	34	8.7	64	16.3
6	I use a pulse oximeter during the insertion of central catheter.	205	52.2	99	25.2	89	22.6
7	I use a pulse oximeter during invasive diagnostic methods related to chest diseases.	264	67.2	59	15.0	70	17.8
8	I use a pulse oximeter during invasive diagnostic procedures for the determination of cardiovascular diseases.	230	58.5	81	20.6	82	20.9
9	I use a pulse oximeter during the interventional procedures used in the diagnosis of gastrointestinal system diseases.	129	32.8	132	33.6	132	33.6
10	I use a pulse oximeter in patient follow-ups in the post-operative period.	265	67.4	61	15.5	67	17.0
11	I use a pulse oximeter in the follow-up of patients with respiratory problems.	312	79.4	35	8.9	46	11.7
12	I use a pulse oximeter in the follow-up of patients undergoing hemodialysis.	173	44.0	124	31.6	96	24.4

may cause the value read on the pulse oximeter to be misinterpreted. Accordingly, it was determined that the nurses participating in our study generally gave correct answers to the questions on this subject. In the study conducted by Yıldız et al.<sup>18</sup>, it was stated that 70.8% of the nurses who frequently used pulse oximeters knew that a moving extremity had an effect on the measurement reliability of the pulse oximeter. These findings show similar results with our study. Similarly, most of the nurses correctly answered that pulse oximeters cause false readings in cases of perfusion failure and in cases of movement in the studies of Milutinovic et al.<sup>23</sup>, Seeley et al.<sup>24</sup> and Giuliano and Liu.<sup>28</sup>

Since the pulse oximeter is designed to detect oxygenated and reduced Hb types, it causes incorrect SpO<sub>2</sub> reading in the presence of other Hb types such as methemoglobin and carboxyhemoglobin. More than half of the nurses participating in the present study knew that carbon monoxide poisoning has an effect on the value read on pulse oximeters. The high rate of correct answers to this statement was an important result for our study. At the same time, in our study, we saw that critical field nurses had high averages on their knowledge scores. Especially in emergency services, nurses who have high levels of knowledge in this field may play an active role in the treatment of patients with carbon monoxide poisoning. In the study conducted by Lee et al.<sup>29</sup> with 44 emergency workers through a similar method, most of the participants correctly knew that carbon monoxide poisoning has an effect on the pulse oximeter value, in parallel with our research results.

It is remarkable that the frequency of following up a patient's vital results and also their O<sub>2</sub> saturation value with pulse oximeter use in possible cases was given as "always" at a rate of only 46.1%. The fact that this behavior was not always carried out indicated that the nurses participating in the present study did not evaluate the O<sub>2</sub> saturation assessment as a vital result and pulse oximeters were not always used when necessary.

In our study, we saw that the frequency of using pulse oximeters in situations which required supplementary O<sub>2</sub> was quite high when the actions of the nurses regarding these possible situations was examined (Table 4). It was seen in the study of Milutinovic et al.<sup>23</sup> that most of the nurses stated that a pulse oximeter should be used when patients received O<sub>2</sub> support.

The generalizability of our findings is limited due to the fact that our study was a single-center study. Although this study was conducted in a medical faculty hospital in a large city in Türkiye, it revealed the conclusion that the nurses' knowledge about pulse oximetry was not at the desired level. Our results indicated a significant gap about pulse oximeters and their measurement and so we can conclude that continuous training is needed. The place of pulse oximeters in the evaluation of vital signs and also that the device is a quick source of information about the oxygenation of patient are supported by the literature. It is thought that the present study can help to determine the training needs of nurses regarding the evaluation of O<sub>2</sub> saturation, to create a protocol about the use of pulse oximeters by hospital management, to eliminate any deficiencies which may be experienced in practice, to enhance the quality of patient care and to contribute to the literature.

## MAIN POINTS

- The measurement of oxygen saturation is considered as an additional indicator for measuring vital signs.

- The measurement of oxygen saturation by pulse oximeters is a part of nursing care allowing for rapid evaluation of patients.
- Training should be regulated to meet the knowledge gaps regarding pulse oximeters and their measurements.

## ETHICS

**Ethics Committee Approval:** The study protocol was officially approved and ethics committee approval was obtained from Ankara University Ethics Committee (approval number: 160/961, date: 19.12.2013).

**Informed Consent:** We obtained written permission from the medical directors of the hospitals and written informed consent from the nurses who agreed to participate in this study.

**Peer-review:** Externally peer reviewed.

## Authorship Contributions

Concept: E.P.K., N.Ü.D., Design: E.P.K., N.Ü.D., Data Collection and/or Processing: E.P.K., N.Ü.D., Literature Search: E.P.K., N.Ü.D., Writing: E.P.K., N.Ü.D.

## DISCLOSURES

**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study had received no financial support

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