Journal of Biomedical Practitioners

JBP

Periodico per le professioni biomediche a carattere tecnico - scientifico - professionale

Titolo articolo / Article title:

Nurses and Medical Physics: an observational study on the knowledge of the physical basis of Medical Devices.

Autori / Authors: Ialria Stura, Caterina Guiot.

Pagine / Pages: 70-82, N.2, Vol.7 - 2023

Submitted: 14 July 2023 – *Revised:* 15 July 2023 – *Accepted*: 25 October 2023 – *Published*: 20 December 2023

Contatto autori / Corresponding author: Ilaria Stura,

ilaria.stura@unito.it

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Journal of Biomedical Practitioners ©

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OPEN ACCESS JOURNAL
http://www.ojs.unito.it/index.php/jbp
ISSN 2532-7925

Journal of Biomedical Practitioners
JBP

A Scientific, Technical and Professional Practice Journal for Biomedical Practitioners

Nurses and Medical Physics: an observational study on the knowledge of the physical basis of Medical Devices.

Ilaria Stura[1], Caterina Guiot[1]

[1] *Dipartimento di Neuroscienze, Università degli Studi di Torino*

Corresponding author: Ilaria Stura, ilaria.stura@unito.it, ORCID: 0000-0001-9815-5446

N. 2, Vol. 7 (2023) – 70:82
Submitted: 14 July 2023
Revised: 15 July 2023
Accepted: 25 October 2023
Published: 20 December 2023

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ABSTRACT

BACKGROUND

In recent decades, nursing is increasingly considered as a scientific discipline. Subjects such as Medical Physics, Statistics, and scientific method are important in professional training. In particular, understanding the physical basis of medical devices, their elaborated parameters, the methods and how information reaches the nurse allows a more informed practice.

OBJECTIVES

Primary objective. Investigate nurses' knowledge of the physical basis of the used medical device.

Secondary objective. Investigate whether the qualification type (professional school, diploma, or degree), the years since the end of the study, age, or Italian regional origin can influence this knowledge.

METHODOLOGY

An observational study was conducted using an anonymous online questionnaire developed ad hoc and addressed to nurses working in Italy. The responses were analyzed with chi-square tests divided by type of studies, years since the end of the study, and Italian region of origin.

RESULTS

More than half of the interviewees were unable to give the correct answer on the functioning of the sphygmomanometer (54.3%) and phonendoscope (53.0%). ECG and oximeter are the most understood instruments (79.0 and 67.9% correct answers respectively). 45.7% of interviewed do not remember that one cubic centimeter (CC) and one milliliter (ml) have a conversion factor of 1. No differences were found by qualification type, years since the end of the study (considering both the median and a limit of 5 years for new graduates), age, and Italian region of work ($p>0.05$).

DISCUSSION and CONCLUSIONS

Knowledge of the physical basis of the used medical devices does not seem to degrade over time. In the light of this, it would be more useful to consolidate these foundations in the three-year degree course of Nursing, rather than investing in post qualification courses. Such training, however, would be desirable to allow current professionals to fill the gaps emerged in this study.

Keywords: medical physics; nurses; continuous training.

INTRODUCTION

The figure of the nurse has significantly evolved over time. In Italy, the first school for nurses dates back to 1896 (Scuola Croce Azzurra of Naples) [1], shortly after the recognition of the profession with the Royal Decree of 15 August 1925, n. 1832. The preparation of students (only women until 1971) was very different to the current one. For example, to enter to these courses an elementary school license was sufficient until in 1973 [1] when a middle school diploma and being sixteen years old was the minimum requirement.

In that year the job description was also created and, with law 795 of 1973, the training course went from two to three years [1], [2]. A further change occurred in 1991 when the three-year University Diploma was established in Nursing Sciences [1]. Finally, in 2001 [3] the Diploma became a real three-year degree until it also obtained a continuation as a specialist degree in 2004 [4].

During the evolution of the profession, as briefly described above, it emerged that nursing belongs to the Science, Technology, Engineering, and Math discipline (STEM) [5].

Nurses must therefore not only learn patient care, but also the scientific approach [6], mathematics [7], statistics, physics, biology, and the use of technological tools [8], [9] which are increasingly used in the healthcare [10], [11].

These skills will increase of importance in nursing practice due to a change in the current legislation [12]. Indeed, “proximity networks, structures and telemedicine for local healthcare assistance” will be reformed in the next years, and “the provision of care will be strengthened”, as well as “the training and quality of human capital” [12]. The nurse is going to be seen as 'case-manager' who integrates all diagnostic and care pathways in 'health homes' or 'community homes'.

Currently, however, while there are many studies on how to teach new technologies [13] to new students, there is a lack of attention to the knowledge of Medical Physics that goes beyond mere radiation protection [14].

The physical knowledge that nurses should acquire in the first year of the three-year degree includes the scientific method, fluid dynamics, biomechanics, radiation protection, thermodynamics, optics, sounds and ultrasounds [15]. These notions should be applied to daily practice such as actions to perform or avoid on a patients (e.g. how to move him, how high to position the drip) as well as a basis for the functioning of some diagnostic tools (e.g. phonendoscope, electrocardiogram, oximeter, optical thermometer, sphygmomanometer or defibrillator).

Understanding the conversion mechanism that connects the measurement with the displayed parameter on a medical device allows a more informed use of the instrument, a more accurate evaluation of the reading and the awareness of repeating the measurement on different conditions or positions.

Furthermore, a basic understanding of units of measurement, their conversion factors, and how to perform proportions is also essential for nurses to perform daily activity (e.g in preparing the dilutions to treat patients).

Because of this knowledge is essential, it is taught and verified in the first year of the Degree Course but, after that, is no longer refreshed or tested. Radiation protection is an exception because it is kept refresh by the professionals.

The aim of this work is to understand whether the physical bases of the devices used by nurses daily, are well assimilated, and if a certain degradation of this knowledge depends on the type of qualification path or years since its completion.

MATERIAL AND METHODS

An observational study was conducted, with as the target population nurses working in Italy.

An anonymous online questionnaire was developed ad hoc [16] and disseminated in the period of May-June 2023 via social channels (Whatsapp, Facebook, nurses associations).

The personal data requested are age, qualification (nursing school/university diploma/degree), years since the end of studies, place of work (hospital facility/territory), and province of work. Eight multiple-choice questions were also asked (see Table 1) on sphygmomanometer, clamp oximeter, optical thermometer, phonendoscope, electrocardiogram, defibrillator, ultrasound and preparation of solutions. Of the three possible answers, only one was correct.

Table 1 Questions and answers from the questionnaire

Request	Correct answer	Wrong answers	
SPHYGMOMANOMETER: the tones I perceive when auscultating are due to:	blood turbulence in the artery	perception of the heartbeat	disturbances of the air contained in the sleeve
'CLAMP' OXIMETER: the determination of the percentage of oxygen saturation is due to:	differential absorption of visible and infrared light	total absorption of red visible light	Pressure applied by the device which press the capillaries thin and allows the red blood cells to be counted
OPTICAL THERMOMETER: it is a measure	of surface heating with optical techniques	of the heat emitted from the deep parts of the	improved by contact with the skin

		body with optical techniques	
PHONENDOSCOPE	collects and amplifies low-frequency sounds	collects and amplifies sounds of all frequencies	it is a simple sound amplifier
THE ELECTROCARDIOGRAM MEASURES	the electrical potentials propagating in the cardiac conduction system	the electrical potentials reaching the cardiac working fibers	the electrical signals (currents) produced by the application of the electrodes
DEFIBRILLATOR: produces an electric shock that:	interrupts active signals in the conduction system	interrupts active signals in the myocardium	it temporarily replaces the physiological one
ULTRASOUND: allows you to create a differential image of the tissues based on the differences:	of ultrasound reflection	of ultrasound absorption	of ultrasound emission
PREPARATION OF SOLUTIONS FOR INJECTION/INGESTION. The leaflet shows me the doses in ml but I only have a beaker graduated in cc	I proceed anyway using the same doses in ml	I'm looking for a suitable becker in another clinic	I find out about the transformation coefficient and proceed

Different hypotheses have been developed regarding the necessary sample size. Considering a correct response rate (total) of 80 or 90%, at least 119 or 78 completed questionnaires, respectively, are needed to notice a rate difference of 10%.

The statistical analysis of the study included a descriptive and inferential analysis; specifically, the relative and absolute frequencies of the categorical variables are reported, as well as the mean, standard deviation, and median of the continuous variables.
The responses were analyzed with chi-square tests divided by type of studies, years since the end of the study, and place of work. About this last point, the study aimed to make a comparison between Italian regions or between geographical macro areas (North, Center, and South). The distribution of the responses, however, as will be seen in the Results section, allowed a division of sample only between the Piedmont region and the rest of Italy. Cohen's kappa index calculation was used to assess the agreement among responses. For each comparison, the p-value is

reported (with first type error at 5%). The statistical software SAS® v. 9.4 was used for the analyses.

RESULTS

81 responses from professional nurses were collected, of which 59 (72.8%) work in a hospital facility and 22 (27.2%) in community. Furthermore, 44 (54.3%) work in Piedmont and 37 (45.7%) in the rest of Italy (6 in Emilia Romagna, 6 in Lazio, and numbers lower than 4 in the other 13 regions). The majority of those interviewed had a university degree (49, 60.5%), while the remaining part of the sample had attended nursing school (25, 30.9%) or a diploma (7, 8.6%). The average age is 42.5 years (standard deviation 10.5, median 43), with an average 18.0 years since the end of studies (standard deviation 12.0, median 18).

The distribution of responses is shown in Table 2.

Table 2 Percentage of responses to the questionnaire. The correct answer to each question is in bold.

Request	Answers	n (%)
SPHYGMOMANOMETER: the tones I perceive when auscultating are due to:	**blood turbulence in the artery**	37 (45.68%)
	perception of the heartbeat	41 (50.62%)
	disturbances of the air contained in the sleeve	3 (3.7%)
'CLAMP' OXIMETER: the determination of the percentage of oxygen saturation is due to:	**differential absorption of visible and infrared light**	55 (67.9%)
	total absorption of red visible light	17 (20.99%)
	Pressure applied by the device which press the capillaries thin and allows the red blood cells to be counted	9 (11.11%)
OPTICAL THERMOMETER: it is a measure	**of surface heating with optical techniques**	48 (59.26%)
	of the heat emitted from the deep parts of the body with optical techniques	33 (40.74%)

	which is improved by contact with the skin	0 (0%)
PHONENDOSCOPE	**collects and amplifies low-frequency sounds**	38 (46.91%)
	collects and amplifies sounds of all frequencies	18 (22.22%)
	it is a simple sound amplifier	25 (30.86%)
THE ELECTROCARDIOGRAM MEASURES	**the electrical potentials propagating in the cardiac conduction system**	64 (79.01%)
	the electrical potentials reaching the cardiac working fibers	3 (3.7%)
	the electrical signals (currents) produced by the application of the electrodes	14 (17.28%)
DEFIBRILLATOR: produces an electric shock that:	**interrupts active signals in the conduction system**	49 (60.49%)
	interrupts active signals in the myocardium	7 (8.64%)
	it temporarily replaces the physiological one	25 (30.86%)
ULTRASOUND: allows you to create a differential image of the tissues based on the differences:	**of ultrasound reflection**	53 (65.43%)
	of ultrasound absorption	21 (25.93%)
	of ultrasound emission	7 (8.64%)
PREPARATION OF SOLUTIONS FOR INJECTION/INGESTION. The leaflet shows me the doses in ml but I only have a beaker graduated in cc	**I proceed anyway using the same doses in ml**	44 (54.32%)
	I'm looking for a suitable becker in another clinic	2 (2.47%)

	I find out about the transformation coefficient and proceed	35 (43.21%)

More than half of the interviewees were unable to give the correct answer on the functioning of the sphygmomanometer (54.3%) and phonendoscope (53.0%), while there were 79.0% and 67.9% correct answers on the functioning of the ECG and oximeter respectively. The 45% of the interviewees do not remember that cubic centimeter (CC) and milliliter (ml) have a conversion factor of one and, among them, 2.47% do not even know how to set the conversion.

The differences were studied by type of work (community/hospital), type of study path (diploma/school of nursing/degree), years since the end of the study (considering both the median of 18 years and a limit of 5 years for recent graduates), age (considering the median of 43 years) and region of work (Piedmont vs the rest of Italy). The analysis of the data is reported in Table 3. It was highlighted that nurses working in a hospital are more knowledgeable about how the sphygmomanometer works (52.5% vs 27.3% of correct answers, p = 0.0423), while there are no differences regarding the other tools or general preparation (at least 4 correct answers: 56.6 vs 59%, p=0.9055). Among all eight questions, only the electrocardiogram query showed significant differences between groups. In particular, younger people are better informed (88.9% of correct answers vs 66.7%, p=0.0147), while those who have attended nursing school are less informed (60% vs 85.7% of graduates and 100% of diploma holders, p = 0.0133); Piedmontese nurses are also more lacking of knowledge than those in other regions of Italy (68.2% vs 91.9%, p=0.009).

Table 3 Results of comparisons by age, years since leaving school, region, and type of work for the eight questions. Numbers and percentages refer to the correct answers for each subgroup.

		SPHYGMO MANOME-TER	'CLAMP' OXIMETER	OPTICAL THERMOME-TER	FUSING PURPOSE	ELECTRO CARDIO -GRAM	DEFIBRIL-LATOR	ULTRA-SOUND	PREPARA-TION OF SOLU-TIONS	More than 4 correct answers
Age	<43	23 (51.11%)	32 (71.11%)	27 (60%)	25 (55.56%)	40 (88.89%)	27 (60%)	29 (64.44%)	25 (55.56%)	28 (62.22%)
	>=43	14 (38.89%)	23 (63.89%)	21 (58.33%)	13 (36.11%)	24 (66.67%)	22 (61.11%)	24 (66.67%)	19 (52.78%)	19 (52.78%)
	p value	*0.2725*	*0.489*	*0.8794*	*0.0814*	***0.0147***	*0.919*	*0.8345*	*0.8031*	*0.3921*
End of study years	<18	22 (50%)	30 (68.18%)	25 (56.82%)	25 (56.82%)	38 (86.36%)	25 (56.82%)	30 (68.18%)	23 (52.27%)	25 (56.82%)
	>=18	15 (40.54%)	25 (67.57%)	40.54 (45.68%)	45.45 (45.68%)	26 (70.27%)	24 (64.86%)	23 (62.16%)	21 (56.76%)	22 (59.46%)
	p value	*0.3946*	*0.953*	*0.6258*	*0.0514*	*0.0764*	*0.4606*	*0.5704*	*0.6865*	*0.8104*

End of study years	<5	10 (62.5%)	11 (68.75%)	8 (16%)	9 (16%)	15 (93.75%)	10 (62.5%)	10 (62.5%)	7 (43.75%)	10 (62.5%)
	>=5	27 (41.54%)	44 (67.69%)	40 (65%)	29 (65%)	49 (75.38%)	39 (60%)	43 (66.15%)	37 (56.92%)	37 (56.92%)
	p value	*0.1316*	*0.9353*	*0.4001*	*0.4035*	*0.1061*	*0.8546*	*0.7831*	*0.34*	*0.6855*
Region	Piedmont	19 (43.18%)	30 (68.18%)	27 (61.36%)	21 (47.73%)	30 (68.18%)	27 (61.36%)	31 (70.45%)	25 (56.82%)	27 (61.36%)
	Rest of Italy	18 (48.65%)	25 (67.57%)	21 (56.76%)	17 (45.95%)	34 (91.89%)	22 (59.46%)	22 (59.46%)	19 (51.35%)	20 (54.05%)
	p value	*0.6227*	*0.953*	*0.6742*	*0.8729*	***0.009***	*0.8614*	*0.3*	*0.6227*	*0.5067*
Work	Agency	31 (52.54%)	42 (71.19%)	37 (62.71%)	24 (40.68%)	46 (77.97%)	33 (55.93%)	39 (66.1%)	33 (55.93%)	34 (57.63%)
	Territory	6 (27.27%)	13 (59.09%)	11 (50%)	14 (63.64%)	18 (81.82%)	16 (72.73%)	14 (63.64%)	11 (50%)	13 (59.09%)
	p value	***0.0423***	*0.2997*	*0.3004*	*0.0655*	*0.7049*	*0.169*	*0.8356*	*0.6336*	*0.9055*
Type of Study	University degree	4 (57.14%)	4 (57.14%)	3 (42.86%)	2 (28.57%)	7 (100%)	4 (57.14%)	7 (100%)	2 (28.57%)	3 (42.86%)
	Degree	25 (51.02%)	33 (67.35%)	29 (59.18%)	27 (55.1%)	42 (85.71%)	29 (59.18%)	31 (63.27%)	28 (57.14%)	29 (59.18%)
	Nursing school	8 (32%)	18 (72%)	16 (64%)	9 (36%)	15 (60%)	16 (64%)	15 (60%)	14 (56%)	15 (60%)
	p value	*0.2442*	*0.7515*	*0.6026*	*0.1772*	***0.0133***	*0.9063*	*0.1271*	*0.3577*	*0.6948*

Comparisons were also carried out between correct and incorrect answers, to identify possible correlation between knowledge or if it is possible to highlight clusters, i.e. if the correct or incorrect answer to a certain question implies a correct or incorrect answer in another one. However, the analysis using Cohen's kappa (see Table 4) provided results all below 0.4. This threshold is considered of poor agreement, and therefore there is no relationship between knowledge, and answering one of the questions correctly does not imply knowing how to answer another correctly.

Table 4Agreement (Cohen's kappa) between correct answers in the eight sections. Legend: kappa<0 no agreement, 0-0.4 poor agreement, 0.4-0.6 fair agreement, 0.6-0.8 good agreement, 0.8-1 excellent agreement.

Cohen's kappa	SPHYGMO-MANOMETER	'CLAMP' OXIMETER	OPTICAL THERMO-METER	PHONENDO-SCOPE	ELECTRO-CARDIOGRAM	DEFIBRIL-LATOR	ULTRA-SOUND
'CLAMP' OXIMETER	0.1378						
OPTICAL THERMOMETER	0.1071	0.1273					
PHONENDOSCOPE	0.0319	-0.0388	-0.0253				
ECG	0.083	0.1585	-0.0512	0.0465			

DEFIBRILLATOR	-0.0186	0.0389	-0.0019	0.0981	0.1847		
ULTRASOUND	0.038	0.0562	-0.0737	-0.1873	-0.0527	0.1023	
PREPARATION OF SOLUTIONS	0.1422	0.0573	-0.0539	-0.228	-0.0918	0.0192	0.1629

DISCUSSION

There is a great attention on the continuous training of nurses in the field of radiation protection [14], on the relationship with patients [17], [18], on IT skills and the use of IT for teaching [13], on managerial skills and of coordination [19]. A recent study by Jokinemi [20] indicated research support, relationship with patients, leadership and 'specific skills' as the most important skills for a nurse.

Basic skills, such as Medical Physics, do not receive as much interest from trainers, although they are equally important for the daily work of these professionals. A correct observation is that knowing the physical basis of the ultrasound is not a sufficient condition for knowing how to use an ultrasound, but it is certainly a necessary condition.

The understanding of the physical basis of the analyzed parameters, the methods used, and how the information reaches the operator allows a more informed approach.

A professional should be able to evaluate the precision of the measurement acquired by considering the medical device strengths and weaknesses and limitations in specific contexts.

Furthermore, the proposed questionnaire demonstrated how potentially dangerous a gap in Medical Physics can be. Imagine the implications for a patient, waiting for a medication, in an emergency scenario in which the medication leaflet shows the doses in millimeter but the professional has only a Becker graduated in cubic centimeter (and the 45.7% of interviewed does not know how to convert them).

Moreover, nurses can play an important cultural role [21] in contrasting beliefs, fake news, and misleading advertising that are increasingly widespread among the population, including in the healthcare field. They should therefore be aware of the scientific basis of their training.

Targeted and rigorous training on the physical principles at the base of clinical measurement, procedures and techniques, possibly integrating these teachings with physiology and nursing, is essential. This study suggests that the training effort made so far is not sufficient in this sense.

Limitations of the study

This study has some limitations, the main one being the small number of participants. There are 455,000 registered nurses in Italy, of which 32,099 in Piedmont [22], so 81 nurses could seem not representative of the entire population. However, 34 participants are sufficient to see a significant difference between the 80% of correct answers hoped and the 60% calculated here. Considering these numbers, the power of our study is 98.9% (calculated with PROC POWER by SAS®). Furthermore, this type of survey, based on voluntariness, often has a low response rate since, when testing specific skills, many people did not respond feeling lacking in some way, even though the questionnaire was anonymous.

Regarding representativeness, there was a disproportion in the regional distribution of the responses. More than half of the sample came from Piedmont, while the others were little or none (such as Calabria, Molise, or Friuli) represented. A comparative analysis was still carried out, but no significant differences were highlighted. This leads us to suggest that Italian geographical origin does not influence the knowledge examined, but this statement should be checked again by expanding the sample into underrepresented regions.

Another limitation is the fact that not all knowledge regarding Medical Physics was tested, but we were limited to eight examples of medical devices functioning. No questions were asked about radiation protection or patient handling, topics in which greater competence is expected from professionals. However, these two topics have already been covered by the scientific literature and were not the main focus of our research.

Finally, this questionnaire highlighted deficiencies in nurses' academic knowledge, which could have repercussions on the performance of their activities. However, no consideration can be made about the actual abilities of the professionals interviewed. It would therefore be interesting to propose this questionnaire again in combination with some practical tests on the practical use of the various tools.

CONCLUSION

Knowledge of the physical bases of medical devices used by nurses does not seem to degrade over time, therefore it would be more useful to consolidate this knowledge in the three-year course of Nursing rather than investing in additional courses for graduates/diplomas. However, additional courses for current professionals would be desirable to allow clinicians to fill the gaps that emerged in this study.

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