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ORIGINAL ARTICLE

# Knowledge, skill, and self-confidence in measuring systemic blood pressure among incoming medical students during the COVID-19 pandemic

## *Conhecimento, habilidade e autoconfiança para medir pressão arterial sistêmica entre estudantes de medicina ingressantes durante a pandemia por COVID-19*

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## ABSTRACT

**Introduction:** The pandemic caused by the SARS-CoV-2 virus made it necessary to transpose the physical learning environment to a remote one, preventing medical students from practicing certain techniques in a simulated environment, such as the measurement of arterial blood pressure. **Objective:** To assess knowledge, psychomotor skills and confidence in two groups of medical students entering the undergraduate program during the COVID-19 pandemic; to prevent the invasive measurement of blood pressure of an adult patient. **Method:** Descriptive and cross-sectional study carried out with incoming medical students during COVID-19 pandemic, in 2020 and 2021. Use of a semi-structured questionnaire created by the authors, aimed at obtaining a characterization of the participants and academic life, as well as information regarding the knowledge, skills and confidence of students when checking blood pressure with an aneroid sphygmomanometer; Questions about knowledge and skills were elaborated according to the 2020Brazilian Guidelines of Arterial Hypertension. **Results:** With a multivariate analysis, it was observed that, in relation to the second-year group, the third-year student group presented greater theoretical knowledge in measuring BP ($p$=0.006); reported being capable of measuring blood pressure with a sphygmomanometer ($p$=0.025); reported being able to obtain an BP estimate through palpation of the radial pulse ($p$<0.001); reported being able to hold the bell of the stethoscope ($p$<0.001); reported being certain that the BP value was correct ($p$=0.008) and presented greater confidence in measuring the BP of adults after responding the same question a second time ($p$=0.009). **Conclusions:** Superior knowledge, confidence and psychomotor skills in the group that began the medical undergraduate program in 2020, in relation to 2021, indicating possible cumulative effect of time enrolled in the program, even in the midst of the pandemic.

Keywords: Medical students; Reading of arterial pressure; Arterial pressure; Sphygmomanometers; COVID-19 Pandemic.

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## RESUMO

**Introdução:** A pandemia causada pelo vírus SARS-CoV-2 trouxe a necessidade de transposição do ensino presencial para o remoto, impossibilitando aos estudantes de Medicina praticarem algumas técnicas em ambiente simulado, como a medida da pressão arterial. **Objetivo:** Avaliar conhecimento, habilidade psicomotora e confiança em dois grupos de estudantes de Medicina ingressantes na graduação durante a pandemia por COVID-19 para medir de maneira não invasiva a pressão arterial de uma pessoa adulta. **Método:** Estudo descritivo e transversal realizado com estudantes de Medicina ingressantes no curso durante a COVID-19, em 2020 e 2021. Utilizou-se questionário semiestruturado criado pelas autoras, contendo a caracterização dos participantes, vida acadêmica e informações sobre conhecimento, habilidades e confiança em medir a pressão arterial com esfigmomanômetro aneroide; questões sobre conhecimento e habilidades foram elaboradas segundo as Diretrizes Brasileiras de Hipertensão Arterial de 2020. **Resultados:** Com a análise múltipla, observou-se que o grupo terceiranista, em relação ao segundanista, apresentou: maior conhecimento teórico para medir a PA ($p$=0,006); referiu ser capaz de medir a PA com esfigmomanômetro ($p$=0,025); informou conseguir estimar a PA palpando o pulso radial ($p$<0,001); referiu conseguir segurar a campânula do estetoscópio ($p$<0,001); referiu ter certeza que o valor da PA está correto ($p$=0,008) e apresentou maior confiança em medir a PA de pessoa adulta após responder pela segunda vez a mesma questão ($p$=0,009). **Conclusões:** Houve maior conhecimento, confiança e habilidades psicomotoras do grupo que iniciou a graduação médica em 2020, em relação a 2021, indicando possível efeito cumulativo do tempo de estudo, mesmo em meio à pandemia.

**Palavras-chave:** Estudantes de medicina; Determinação da pressão arterial; Pressão arterial; Esfigmomanômetros; Pandemia por COVID-19.

## Introduction

During the COVID-19 pandemic, ordinance no. 345, March 19th, 2020, authorized Brazilian medical education to replace in-person classes with electronic means of communication for undergraduate students from the first to fourth year of medical school[1]. Therefore, in 2020 and 2021, teaching and learning were restricted to theoretical content in an online environment. Despite the recommendation made by the 2014 Brazilian National Curricular Guidelines that "learning should take place in controlled and protected situations and environments, identifying and assessing mistakes, as the basis of professional and organizational learning and pedagogical support"[2], at that time it was not possible for students to have said experience.

Among the technical trainings that take place at the beginning of the medical program is the measurement of blood pressure (BP). This skill is essential in identifying pathological conditions in the population, notably Arterial Hypertension (AH), estimated to affect 45% of Brazilians between the ages of 30 and 79, approximately 50 million people. According to the 2023 World Health Organization (WHO) report[3], the global average of adults in the same age range affected by the disease is 33%.

Indirect BP measuring, done correctly, is fundamental given the gravity of the issue for public health in Brazil and worldwide. The 2020 Brazilian Guidelines for Arterial Hypertension (DBHA) determine that BP measurement should take place in all evaluations by physicians of any specialty and any other qualified health professionals[4].

This study was carried out because students who enrolled during the pandemic, at the time of this research, were in the 2nd or 3rd year of the undergraduate medical program and had not experienced the same training by simulation in safe and controlled environments, supervised by instructors, that students generally experience.

The objective was to assess knowledge, psychomotor skill and confidence in measuring adult blood pressure (BP) non-invasively in two medical student groups who enrolled in the undergraduate program during the COVID-19 pandemic.

## Methods

This was a cross-sectional descriptive and comparative study with a quantitative approach. Competency in blood pressure measurement was described for each group and for the total sample. It was carried out with students at Faculdade de Medicina de Jundiaí (FMJ) located in Jundiaí in the state of São Paulo, Brazil. The undergraduate medical program at this institution is full-time and has 120 vacancies for every year of the six-year program.

The sample was composed of medical students who entered the undergraduate course in 2020 or 2021 and, during data collection, were, respectively, at the end of the 3rd year (sixth semester) or the 2nd year (fourth semester). Since this was a Pilot study, data was collected without an initial sample size calculation; however, all students from both years were approached to participate in the study.

The sample included adults 18 years or older enrolled in the second or third year of the medical undergraduate program. Students transferred from other institutions, those who had not taken the Fundamentos Assistenciais e Noções de Primeiros socorros (FAePS – Fundamental assistance and notions of first aid) class, those with a previous formal training in healthcare, and the student authors of this study were excluded from the sample.

This study's defined exposure variable corresponds to the group, meaning, the 3rd year Group, first enrolled in 2020, and the 2nd year Group, enrolled in 2021.

The primary outcome variables, called dependent variables, of this study were the steps taken to measure BP, according to the guidelines, i.e., knowledge, psychomotor skill and confidence. The questionnaire was constructed with three open-ended questions about factors that interfere with BP measuring: anamnesis, anatomical knowledge and the patient's body position; as well as statements with response options ordered in a Likert-type scale. It should be noted that for knowledge and skill, totally agree and agree were considered positive perception answers. The independent variables were those related to the students' sociodemographic characteristics.

These variables were presented in a printed questionnaire developed by the authors of this study. This instrument was divided into two sections: the first, composed by semi-structured questions about the independent variables that characterize the medical students; and the second, composed of the dependent variables.

The first part of the questionnaire consisted of questions about the independent variables possibly associated to the phenomenon under study. The second part consisted of 34 questions which addressed the medical student's perception of their knowledge, skill and confidence in measuring non-invasively an adult's BP, utilizing an aneroid sphygmomanometer. The 2020 Brazilian Guidelines for Arterial Hypertension (DBHA)[4] were used to formulate the questions on knowledge, skill and confidence.

Instrument testing and data gathering were done only after the study was approved by the school's Research Ethics Committee (CEP) (CAAE: 60674322.2.0000.5412), with approval report number 5.760.106. The instrument was tested with 12 unidentified medical students enrolled in the fourth, fifth or sixth year at FMJ. Suggestions were then carefully evaluated and adjustments were made.

Recruitment and data collection were carried out by four medical students instructed by a professor, all of them authors of this study. These activities occurred in November of 2022 at the school campus in classrooms in which any teaching activities had already ended, after the authorization of the respective professor. Data collection started after explanations and clarifications surrounding the study's objectives and the implications of the students' participation. After any doubts from the students about their participation in the study were resolved, the researchers presented the Consent Form (TCLE). A copy of said document was handed to those who voluntarily agreed to participate in the study and signed the form.

The printed-out questionnaire was handed out to be answered and later returned during the same classroom period. Two laptops with passwords, fingerprint scanners and data protection, owned by the researchers, were used to type up the answers. The data collected was stored and saved through Microsoft Excel® software in a database. Quality control procedures were performed by verifications of simple and logical consistency, after exporting the database to SPSS v. 20 software for analysis.

Initially, a simple descriptive analysis was done, consisting of the absolute and relative frequency of the qualitative variables, as well as average and standard deviation of the age variable (quantitative). Subsequentially, a bidimensional analysis was performed, taking into account variables of knowledge, skill and confidence in measuring arterial blood pressure, according to the year of enrollment in the program. To do this, the adequate chi-squared test was used for each dimension of the table (Yates chi-squared test for 2x2 dimension tables; or Fisher's exact test 2x2 tables when the Yates test was not valid; and Pearson's chi-squared test for tables larger than 2x2). Finally, multivariate logistic regression was carried out for dependent variables that presented the group as a significant variable in the bidimensional analysis. The predictive variables considered in the regression models were group (1: 3rd year/ 0: 2nd year); age (completed age); sex (0: female/ 1: male); ethnicity (1: white/ 0: other); average monthly family income (0: up to 11 minimum wages/ 1: >11 minimum wages); own a aneroid device for BP measuring (0: no/ 1: yes); own a stethoscope (0: no/ 1: yes). The forward Euler method for variable selection, the Wald test and the percentage of correct classification – used for evaluating the performance

of the adjusted model – were used for multivariate analysis. The significance level adopted in the bidimensional and multivariate analyses was 5% (α=0.05).

## Results

A total of 139 medical students participated in this study (response rate of 62.6%), of which 71 were in the 3rd year (51.1%) and 68 in the 2nd year (48.9%), with response rates of 67.0% and 58.6% respectively. At the time of this research, most subjects were up to 22 years old (56.0%), 45.8% of which were in the 3rd year and 70.7% were in the 2nd year (*p*=0,023). Most of the sample was composed of women (64.5%), white (81.9%), with an average monthly household income above 11 minimum wages (57.6%), measured an adults BP with an aneroid device (95.6%) and approximately half (49.6%) owned an aneroid device for BP measuring, with no statistical differences between the two groups. Almost all owned a stethoscope (96.3%), 100% of 3rd year students and 92.5% of 2nd year students (*p*=0.027).

As for academic activities, most reported not having been a teacher's assistant (68.3%), participated at any point in a *liga academica* (94.2%), and mentioned being involved in extracurricular activities (78.8%), with no significant differences between the two groups. 95.6% of the sample reported having measured an adults BP, 100.0% in the 3rd year group and 91.0% in the 2nd year group (*p*=0,012).

Regarding the history taking (*anamnesis*) of factors interfering with blood pressure measurement, of all the inquiries listed in the DBHA[4], the question related to coffee intake was more frequently mentioned by the third-year group (91.4%) than by the second-year group (73.8%), and there was statistical significance (*p*=0.014).

Regarding anatomical knowledge, a minority in both groups mentioned the olecranon — third-year group (13%), second-year group (24.1%) — and the acromion — third-year group (17.4%) and second-year group (25.9%). Brachial and radial arteries were mentioned by the majority of students. None of the four variables showed a significant difference between groups. Regarding anatomical positioning, the variable "arm at heart level" was the most cited by the third-year group (74.2%) compared to the second-year group (51.7%), with a significant difference (*p*=0.016) (Table 1).

Regarding having theoretical knowledge to measure the blood pressure of an adult, the frequency was higher for third-year students (91.4%; 95% CI: 84.9 – 98.0%) compared to second-year students (73.1%; 95% CI: 62.5 – 83.7%) (p=0.010). There were no significant differences between the groups regarding knowledge about appropriate cuff size and knowing how to identify physiological conditions that can underestimate or overestimate BP (Table 2).

Regarding the perception of medical students' skills to measure blood pressure, significant differences were observed between the third-year and second-year groups. The highest frequencies of "agree" or "strongly agree" responses were, respectively: can measure BP alone (95.3% vs. 78.2%; *p*=0.011); is capable of measuring an adult's BP with a sphygmomanometer (97.1% vs. 83.6%; *p*=0.016); can estimate BP by palpation of the radial pulse (76.1% vs. 38.8%; *p*<0.001); can hold the stethoscope bell/diaphragm with the correct compression over the antecubital fossa region (83.1% vs. 60.6%; *p*=0.006); is certain that the measured BP value is correct (52.9% vs. 28.8%; *p*=0.007); can identify diastolic BP at the disappearance of sounds (Korotkoff Phase V) (80.3% vs. 59.1%; *p*=0.012). More than 60% in both groups reported being able to palpate the acromion and olecranon, with no statistical difference (Table 3).

Regarding confidence in measuring blood pressure before and after being questioned about theoretical knowledge, there was a significant difference between groups only for confidence after the questionnaire was applied, with the "Very" category observed in 44.1% of third-year students and 30.6% of second-year students, and the "Extremely"

**Table 1.** Percentage distribution of students for variables related to factors interfering with blood pressure measurement regarding history taking, anatomical knowledge, and patient's body position, by group.

| Variable | Group (3rd year) | | Group (2nd year) | | |
|---|---|---|---|---|---|
| **Factors interfering with BP measurement** | **n** | **%** | **n** | **%** | ***p*** |
| **Anamnesis**[a] | | | | | |
| **Bladder** | | | | | 0,778 |
| Mentioned | 42 | 60,0 | 39 | 63,9 | |
| **Coffee** | | | | | 0,014 |
| Mentioned | 64 | 91,4 | 45 | 73,8 | |
| **Tobacco** | | | | | 0,936 |
| Mentioned | 52 | 74,3 | 74 | 72,1 | |
| **Physical exercise** | | | | | 0,723 |
| Mentioned | 65 | 92,9 | 58 | 95,1 | |
| **Food** | | | | | 0,092 |
| Mentioned | 20 | 28,6 | 27 | 44,3 | |

continue...

... continuation Table 1

| Variable | Group (3rd year) | | Group (2nd year) | | |
|---|---|---|---|---|---|
| **Factors interfering with BP measurement** | **n** | **%** | **n** | **%** | ***p*** |
| **Anatomical Knowledge**[b] | | | | | |
| **Brachial Artery** | | | | | 0,299* |
| Mentioned | 66 | 95,7 | 52 | 89,7 | |
| **Radial Artery** | | | | | 0,236 |
| Mentioned | 55 | 79,7 | 40 | 69,0 | |
| **Olecranon** | | | | | 0,166 |
| Mentioned | 9 | 13,0 | 14 | 24,1 | |
| **Acromion** | | | | | 0,345 |
| Mentioned | 12 | 17,4 | 15 | 25,9 | |
| **Patient's Body Position**[c] | | | | | |
| **Feet supported** | | | | | 0,745 |
| Mentioned | 36 | 54,5 | 29 | 50,0 | |
| **Legs uncrossed** | | | | | 0,986 |
| Mentioned | 41 | 62,1 | 35 | 60,3 | |
| **Back supported** | | | | | 0,431 |
| Mentioned | 20 | 30,3 | 13 | 22,4 | |
| **Arm at heart level** | | | | | 0,016 |
| Mentioned | 49 | 74,2 | 30 | 51,7 | |

**Information missing for:** [a]: 8 students; [b]: 12 students; [c]: 15 students.
**Legend:** n = Number; % = Percentage; *p* = *p*-value; BP = Blood Pressure.
**Source:** Prepared by the authors, 2025.

**Table 2.** Variables referring to knowledge for measuring blood pressure, by group.

| Variable | Group (3rd year) | | Group (2nd year) | | |
|---|---|---|---|---|---|
| | **n** | **%** | **n** | **%** | ***p*** |
| Knows how to select appropriate cuff size[a] | 39 | 54,9 | 35 | 52,2 | 0,884 |
| Knows how to identify physiological conditions that can underestimate or overestimate BP[b] | 59 | 84,3 | 48 | 72,7 | 0,151 |
| Has theoretical knowledge to measure BP[c] | 64 | 91,4 | 49 | 73,1 | **0,010** |

**Information missing for:** [a]: 1 student; [b]: 3 students; [c]: 2 students.
**Legend:** n = Number; % = Percentage; *p* = *p*-value; BP = Blood Pressure.
**Source:** Prepared by the authors, 2025.

category observed in 22.1% of third-year students and 11.3% of second-year students ($p$=0.018) (Table 4).

After adjusting the logistic regression models, it was observed that the group variable was significant for most dependent variables of knowledge, skill, and confidence. The third-year group presented greater theoretical knowledge to measure BP ($p$=0.006); reported being capable of measuring BP with a sphygmomanometer ($p$=0.025); reported being able to estimate BP by palpating the radial pulse ($p$<0.001); reported being able to hold the stethoscope bell ($p$<0.001); reported being certain that the BP value is correct ($p$=0.008); and presented greater confidence in measuring an adult's BP after answering the questionnaire ($p$=0.009). The percentage of correct classification was greater than 60% for the six models that presented at least one significant variable (Table 5).

## Discussion

The results of the present study, conducted with students who had begun medical school during the COVID-19 pandemic, showed that the third-year group had better

**Table 3.** Variables referring to participants' psychomotor skills to measure blood pressure, by group.

| Variable | Group (3rd year) | | Group (2nd year) | | |
|---|---|---|---|---|---|
| | n | % | n | % | *p* |
| Can measure BP alone[a] | 61 | 95,3 | 43 | 78,2 | 0,011 |
| Capable of measuring BP with sphygmomanometer[b] | 68 | 97,1 | 67 | 83,6 | 0,016 |
| Knows how to palpate brachial artery[c] | 60 | 85,7 | 49 | 75,4 | 0,193 |
| Knows how to palpate the acromion[d] | 44 | 62,0 | 45 | 67,2 | 0,646 |
| Can auscultate 1st sound (Korotkoff Phase I)[d] | 56 | 78,9 | 47 | 70,1 | 0,326 |
| Can palpate the olecranon[b] | 48 | 68,6 | 44 | 65,7 | 0,858 |
| Can estimate BP by palpation of radial pulse[d] | 54 | 76,1 | 26 | 38,8 | <0,001 |
| Can hold stethoscope bell/diaphragm with correct compression on antecubital fossa[b] | 59 | 83,1 | 40 | 60,6 | 0,006 |
| Certain that the measured BP value is correct[e] | 37 | 52,9 | 19 | 28,8 | 0,007 |
| Can identify DBP (Korotkoff Phase V)[b] | 57 | 80,3 | 39 | 59,1 | 0,012 |

**Information missing for:** [a]: 20 students; [b]: 2 students; [c]: 4 students; [d]: 1 student; [e]: 3 students.
**Legend:** n = Number; % = Percentage; p = p-value; BP = Blood Pressure; DBP = Diastolic Blood Pressure.
**Source:** Prepared by the authors, 2025.

**Table 4.** Percentage of distribution of participants for variables referring to confidence in measuring blood pressure before and after being questioned about theoretical knowledge, by group.

| Variable | Group (3rd year) | | Group (2nd year) | | *p* |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Confidence in measuring BP in adults (before answering questionnaire)[a] | | | | | 0,073 |
| None; little | 3 | 4,3 | 9 | 13,6 | |
| More or less | 25 | 36,2 | 31 | 47,0 | |
| Very confident | 34 | 49,3 | 22 | 33,3 | |
| Extremely confident | 7 | 10,1 | 4 | 6,1 | |
| Confidence in measuring BP in adults (after answering questionnaire)[b] | | | | | 0,018 |
| Little; More or less | 23 | 33,8 | 36 | 58,1 | |
| Very confident | 30 | 44,1 | 19 | 30,6 | |
| Extremely confident | 15 | 22,1 | 7 | 11,3 | |

**Information missing for:** [a]: 4 students; [b]: 9 students.
**Legend:** n = Number; % = Percentage; *p* = *p*-value; BP = Blood Pressure.
**Source:** Prepared by the authors, 2025.

**Table 5.** Variables associated with knowledge, psychomotor skills, and confidence (multiple logistic regression)*

| Dependent variable/ Independent variable | Coeff. | E.P. coeff. | p | % correct classifi |
|---|---|---|---|---|
| Has theoretical knowledge to measure BP (agree; strongly agree) [n=89] | | | | 83,1 |
| Group (third-year) | 1,75 | 0,63 | **0,006** | |
| Constant[a] | 0,78 | 0,36 | **0,032** | |

continue...

... continuation Table 5

| Dependent variable/ Independent variable | Coeff. | E.P. coeff. | p | % correct classifi |
|---|---|---|---|---|
| BP Measurement (can measure alone) | | | | |
| [No associated variable] | - | - | - | |
| Capable of measuring BP with sphygmo. (agree; strongly agree) [n=89] | | | | 89,9 |
| Group (third-year) | 1,87 | 0,84 | **0,025** | |
| Constant[a] | 1,39 | 0,42 | **0,001** | |
| Can estimate BP radial pulse palpation (agree; strongly agree) [n=90] | | | | 62,2 |
| Group (third-year) | 1,28 | 0,33 | **<0,001** | |
| Can hold the stetho and bell. (agree; strongly agree) [n=90] | | | | 74,4 |
| Group (third-year) | 1,93 | 0,41 | **<0,001** | |
| Certain that the measured BP value is correct (agree; strongly agree) [n=88] | | | | 68,2 |
| Group (third-year) | 1,37 | 0,52 | **0,008** | |
| Owns aneroid device to measure BP | 1,06 | 0,48 | **0,027** | |
| Constant[a] | -1,90 | 0,52 | **<0,001** | |
| Can identify DBP (Korotkoff Phase V) (agree; strongly agree) [n=89] | | | | |
| [No associated variable] | - | - | - | |
| Confidence in measuring adult BP (after questionnaire) (very; extremely) [n=87] | | | | 65,5 |
| Group (third-year) | 1,25 | 0,48 | **0,009** | |
| Owns stethoscope | 1,16 | 0,47 | **0,013** | |
| Constant[a] | -1,17 | 0,45 | **0,009** | |

[a] The constant can be part of the mathematical model if it is significant, and thus it must be used to estimate the probability of a specific dependent variable.

**Legend:** n = Number; % = Percentage; *p* = *p*-value; Coeff. = Coefficient; S.E. coeff. = Standard Error of Coefficient; % Correct Classif. = Percentage of Correct Classification; BP = Blood Pressure; DBP = Diastolic Blood Pressure; Aneroid Dev. = Aneroid Device; Sphygmo. = Sphygmomanometer; Stetho. = Stethoscope.

**Source:** Prepared by the authors, 2025.

results than the second-year group in terms of knowledge, skill, and confidence in measuring an adult's blood pressure (BP) with an aneroid sphygmomanometer. These significant results were obtained through bivariate and multiple analyses after controlling for six predictor variables, including the "group" variable, which was the primary focus of this study.

The findings indicate that both second-year and third-year students acquired theoretical and practical knowledge based on the 2020 Brazilian Guidelines for Arterial Hypertension (DBHA)[4]. Although the plan for didactic transposition from in-person to remote learning was carefully designed by professors—with synchronous lectures and asynchronous practical training at home with family members—it was expected that theoretical knowledge and perceived competence would be lower in both groups.

In fact, the results were more significant than the researchers anticipated, especially considering that national and international studies prior to SARS-CoV-2 highlighted deficiencies in knowledge and skills among medical students for non-invasive blood pressure determination in adults[5-12]. Those studies indicate that proficiency in performing the technique is often low among students, emphasizing the need for a curriculum with teaching and assessment methods capable of maintaining such proficiency[5-12].

In a pilot study conducted during the pandemic, medical and nursing students tested a series of online courses on BP measurement. Data suggested that basic modules can help improve knowledge and the ability to identify necessary skills. While critical video analysis is valuable, e-learning should complement, not replace, in-person teaching[13].

Another study with medical students from 2021 and 2022 found that the pandemic period negatively affected education, resulting in low adherence to proper BP measurement techniques[14].

Differences between the results of this research and existing literature prompted a reflection on the actions taken during the Assistive Fundamentals and Notions of First Aid (FAePS) course. Two factors were deemed relevant: 1) the college's equipment loan program and 2) technical training with family members. These actions ensured that the technique was practiced even during remote learning. Having material resources and family participation allowed the learning process to occur at the student's own pace and frequency, which is vital as repeated practice is essential for skill improvement[11].

While knowledge, skill, and self-confidence are essential, proper equipment (sphygmomanometer, stethoscope, and measuring tape) is also required. This research identified that, post-isolation, most students owned only a stethoscope. The reasons for prioritizing a stethoscope over a sphygmomanometer—whether cultural, utilitarian, or financial — limit the development of BP measurement skills.

The difference between the two groups regarding knowledge, skill, and confidence was expected due to the cumulative effect of the curriculum. These topics were revisited in Propaedeutics I (second year) and Propaedeutics II and Cardiology (third year). Research shows that accuracy in BP measurement improves through continuous training, practice, and repetition[14-16].

Institutions vary in how they train students for BP determination[17]. Strategies such as peer training, simulation-based learning, case-based learning, and e-learning are used globally[11,18]. For instance, some curricula implement a longitudinal approach over three semesters, combining e-learning with practical training[11,19-20] and clinical reasoning[11,9-20].

For instance, in an attempt to overcome gaps related to blood pressure measurement, Fisher et al. (2023)[17] proposed the implementation of a longitudinal curriculum over three semesters, combining e-learning and practical training for medical students. The objective was to implement essential BP measurement modules, expose medical students to healthcare disparities related to hypertension, and combine BP measurement training with clinical reasoning and chronic disease management using clinical cases focused on hypertension.A concern arose regarding the "gaps" identified: a small portion of second-year students reported they had never measured an adult's BP with an aneroid device, even after the return to in-person training in 2022. Longitudinal studies show that skills are lost over time if not practiced but can be recovered through review and real-life BPplication[21].

Other points of concern involve specific techniques: positioning of the back and feet, Korotkoff sound auscultation, and handling the stethoscope. Less than a third of students verified if the patient's back was supported, and only about half checked if both feet were on the floor or identified crossed legs as a relevant variable.

Technically, measuring BP with an aneroid sphygmomanometer using the auscultatory method is a complex procedure that demands the mastery of multiple simultaneous skills, requiring the student to have hand, eye, and ear coordination[8,2]. The use of tools such as a life-size mannequin arm with auscultation improves dexterity[11]; the use of sound-amplifying devices on the stethoscope and a quiet environment improve the auscultation of Korotkoff sounds[13,18]; and simulation is a technique that enhances students' clinical performance[23]. Furthermore, intensifying and repeating training at regular intervals can increase the rate of accurate BP measurements[14].

Knowledge of the anatomical structures of the olecranon and acromion is essential to determine the mid-upper arm circumference and calculate the ideal cuff size, as selecting an inadequate size can reduce the accuracy of the measured values[12]. The cuff width directly interferes with the obtained BP values, since pressure is underestimated when wide cuffs are used and overestimated in the case of narrow cuffs[24]. At the Jundiaí Medical School (FMJ), the anatomy discipline is taught in the first and second years. During emergency remote teaching, the programmed theoretical content was maintained. However, the impossibility of practical integration between the two disciplines may have contributed to the fact that just over half of the students responded that they know how to palpate the acromion and olecranon and how to select the appropriate cuff size. These data reinforce the need for in-person interdisciplinary teaching with activities based on psychomotor skills and simulation.

Regarding the measured BP value, there is hesitation concerning the certainty of the measurement. It is inferred that the impossibility of training in skills laboratories and simulated environments—with professors present to monitor and indicate whether the measurement was correct or not—contributed to this result. Lack of supervision was also mentioned in the AMA Challenge as one of the reasons for student failure in measurement accuracy[8].

Feedback is an effective strategy for promoting medium-term retention of the practical activity of BP measurement[10]. Most medical students who received structured oral feedback provided by a facilitator agreed that it enabled reflection on procedural execution, behavior, and attitude, aided the self-assessment process, and expressed a desire to experience feedback more often[10]. Receiving feedback is essential for the development of optimal clinical skills[12].

A systematic review conducted in 2017, including 328 studies, identified 29 potential sources of inaccuracy in BP measurement related to the adult patient, the observer, the devices, and the procedure. The results complement existing guidelines, and the authors state that it is beneficial to know the factors that can affect the accuracy of BP measurement for proper data interpretation[25]. Regardless of the guidelines or frameworks used, sources of inaccuracy have effects that lead to overestimating or underestimating real BP values.

In the present study, a change in students' perception was noted throughout their participation. Although the question regarding confidence presented at the beginning and the end of the questionnaire was the same, the medical students' self-perception improved when answering the same inquiry for the second time. It is inferred that answering

the question again after completing the list allowed some students to identify knowledge and skills anchored in the guidelines, providing a more reflective self-criticism of their performance based on pre-existing and relevant knowledge for the construction of new learning.

It should be noted that the results of this research could not be fully compared with others because they are based on different methodologies. However, it was possible to identify that special attention is still needed so that the teaching-learning process of non-invasive BP measurement achieves all the educational objectives proposed in the FAePS teaching plan.

Constant educational actions and Evidence-Based Simulations in the classroom for BP determination training throughout the undergraduate years are necessary to refine skills and increase self-confidence regarding the blood pressure values obtained. Realistic simulation makes it possible to develop knowledge in a controlled environment under faculty supervision and guidance, contributing to professional excellence[26-29].

The present study has some limitations. As it is a pilot study, the sample was non-probabilistic and, therefore, does not allow for the generalization of results to all second- and third-year medical students. Another limitation was the lack of previous sample size calculations that considered each of the various dependent variables in this study. It should also be noted that the absence of any type of practical assessment of blood pressure measurement can be considered a limitation and, finally, the use of a questionnaire not validated by experts.

However, it is worth noting that the results of this study provide situational data from the post-pandemic context that can be used to define anchors for the design of educational tools and methodological strategies more suited to the profile of this group of medical students who experienced a situation never before faced in medical education. This context originated cognitive and psychomotor needs related to non-invasive blood pressure measurement with an aneroid sphygmomanometer. Furthermore, if necessary, in a situation similar to the COVID-19 pandemic, the results discussed here can support the planning of even more effective educational actions for learning related to blood pressure measurement by medical students.

## Conclusions

The study conducted with this sample allowed for the identification that, despite the challenges faced by students and faculty during the pandemic, there was evidence of acquisition of knowledge, skill, and confidence in performing non-invasive blood pressure measurement with an aneroid sphygmomanometer. When comparing the two groups, the third-year students, who began their medical undergraduate studies in 2020, reported greater theoretical knowledge for measuring BP, the ability to estimate BP by palpating the radial pulse, and greater skill in measuring with a sphygmomanometer and holding the stethoscope bell. These results were observed in the bivariate analysis and corroborated by the multiple analysis after controlling for independent variables. This indicates a possible cumulative effect of study time, even amidst the COVID-19 pandemic, and the contribution of other disciplines that addressed blood pressure measurement, albeit in different ways.

## Authors' contribution

We describe contributions to the papers using the taxanomy (CRediT) provided above: *Conceptualization, Investigation, Methodology, Visualization & Writing – review & editing*: CL Gyotoku; AY Kochi; CGL de Moraes; SY Li. *Project administration, Supervision & Writing – original draft*: FL de Holanda. *Validation & Software:* MH de Sousa. *Resources & Funding acquisition*: CL Gyotoku; AY Kochi; CGL de Moraes; SY Li. *Data curation & Formal Analysis*: MH de Sousa.

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