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SENPE

Ultrasonido en el punto de atención en Nutrición: evaluación de la confiabilidad de la medición del grosor del cuádriceps femoral por parte de profesionales de la salud novatos

Point-of-care ultrasound (POCUS) in Nutrition — Evaluating the reliability of quadriceps femoris thickness measurement by novice healthcare professionals

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Alfredo Gutiérrez-Hernández and Daffne Danae Baldwin-Monroy have equally contributed to this work.

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ABSTRACT

Introduction: the study aims to train and standardize novice healthcare professionals (NHPs) in the use of point-of-care ultrasound (POCUS) for quadriceps femoris thickness measurement (QFT) and evaluate the reliability of measurements performed by NHPs.

Methods: this study was conducted in a pediatric center in Mexico City between May and July 2024, where the NHPs were trained in ultrasound (US). The training included 12 hours of theory and practice. Measurements were evaluated through an intra- and inter-rater reliability analysis using triplicate measurements from 11 healthy adult volunteers.

Results: excellent agreement was observed between the NHPs and the expert instructor's measurements, with an intraclass correlation coefficient (ICC) of 0.91. Furthermore, inter-rater reliability was very good, with an ICC of 0.997 for the instructor and 0.992 for the NHPs. The Bland-Altman analysis showed a small bias error, indicating high precision in the novice measurements. The results suggest that NHPs can make reliable measurements after appropriate training. These findings are consistent with previous studies and highlight the importance of protocolizing the measurements and structured training to guarantee their reliability.

Conclusions: ultrasound is a reliable tool for Quadriceps Femoris Thickness Measurement (QFTM) that NHPs can use. Theoretical-practical training and standardization reduce biases in the precision of measurements made by the US.

Keywords: Point-of-care ultrasound. Quadriceps femoris thickness measurements. Reliability. Muscular mass. Healthcare professionals.

RESUMEN

Introducción: el estudio tiene como objetivo capacitar y estandarizar a los profesionales de la salud novatos (PSN) en el uso de ultrasonido en el punto de atención (POCUS, por sus siglas en inglés) para la medición del grosor del cuádriceps femoral (GCF) y evaluar la fiabilidad de las mediciones realizadas por los PSNs.

Métodos: este estudio se llevó a cabo en un centro pediátrico en la Ciudad de México entre mayo y julio de 2024, donde los PSNs fueron capacitados en ultrasonido (US). La formación incluyó 12 horas de teoría y práctica. Las mediciones fueron evaluadas mediante un análisis de fiabilidad intra e interevaluador utilizando mediciones triplicadas de 11 voluntarios adultos sanos.

Resultados: se observó una excelente concordancia entre las mediciones realizadas por los PSNs y las del instructor experto, con un coeficiente de correlación intraclase (CCI) de 0,91. Además, la fiabilidad interevaluador fue muy buena, con un CCI de 0,997 para el instructor y 0,992 para los PSNs. El análisis de Bland-Altman mostró un pequeño error de sesgo, lo que indica una alta precisión en las mediciones realizadas por los novatos. Los resultados sugieren que los PSNs pueden realizar mediciones fiables después de una formación adecuada. Estos hallazgos son consistentes con estudios previos y destacan la importancia de protocolizar las mediciones y ofrecer una capacitación estructurada para garantizar su fiabilidad.

Conclusiones: el ultrasonido es una herramienta fiable para la medición del grosor del cuádriceps femoral (GCF) que los PSNs pueden utilizar. La formación teórico-práctica y la estandarización reducen los sesgos en la precisión de las mediciones realizadas con ultrasonido.

Palabras clave: Ultrasonido en el punto de atención. Mediciones del grosor del cuádriceps femoral. Fiabilidad. Masa muscular. Profesionales de la salud.

INTRODUCTION

The evaluation of body composition by ultrasound, called "nutritional ultrasound (NUS)," has been presented as a viable alternative to traditional methods such as DEXA, computerized axial tomography (CT), and Magnetic Resonance Imaging (MRI) (1,2). The high costs, as well as the risks of exposure to radiation and the difficulty represented by the mobilization of some patients to the areas where this equipment are located (DEXA, Tomography, and Resonance), despite their precision, limit their usefulness in clinical practice (3,4). Clinical evidence on the use of ultrasound (US) in measuring body composition has increased because this method has shown reliability and validity when compared with other highly specialized methods such as CT or MRI. a low coefficient of variation (5-12), this has positioned ultrasound as a radiation-free, economical and feasible technique to perform at the patient's bedside and its application has extended to professionals such as doctors, nurses, dietitians, and respiratory therapists (13).

Using ultrasound by non-radiologists was first established in adult specialties in 1990 when the American College of Emergency Physicians (ACEP) defined the ultrasound skills that emergency physicians must demonstrate to be competent (14). The American Academy of Pediatrics, later established a position on pediatricians' use of this tool in 2015 (15). With this background, it has been demonstrated that specialists with adequate training can effectively use ultrasound at the point of care. Studies such as that of Young et al. demonstrated that respiratory therapists can be competent in using point-of-care ultrasound to identify different pulmonary syndromes (16). Similar results have been found among healthcare professionals without previous experience in using ultrasound after having received brief training (17-19).

In clinical nutrition, the US has been incorporated as a tool for measuring body composition and can help guide the prescription of nutritional support (7). Therefore, it can be a helpful tool in training nutrition professionals. However, the American Society for Enteral and Parenteral Nutrition (ASPEN) developed a survey. In terms of hospital nutritional assessment practices, it was reported that only 1 % of nutrition professionals use the US as part of nutritional assessment (20).

Nawata, in a similar study carried out in Japan, reported that of the dietitians who participated in their study, 24 % had used the US to assess muscle mass (21). These data show that nutrition professionals barely use the US in their activities. However, they have shown interest in acquiring the knowledge and practical skills that allow them to use it (20). The main barriers perceived for its use are the lack of training, lack of HCP well-capacitated, and absence of protocols that standardize its use (21).

Therefore, spreading the usefulness of nutritional ultrasound can improve the quality of the evaluation and treatment provided by nutrition professionals since it is little used, as reflected in the little research on the subject (7). Therefore, the objective of the present study was to train and standardize novice healthcare professionals in the use of Point-of-Care Ultrasound (POCUS) to quadriceps femoris thickness measurement and evaluate intra- and inter-observer reliability of the measurements.

MATERIAL AND METHODS

Selection of participants

The study was conducted in a tertiary care pediatric center in Mexico City from May to July 2024. Dietitians and physicians without experience using point-of-care ultrasound were invited to participate. Those who agreed to participate were referred to in the present study as novice healthcare professionals (NHP). Those who signed the consent form to participate in the project also participated in the study. All participants were included in the training activities.

Point-of-care ultrasound training

A theoretical-practical training lasting six theoretical and six practical hours was carried out by the instructor, AGH (a doctor specializing in pediatric intensive care), with experience in ultrasound at the point of care. The NHPs received training on the following topics through classes, watching videos, and answering online questionnaires:

1. Approach to ultrasound at the point of care (generalities),
2. Physics of ultrasound,
3. Orientation and movements for image acquisition
4. Basic modes in ultrasound (two-dimensional mode)
5. Buttonology and image optimization,
6. Quadriceps femoris thickness measurement (QFTM)

Protocol

The NHPs, using the measurement protocol proposed by Valla et al. (22), carried out two practical sessions to evaluate the thickness of the quadriceps femoris in healthy adults. The measurements were carried out under the supervision and feedback of the instructor as part of the training, and they were not considered for the analyses. The direct supervision of the instructor had special emphasis on the acquisition of an adequate image (with sufficient depth to visualize the femur, adjustment of the general gains, and central image on the screen), placing an abundant amount of gel for image acquisition, avoiding compressing the thigh and perpendicular placement of the transducer about the thigh.

After the training, each NHP measured the 11 models in triplicate. The instructor supervised all measurements, and those that did not meet the image quality required were discarded. In a blinded manner, the instructor measured each model in triplicate without notifying the NHP of the result.

Ultrasound

For this research, a GE Venue R2® ultrasound machine was used, with a linear transducer (12L-RS) and, for large thighs, a convex transducer (C1-5-RS), using the preset values for musculoskeletal imaging.

Measurement technique

For the FQTM, the following steps were ensured:

1. The subject was positioned supine on the bed with the bed's headrest at 0° elevation.
2. The lower limbs were fully extended on the bed in a relaxed position, with a neutral rotational alignment to avoid quadriceps contraction.
3. On the right lower extremity, the superior border of the patella and the anterosuperior border of the right iliac crest were identified. A line was drawn to mark the mid-distance between these two points (Fig. 1A).
4. Once the mid-distance of the patella-iliac crest line was identified, it was marked with indelible ink to ensure measurements were taken at the same point (22).
5. The transducer was placed over the mark made in the previous step, positioning it perpendicular to the horizontal plane of the thigh. A generous amount of ultrasound gel was used to avoid applying pressure on the thigh, and the image was then acquired for subsequent measurement (Fig. 1B and 1C). It is essential to avoid pressure on the thigh when taking measurements to obtain

the correct distance (Fig. 2A and 2B). This last step was performed in triplicate.

Study design

To evaluate the reliability of the measurements after training, a prospective observational study was conducted to measure the Quadriceps femoris thickness in 11 healthy adult volunteers. Intra- and inter-rater reliability were assessed. To determine intra-rater reliability, all NHPs measured the 11 volunteers (all measurements were taken in triplicate), and the triplicate measurements of each evaluator were compared across the 11 healthy volunteers. Inter-rater reliability was also analyzed by comparing the measurements of the NHPs against those of the instructor. The measurements were blinded between NHPs and the instructor and NHPs.

The association between the instructor's measurements vs those of the NHPs was evaluated using Pearson's correlation coefficient, and the correlations were displayed in a heatmap. To assess the agreement between the quantitative QFTMs of the instructor and the NHPs, the Intraclass Correlation Coefficient (ICC) was used with a 95 % confidence interval. The agreement was categorized as ICC > 0.90 very good agreement, 0.71-0.90 good agreement, and 0.51-0.70 moderate agreement (23). The Bland-Altman method (24) was used to evaluate the agreement and estimate the bias between the instructor's measurements and those of the NHPs by plotting the distribution of the differences between the NHPs measurements and the instructor's measurements (mean bias) against their respective average values. A *p*-value ≤ 0.05 was considered statistically significant. Statistical analyses were performed using SPSS software (version 25 Inc, Chicago, IL) and GraphPad Prism software (version 7.0, GraphPad Software, Inc, San Diego, CA).

RESULTS

The participation of 11 NHPs was obtained, of which 81.8 % (*n* = 8) were dietitians by profession, and the others were medical doctors (Table I). Each participant performed 33 measurements, and the average of the triplicate measurements (11 measurements per person) was analyzed, totaling 363 measurements.

In the Pearson correlation analysis, when compared with the instructor, a good relationship was found between the instructor and the NHPs (Fig. 3). The best association was r = 0.971 (95 % CI, 0.888-0.992), $p < 0.0001$, and the worst association was r = 0.769 (95 % CI, 0.314-0.936), $p < 0.0056$.

When analyzing the Intraclass Correlation Coefficient (ICC) compared to the instructor (intra-rater reliability), the overall value for all NHPs was ICC = 0.91 (95 % CI, 0.807-0.966), categorized as very good agreement. For the healthcare professionals in the nutrition field, the highest ICC was 0.97 (95 % CI, 0.90-0.99), and the lowest was ICC = 0.75 (95 % CI, 0.30-0.92); for the medical doctors, the highest was ICC = 0.91 (95 % CI, 0.72-0.97) and the lowest was ICC = 0.87 (95 % CI, 0.62-0.96) (Fig. 4). In all, 63.6 % (*n* = 7) of the NHPs' measurements were categorized as very good agreement, and the rest as good agreement.

When analyzing inter-rater reliability, it was observed that the instructor obtained very good reliability (ICC, 0.997, 95 % CI, 0.992-0.999), $p < 0.0001$, and the NHPs also had very good reliability, but with a lower ICC (ICC, 0.992, 95 % CI, 0.988-0.994), $p < 0.0001$. The lowest individual value obtained was good agreement with an ICC of 0.962 (95 % CI, 0.891-0.990), and the highest was 0.997 (95 % CI, 0.992-0.999), like that of the instructor (Table II).

Regarding agreement and bias estimation evaluated with the Bland-Altman model compared to the instructor's measurements, the highest bias was 1.5 ± 3.5, and the lowest was 0.009 ± 3 (Fig. 5).

DISCUSSION

The results contribute to the growing body of literature supporting the use that healthcare professionals without prior experience in ultrasound can perform reliable measurements after receiving training and standardization to QFTM.

Other authors have reported similar findings in measuring muscle thickness in the thigh or arm. Measurements performed by different professionals (nurses, physiotherapists, and clinical doctors) without prior experience in ultrasound obtained Intraclass Correlation Coefficients (ICC) greater than 0.9 after adequate training (19,25-27). The results confirm the feasibility of individuals without prior ultrasound experience to perform reliable QFTM after structured training.

This research is notable because it provides evidence that nutrition professionals can obtain reliable QFTM in healthy adults after training. Previous studies, including dietitians' studies, have limited participants to one or two individuals (28,29). However, ultrasound already has a recognized place among body composition assessment methods and in evaluating muscle mass depletion and nutritional management (7,12,13), suggesting its incorporation into everyday clinical nutrition practice (1). Despite its potential, some surveys have shown that dietitians rarely report using ultrasound as a body composition assessment method, probably due to the limited training opportunities (20,21). Operators must receive proper training to obtain optimal results when measuring muscle thickness using ultrasound, especially when they are not radiology experts (30). Training ranges from 3 to 33 hours, although there is no consensus on the minimum duration needed to acquire competence in these measurements. In this study, the training lasted 12 hours, which explains the reliability of the measurements obtained, comparable to those made by an expert.

Besides formal training, it is crucial to have a standardized protocol that systematizes QFTM. A systematic review identified that studies with higher ICCs ensure the reproducibility of the technique (31). Factors such as patient positioning, applied pressure, the angle between the transducer and the thigh, the amount of gel used, and even the type of device can influence the results (28,32). In this research, the methodology described by Valla was followed to standardize the measurements (22).

Limitations of the study and future proposals

Although most participants in this study were dietitians, studies that include them are still scarce. It represents an opportunity to develop research with larger samples of dietitians trained in nutritional ultrasound. Formal educational programs, composed of theoretical and practical curricula, have proven effective in acquiring the necessary competencies to perform reliable QFTM. Dietitians in these programs will facilitate the expansion of nutritional ultrasound use, positively impacting muscular depletion assessment in different clinical scenarios.

The limitations of this research are the small sample size, its conduct at a single center, and the controlled setting and healthy models. Movement restrictions associated with the patient's health status, the presence of probes or bandages, and the lack of patient cooperation could significantly influence the measurements.

As the integration of point-of-care ultrasound (POCUS) into clinical practice progresses, it becomes imperative to understand the learning curves associated with the psychomotor skills of trainees. These curves graphically represent the relationship between repetitive practice and learning progress, and they largely depend on the duration and quality of the instruction received. While the study results show excellent reliability in measurements performed by novice healthcare professionals, it is crucial to consider the limitations noted by the authors, particularly that measurements were conducted on healthy volunteers under controlled conditions. In a real clinical setting, factors such as edema, pain, sutures, or bandages could significantly affect the visibility and accessibility of the muscle, potentially impacting the accuracy and reliability of measurements performed by trainees. De Oliveira found that NHP, after receiving a capacitation, performs similar measurements in pediatric critical care patients, with an ICC > 0.81. However, more studies should evaluate the performance of trained professionals in actual clinical populations to determine whether the high levels of agreement observed are maintained under more complex and representative conditions of daily practice.

Although the study shows that 12 hours of training, combining theory and practice, is sufficient to achieve reliable measurements in a controlled environment with healthy volunteers, it cannot necessarily be assumed that the same amount of training would be adequate in all contexts. Blehar and colleagues reported that achieving a learning plateau—defined as the point where no further significant improvement in image quality is observed—requires 18 soft tissue ultrasound studies (34).

In more complex clinical settings, where specific conditions of hospitalized patients are present, technical challenges increase and may require more extensive or specialized training. In the study conducted, each student performed thirty evaluations (considering triplicate measurements for each model), all under the supervision of experienced personnel. This supervision adds value to the measurements obtained by novices, as the learning curve is directly related to the quality of the instruction provided.

CONCLUSIONS

The findings of this study demonstrate that nutritional ultrasound, used to identify quadriceps femoris thickness as part of muscle mass assessment in healthy adults performed by healthcare professionals with no prior ultrasound knowledge, is a reliable measure, with good to very good agreements compared to those of an expert.

The theoretical-practical training allows the standardization and protocolization of the measurement technique, reducing biases and limitations in ultrasound measurements.

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Table I. Demographic characteristics of novice health professionals (n = 11)

Age years	33.9 (22-41)
Sex	
Women	100 % (n = 11)
Highest level of education	
Undergraduate student	27.3 % (n = 3)
Bachelor's degree	9.1 % (n = 1)
Master degree	45.5 % (n = 5)
PhD	18.2 % (n = 2)
Profession	
Physicians	18.2 % (n = 2)
Dietitians	81.8 % (n = 11)
Professional practice, years	*8.7 (0-20)*
0-5	45.5 % (n = 5)
5-10	9.1 % (n = 1)
> 10	45.5 % (n = 5)

Table II. Inter-rater reliability

	ICC (95 % CI)	***p***
Instructor	0.997 (0.992-0.999)	< 0.0001
Novice Healthcare Professionals	0.992 (0.988-0.994)	< 0.0001
D1	0.990 (0.972-0.997)	< 0.0001
D2	0.990 (0.970-0.997)	< 0.0001
D3	0.993 (0.980-0.998)	< 0.0001
D4	0.993 (0.979-0.998)	< 0.0001
D5	0.993 (0.978-0.998)	< 0.0001
D6	0.996 (0.989-0.999)	< 0.0001
D7	0.997 (0.992-0.999)	< 0.0001
D8	0.962 (0.891-0.990)	< 0.0001
P1	0.997 (0.990-0.999)	< 0.0001
P2	0.990 (0.970-0.997)	< 0.0001
P3	0.995 (0.986-0.999)	< 0.0001

D: dietitians; P: physicians.

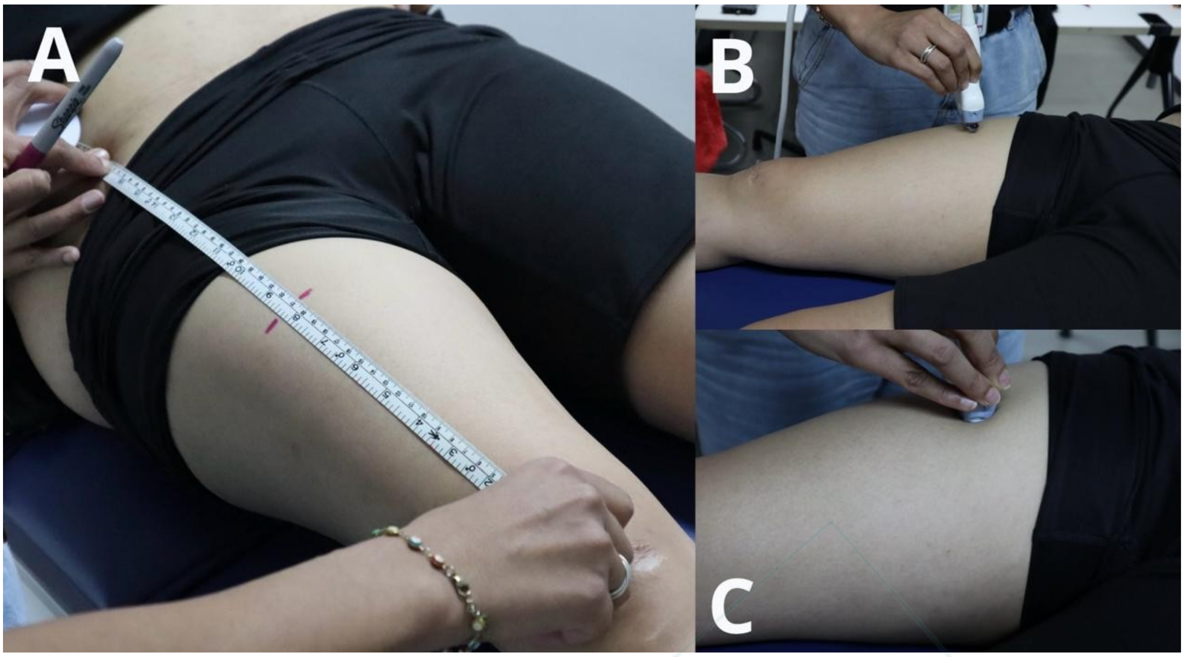

Figure 1. Measurement position. A. The patient is supine with the lower limbs fully extended, and the feet relaxed to avoid muscle contraction. A straight line is drawn from the upper edge of the knee to the anterior superior iliac spine, and the midpoint of this distance is marked. B. The transducer is placed over the previously marked point, perpendicular to the horizontal plane of the thigh. C. Abundant gel is used to avoid inaccurate measurements.

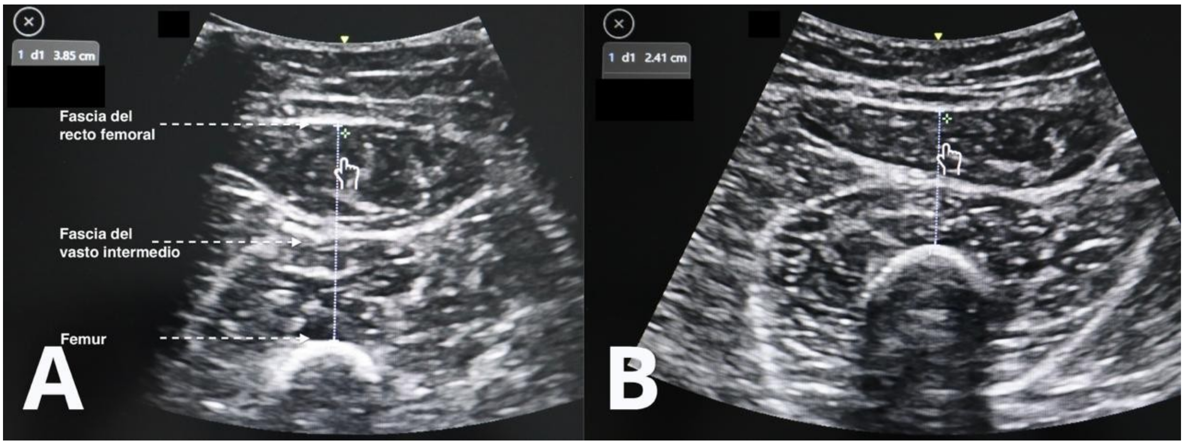

Figure 2. Quadriceps femoris thickness measurement. A. The ultrasound measurement is taken from the edge of the femur to the fascia of the rectus femoris, including the thickness of the vastus intermedius and rectus femoris. B. When excessive pressure is applied to the thigh, the thickness of the muscle’s changes, leading to inaccurate measurements. Images A and B are from the same model, with image A showing abundant ultrasound gel and no pressure applied to the thigh (measurement: 3.8 cm), and image B showing pressure applied to the thigh (measurement: 2.4 cm).

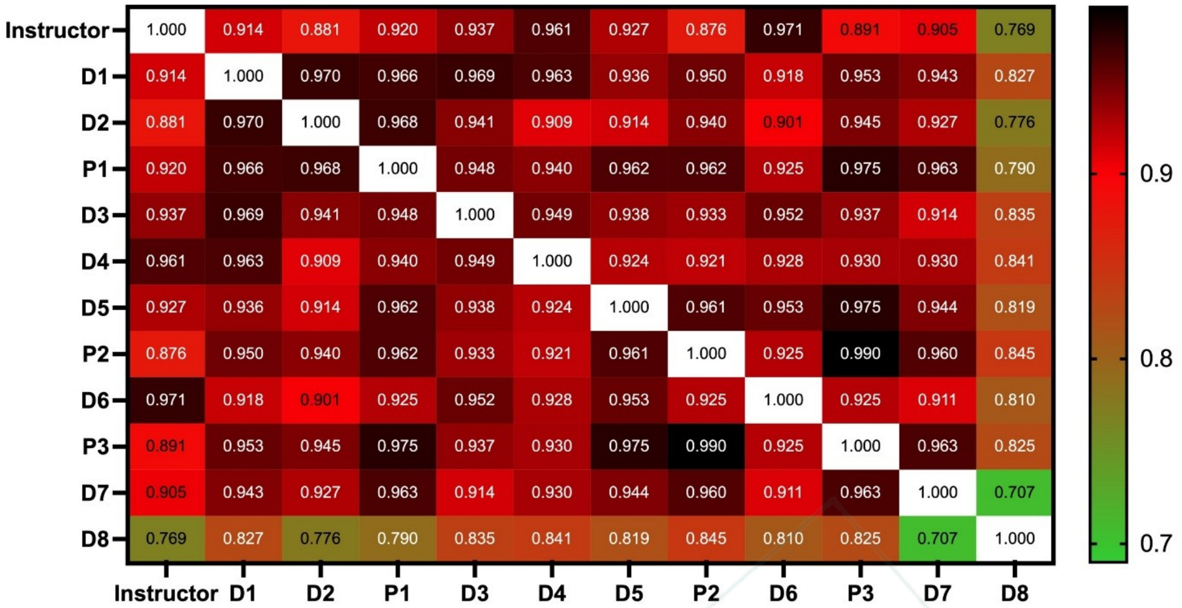

Figure 3. Pearson correlation analysis between the Instructor's and Novice Healthcare Professionals' measurements.

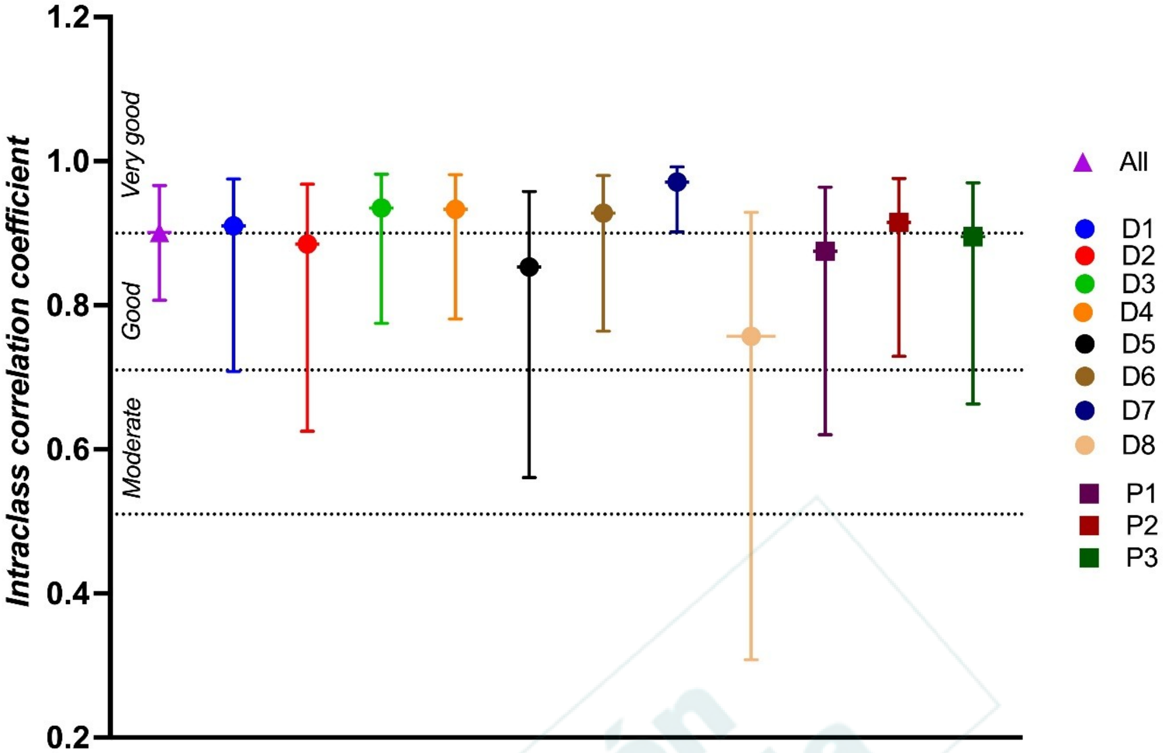

Figure 4. Intraclass correlation coefficient compared to the instructor.

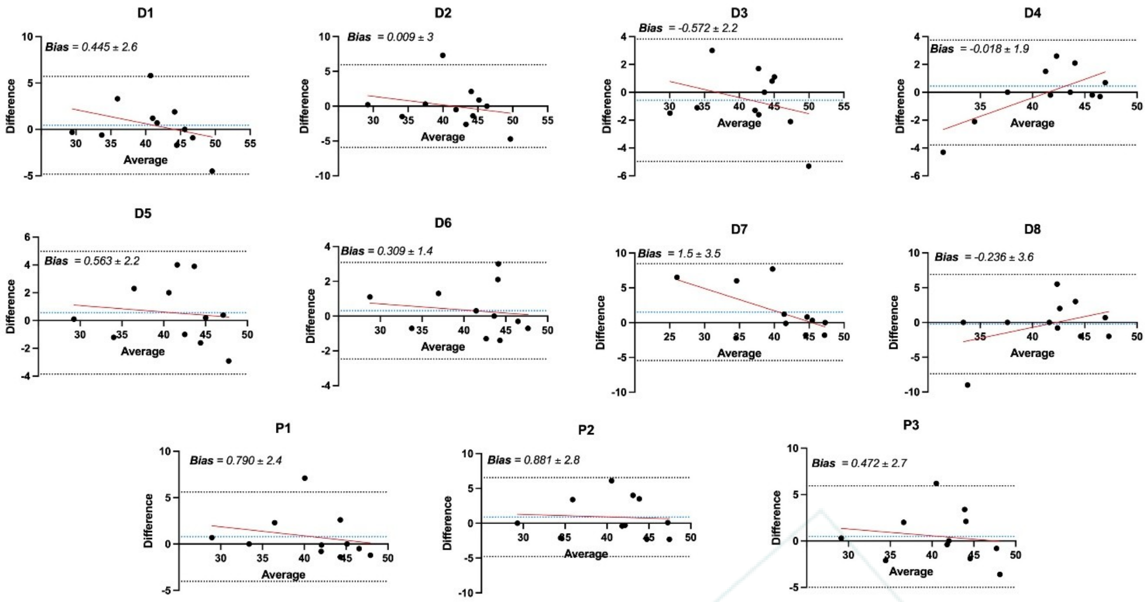

Figure 5. Agreement between the Instructor and Novice Healthcare professionals.