OBJN
ONLINE BRAZILIAN JOURNAL OF NURSING

ISSN: 1676-4285

Phase angle for assessing lesion risk or healing: a systematic review

Ângulo de fase para avaliar risco ou cicatrização de lesões: revisão sistemática

Ángulo de fase para evaluar el riesgo o la cicatrización de lesiones: revisión sistemática

Rodrigo França Mota[1]
ORCID: 0000-0001-5762-9377

Barbara Pompeu Chistovam[1]
ORCID: 0000-0002-9135-8379

Érica Brandão de Moraes[1]
ORCID: 0000-0003-3052-158X

Cláudio José de Souza[1]
ORCID: 0000-0001-7866-039X

Ana Paula Amorim Moreira[1]
ORCID: 0000-0003-1047-0658

Graciele Oroski Paes[2]
ORCID: 0000-0001-8814-5770

1 Fluminense Federal University
2 Federal University of Rio de Janeiro

Editor:Paula Vanessa Peclat Flores
ORCID: 0000-0002-9726-5229

Submission: 12/20/2020
Approved: 04/26/2021

ABSTRACT
Objective: To assess the effectiveness of the phase angle measured by electrical bioimpedance as a predictor for healing evaluation in patients with skin lesions or risk of developing them. **Method:** A systematic review operationalized according to Joanna Briggs Institute methodology, PRISMA checklist recommendations. The sample included patients over 18 years old with varied skin lesions. **Results:** Four studies demonstrated the use of phase angle for the healing outcome and one study indicated a possible relationship between phase angle and the prediction of the onset and risk of pressure ulcer. Cut-off points were obtained for certain lesions. As it was not possible to perform a meta-analysis, it is proposed to conduct primary studies on the theme of this study. **Conclusion:** Although there are few scientific papers with the theme proposed, it was possible to demonstrate moderate evidence for the "healing" outcome and low evidence for the "risk of lesion" outcome. Registration in PROSPERO with number CRD420201549.
DESCRIPTORS: Pressure Ulcer; Healing; Nursing; Electrical Impedance; Injuries and Lesions; Skin.

RESUMO
Objetivo: Avaliar a efetividade do ângulo de fase medido por bioimpedância elétrica como preditor para avaliação de cicatrização em pacientes com lesões cutâneas ou risco de desenvolvê-las. **Método** Revisão sistemática operacionalizada segundo metodologia Joanna Briggs Institute, recomendações checklist PRISMA. A amostra contemplou pacientes acima de 18 anos com lesões cutâneas variadas. **Resultados**: Quatro estudos demonstraram o uso do ângulo de fase para o desfecho cicatrização e um estudo apontou uma possível relação do ângulo de fase com previsão de surgimento e risco de lesão por pressão. Foram obtidos pontos de cortes para determinadas lesões. Por não ter sido possível metanálise, se propõe a realização de estudos primários sobre o tema deste estudo. **Conclusão**: Apesar de serem poucos os trabalhos científicos com o tema proposto, foi possível demonstrar evidência moderada para o desfecho "cicatrização" e baixa para o desfecho "risco de lesão". Registro no PROSPERO com número CRD420201549.
DESCRITORES: Lesão por Pressão; Cicatrização; Enfermagem; Impedância Elétrica; Ferimentos e Lesões; Pele.

RESUMEN
Objetivo: Evaluar la efectividad del ángulo de fase medido por bioimpedancia eléctrica como predictor para la evaluación de la cicatrización en pacientes con lesiones cutáneas o riesgo de desarrollarlas. **Método**: Revisión sistemática realizada según la metodología del *Joanna Briggs Institute*, recomendaciones checklist PRISMA. La muestra incluyó a pacientes mayores de 18 años con diferentes lesiones cutáneas. **Resultados**: Cuatro estudios demostraron el uso del ángulo de fase para el resultado cicatrización y un estudio señaló una posible relación entre el ángulo de fase y la previsión de la aparición y el riesgo de lesión por presión. Se obtuvieron puntos de corte para ciertas lesiones. Como no fue posible realizar un metaanálisis, se propone realizar estudios primarios sobre el tema de este estudio. **Conclusión**: Aunque hay pocos estudios científicos sobre el tema propuesto, fue posible demostrar evidencia moderada para el resultado "cicatrización" y baja para el resultado "riesgo de lesión". Inscripción en PROSPERO con número CRD420201549.
DESCRIPTORES: Lesión por Presión; Cicatrización; Enfermería; Impedancia Eléctrica; Heridas y Lesiones; Piel.

Mota RF, Chistovam BP, Moraes EB, Souza CJ, Moreira APA, Paes GO. Phase angle for assessing lesion risk or healing: a systematic review. Online Braz J Nurs [Internet]. 2021 Mês [cited year month day];20:e20216481. Available from: https://doi.org/10.17665/1676-4285.20216481

INTRODUCTION

Technological advances and the need for more precise measures that assess body composition, especially cellular state, have caused the use of electrical bioimpedance (EBI) as a physiological marker to increase in recent years. EBI is a non-invasive, practical, reproducible, cost-effective and agile method with high-speed information processing. Among the measurements obtained in performing EBI, the phase angle (PA) biomarker stands out, used to estimate intra and extracellular fluid, predicting with this information the cellular health, size and integrity. The measurement values of this biomarker are expressed in degrees, which commonly range from 0º to 10º, and some studies mention values up to 15º[1].

A number of studies show that PA values can be used as markers of cellular conditions in several clinical situations, its relationship having been proved in several studies, such as a negative correlation between PA and the degree of Congestive Heart Failure[2]. In addition, the positive association in critically-ill patients with low PA and renal failure, malnutrition, hypoalbuminemia, anemia, score and APACHE II (Acute Physiology and Chronic Health Disease Classification System II)[3].

PA values above 4º are related to cell membrane integrity and, consequently, to better cell health. Similarly, the lower the PA value and the closer to 0º, the worse the cellular health. Therefore, low PA values are associated with cell death or to some alteration in the selective permeability of the membrane, indicating worsening of the disease and worse prognosis, with a consequent increase in morbidity and mortality[4].

Being interpreted as an indicator of membrane integrity and predictor of Body Cell Mass (BCM), it is possible to use PA to monitor the evolution of wounds and the healing process, or even to predict the appearance of new skin lesions[5].

A recent study evidenced that the values of the phase angles were significantly lower in the high-risk group for pressure ulcer when compared to the control group[6]. Therefore, interest in the use of the bioimpedance method for wound evaluation has increased in recent years[7].

Skin lesions are a serious global public health problem, with increased costs to the health systems and significant morbidity and mortality rate[8]. This fact is directly related to some limitations of the methods for the evaluation and follow-up of wound healing. Multicausality and involvement of intrinsic and extrinsic factors are often not reflected when using methods based on visual inspections and size and depth measurement tools. In addition to that, during the removal of the dressing for evaluation, there may be movements that harm and impair the healing process[7].

In relation to the tools used in the assessment of the risk for the development of skin lesions, there is a variety of scales available and validated internationally, the most used being those of Braden and Waterlow. The Braden Scale was developed as a means to optimize prevention strategies and thus reduce its incidence[9]. The Waterlow Scale has the differential of including a greater number of variables to be analyzed, among them,

nutritional status translated by the assessment of Body Mass Index (BMI) and appetite, in addition to some characteristics of the skin[10]. Although validated, their use needs to be standardized in the institution and the team must be properly trained so that there is a uniform evaluation of the scale items.

It is known that the use of scales contributed to the advance in the assessment of risk and prevention of the appearance of skin lesions in several contexts. However, physiological measures of the cellular state of these patients reduce the interference of the evaluator and bring about greater precision to these risk and follow-up estimates. Related to this, the use of EBI with PA to assess risk and monitor the evolution of the lesions would give more safety to the health professional in the planning of conducts, as it would provide intrinsic values of worsening or improvement of cellular state[11].

This said, evaluating the effectiveness of a marker that may serve as an assessment indicator for the risk and healing of these lesions would benefit many services, reducing morbidity and mortality due to complications generated by skin lesions in hospitalized or outpatient patients, in addition to reducing costs[12]. In this sense, it becomes relevant to incorporate new technologies, especially non-invasive, to support actions for preventing and treating skin lesions.

In a preliminary search, no systematic reviews on the theme were found in the literature, involving phase angle measured by electrical bioimpedance and skin lesions/wounds. Thus, this study aims at evaluating the effectiveness of phase angle measured by electrical bioimpedance as a predictor for healing assessment in patients with skin lesions or at risk for developing them.

METHOD

A systematic review was carried out according to the Joanna Briggs Institute methodology[13]. Furthermore, there were recommendations from the PRISMA checklist for systematic reviews in order to answer the research question: "Is phase angle measured by electrical bioimpedance effective to assess improvement and healing and/or to predict the appearance of skin lesions in patients?", according to the PICO acronym where P (Patient) = Patients with skin lesions or at risk for developing them; I (Intervention) = Phase angle measured by electrical bioimpedance; C (Comparison) = Absent for the question; and O (outcome) = Improvement in lesion, healing and/or prediction of onset in patients at risk of lesion[14].

Protocol and registration

The protocol for the development of this review was elaborated carefully following the guidelines set forth in PROSPERO, the International prospective register of systematic reviews, which is an international database for the registration of protocols of systematic reviews[14]. This information source serves to collaborate in the quality of scientific publications, favoring transparency in research, reducing duplication and minimizing bias in the reviews. The protocol is registered under the number CRD420201549.

Eligibility criteria

The studies included were those that evaluated

patients with lesions, regardless of type, severity and underlying pathology, or studies that evaluated the risk of developing any lesion. The patients in the studies had to be 18 years old or older, without restriction of gender, followed-up in outpatient clinics or hospitals. As intervention, those studies that used the evaluation of phase angle measured by any model of EBI device were included. The evaluated outcomes were the following: improvement and healing of the lesions, and risk for developing a lesion. Experimental and observational studies were considered primarily, with no time and language restrictions.

Studies that used animals to evaluate PA were excluded, as well as those that evaluated wounds in mucous membranes or inner organs in the human body, and studies that performed In Vitro tests in order to evaluate the potential of phase angle in the evaluation of lesions and prognoses related to the intrinsic risk factors.

Information sources

The search was conducted on December 18th, 2019, and updated on October 14th, 2020, where the following electronic bibliographic databases were searched: Medical Literature, Analysis, and Retrieval System Online (MEDLINE), Excerpta Medica DataBASE (EMBASE), *Literatura Latino-Americana e do Caribe em Ciências da Saúde* (LILACS), THE COCHRANE LIBRARY, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The search in the gray literature was carried out in Thesis and Dissertation Databases and in Google Scholar.

Search strategy

The search strategy included controlled terms and keywords related to the items that make up the PICO strategy, combined with the Boolean operators AND and OR. The terms were combined and adapted for use in each database, as shown in Chart 1.

Chart 1 - Search strategies in the databases. Niterói, RJ, Brazil, 2020.

Databases	Search Strategy
EMBASE	('decubitus'/exp OR 'bed sore':ti,ab OR 'bedsore':ti,ab OR 'decubital ulcer':ti,ab OR 'decubital ulcus':ti,ab OR 'decubitus':ti,ab OR 'decubitus ulcer':ti,ab OR 'decubitus ulceration':ti,ab OR 'decubitus ulcers':ti,ab OR 'decubitus ulcus':ti,ab OR 'decubus ulcer':ti,ab OR 'pressure sore':ti,ab OR 'pressure ulcer':ti,ab OR 'sore, pressure':ti,ab OR 'ulcer, pressure':ti,ab OR 'ulcus decubitus':ti,ab OR 'skin defect'/exp OR 'cutaneous lesion':ti,ab OR 'lesion, skin':ti,ab OR 'skin damage':ti,ab OR 'skin lesion':ti,ab OR wounds:ti,ab) AND ('phase angle':ti,ab OR bioimpedance:ti,ab OR 'bioelectral impedance':ti,ab OR 'bioelectric impedance':ti,ab OR 'impedance'/exp OR 'electric impedance':ti,ab OR 'electric bioimpedance':ti,ab OR 'electrical bioimpedance':ti,ab OR 'electrical impedance':ti,ab OR 'impedance':ti,ab OR 'body composition'/exp OR 'body composition':ti,ab OR 'composition, body':ti,ab) AND [embase]/lim NOT ([embase]/lim AND [medline]/lim)
MEDLINE	((Electric Impedance[mh] OR Body Composition[mh] OR Body Composition[tiab] OR Bioimpedance[tiab] OR "Bioelectrical Impedance Phase Angle"[tiab] OR "Bioelectric Impedance Phase Angle"[tiab] OR "Bioimpedance Phase Angle"[tiab] OR "Impedance Phase Angle"[tiab] OR "Phase Angle"[tiab]) OR (((bioelectric*[tiab] OR electric*[tiab]) AND (bioimpedance[tiab] OR impedance[tiab] OR resistance[tiab])) AND Phase Angle[tiab]) AND (Skin Ulcer[mh] OR Pressure Ulcer[mh] OR Decubitus

	Ulcer*[tiab] OR Pressure Sore[tiab] OR Bed Sore[tiab] OR Wound*[tiab] OR Ulcer*[tiab] OR Skin Lesion*[tiab] OR Skin Injurie*[tiab]))
BVS/ LILACS	(tw:(Bioimpedance OR "Body Composition" OR "Bioelectrical Impedance" OR "Bioelectrical Impedance Phase Angle" OR "Bioelectric Impedance Phase Angle" OR "Bioimpedance Phase Angle" OR "Impedance Phase Angle" OR "Phase Angle" OR "Impedancia eletrica" OR "Composicao corporal" OR "Angulo de fase de impedancia bioeletrica" OR "Angulo de fase de bioimpedancia" OR "Angulo de fase de impedancia" OR "Angulo de fase" OR "Impedancia electrica" OR Bioimpedancia OR "Composicion del cuerpo" OR "Angulo de fase de impedancia bioelectrica" OR "Angulo de fase de bioimpedancia" OR "Angulo de fase de impedancia" OR "Angulo de fase")) AND (tw:("Skin Ulcer" OR "Skin Ulcers" OR "Pressure Ulcer" OR "Pressure Ulcers" OR "Decubitus Ulcer" OR "Pressure Sore" OR "Bed Sore" OR Wound* OR Ulcer* OR "Skin Lesion" OR "Skin Lesions" OR "Skin Injurie" OR "Skin Injuries" OR "Ulcera cutanea" OR "Ulcera por Pressao" OR "Ulcera por decubito" OR "Lesoes de Pele" OR "Lesao por pressao" OR "Lesoes por pressao" OR "Lesoes de Pele" OR "Lesao de Pele" OR Ferida* OR Ulcera* OR "Lesao cutanea" OR "Lesoes cutaneas" OR "Ulcera de piel" OR "Ulcera por presion" OR "Lesiones de piel" OR "Lesion de piel" OR Herida* OR "Lesion por presion")) AND (db:("LILACS"))
CINAHL	(("Electric Impedance" OR "Body Composition" OR Bioimpedance OR "Bioelectrical Impedance Phase Angle" OR "Bioelectric Impedance Phase Angle" OR "Bioimpedance Phase Angle" OR "Impedance Phase Angle" OR "Phase Angle" OR "bioelectric impedance" OR "bioelectrical impedance" OR "electric impedance" OR "electrical impedance" OR "electric bioimpedance" OR "electrical bioimpedance" OR "electrical resistance" OR "electric resistance" OR impedance) AND ("Skin Ulcer" OR "Pressure Ulcer" OR "Decubitus Ulcer" OR "Pressure Sore" OR "Bed Sore" OR Wound* OR Ulcer* OR Skin Lesion* OR Skin Injurie*))
COCHRANE	(([mh "Pressure Ulcer"] OR "bed sore":ti,ab OR bedsore:ti,ab OR decubital ulcer*:ti,ab OR "decubital ulcus":ti,ab OR decubitus:ti,ab OR "decubitus ulcer":ti,ab OR "decubitus ulceration":ti,ab OR "decubitus ulcers":ti,ab OR "decubitus ulcus":ti,ab OR "decubus ulcer":ti,ab OR "pressure sore":ti,ab OR pressure ulcer*:ti,ab OR "pressure lesion":ti,ab OR "pressure lesions":ti,ab OR "ulcus decubitus":ti,ab OR "skin lesion":ti,ab OR "skin lesions":ti,ab OR "cutaneous lesion":ti,ab OR "skin damage":ti,ab OR "skin lesion":ti,ab OR "skin lesions":ti,ab OR wound*:ti,ab OR skin:ti) AND ("phase angle":ti,ab OR bioimpedance:ti,ab OR "bioelectral impedance":ti,ab OR "bioelectric impedance":ti,ab OR [mh "impedance"] OR "electric impedance":ti,ab OR "electric bioimpedance":ti,ab OR "electrical bioimpedance":ti,ab OR "electrical impedance":ti,ab OR impedance:ti,ab OR [mh "body composition"] OR "body composition":ti,ab))

Source: The author.

Selection of the studies

For the selection of studies, the search results were sent to a referral management program called Endnote Web to remove duplicate articles. Subsequently, the studies were selected by two reviewers who independently evaluated the inclusion of the studies. In case of doubts or disagreements, they would seek consensus or invite a third reviewer. At first moment, the articles were selected by title and abstract. Subsequently, those that met the eligibility criteria were selected for full-reading. For the articles excluded after full-reading, the reason for exclusion was recorded.

Data extraction

For data extraction, an instrument elaborated by the authors was used, containing the following information: Author(s), Year and Country; Research Design; Method; Type of Lesion; Main Findings.

Risk of bias analysis and quality of the evidence

For the risk of bias analysis, the Joanna Briggs Institute's critical analysis tools specific to each type of study were used. The following was considered to calculate the percentage of positive answers: the number of items with a "yes" answer, divided by the total number of items times 100[13]. The quality of the evidence was performed in the *GRADEpro Guideline Development Tool*[14] software.

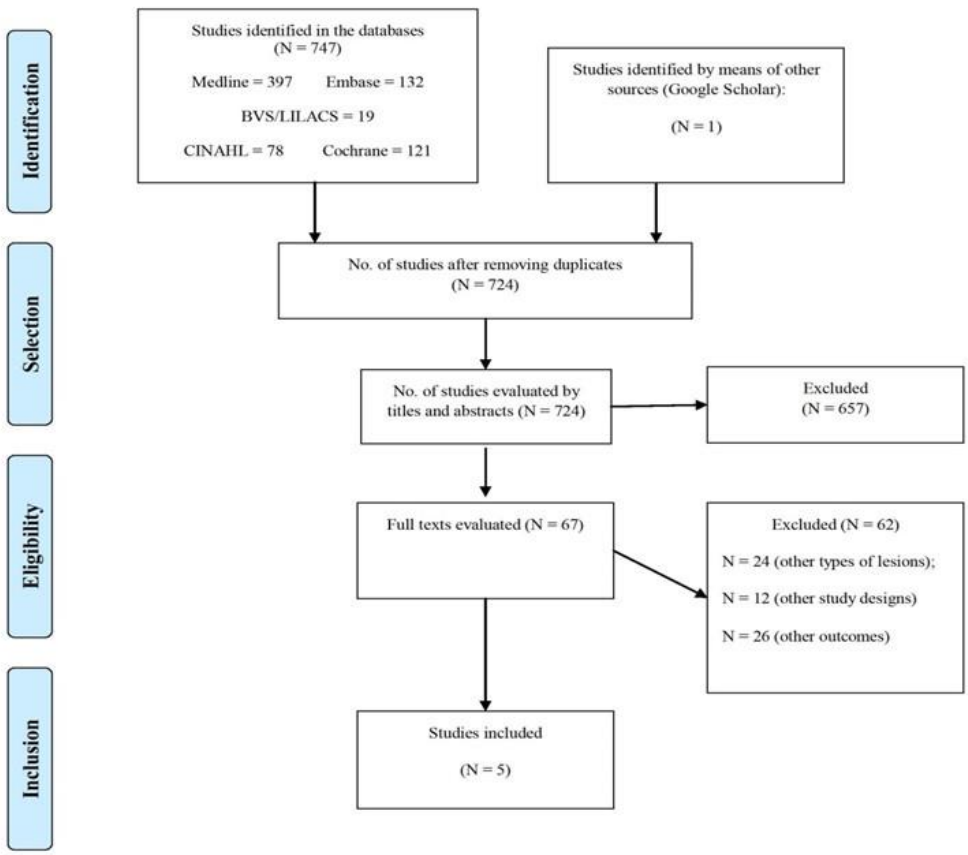
Synthesis of the results

The studies are presented in tables containing the qualitative synthesis of the data. Due to the heterogeneity of the studies and to the diversity of the measurement parameters and equipment, it was not possible to make a quantitative synthesis with meta-analysis.

RESULTS

After a comprehensive search in the databases, 747 scientific papers were found and 1 additional study was identified in other sources, totaling 748 articles. A total of 24 articles were removed, obtaining 724 for reading their titles and abstracts. Of these, 67 were selected for full-reading. After reading the full texts, 5 studies were included for the qualitative synthesis, as shown in Figure 1.

Figure 1 - Flowchart for the search/selection of articles. Niterói, RJ, Brazil, 2020.



Source: PRISMA checklist.

Chart 2 shows the characteristics of the studies included. The studies were published between 2007 and 2019, and came from the following countries: United States of America (USA), Australia, Colombia and Brazil. As for the study design, one quasi-experimental study, two cohort studies, one case-control study and one cross-sectional study were obtained. The EBI equipment used in the studies was as follows: Quantum IV – RJL, Nutrigard 2000-M, ImpediMed – SFB7, 4000B – XITRON and InBody S10.

In relation to the outcomes, four evaluated wound healing (E1, E2, E3, E4)[15-18].

One (E5) evaluated the possible relationship of PA with the prediction of the appearance and risk of pressure ulcer (PU), because it identified that low values of this biological marker correlated with the appearance of these lesions[19].

Study E1 tested PA as an alternative physiological tool to evaluate the treatment of chronic non-healing wounds[15]. In all the patients, the measurement of the phase angle of EBI was effective, as it reflected the intrinsic state of the wound and provided an accurate tool to assess the regional health of the tissues, providing a valuable insight to measure the effectiveness of a systemic treatment. In patients whose wounds healed, a positive increase in PA was observed. In patients with clinical signs of deterioration due to infection, there was a rapid decrease in PA. With the use of the nutritional supplement during the intervention, it was observed that PA began to rise in the measurements taken from the 6th day, with better response in 1 to 2 weeks of using the supplement.

In Study E2, no association between PA and wound healing was demonstrated[16]. During the evaluation of the patients, it was observed that the resistance markers at zero frequency (indicative of edema) and the resistance of the total body fluid increased significantly with healing in small burns, but the resistance of the intracellular fluid and of phase angle did not change.

Study E3, conducted in patients with pressure ulcer (PU), showed that PA was effective in the evaluation of lesions since it significantly decreased in these patients[17]. The total PA of patients with PU (3.4° [range of 2.7–4.2]) was 10% lower when compared to patients without PU (3.8° [range of 3.2-4.3]). The authors also demonstrated that there is a correlation between the Norton scale and PA values.

In another study (E4), which evaluated PA in foot ulcers, the authors could not demonstrate effectiveness in the use of PA related to the healing process[18]. Although there was healing in the patients, without complications, the EBI parameters did not increase during treatment, as expected.

In Study E5, PA showed effectiveness to predict the risk of skin lesions, demonstrating that low PA values may be correlated with decreased cellular integrity and, consequently, to the appearance of pressure ulcers since, of the 11 patients evaluated who developed PUs, 10 presented a total PA value below 4º (gold standard for this study)[19].

The authors of this study identified that the means of the PAs examined ranged from 2.09º

to 4.53º, with an overall mean of 3.18º (+0.55º).

Chart 2 – Characteristics of the studies on PA behavior in patients with skin lesions. Niterói, RJ, Brazil, 2020.

Identification, Author(s), Year & Country	Research Design	Method	PA measurement equipment	Type of lesion	Main findings
E1[15] Moore et al., 2011. USA.	Quasi-experimental	Eleven patients were included in the study, 7 women and 4 men, with a mean age of 62.54 years old. Phase angle measurements were performed weekly for 12 weeks or until wound closure. The frequency used was not clear, the author reported from 4 to 1,000 kHz.	Quantum IV – RJL	Chronic unhealed wounds. The etiologies (and numbers) of the wounds were arterial (1), venous (3), neurotrophic (3), traumatic (1), surgical (1) and infectious (2)	PA was effective in assessing wound healing.
E2[16] Kenworthy et al., 2017 Australia	Cohort Study	A study with 28 patients over 18 years old. A value of 50 kHz was used to measure EBI	ImpediMed - SFB7 tetrapolar	Minor burns in limbs	PA was been significantly associated with wound healing.
E3[17] Hengstermann et al., 2007 USA	Cohort Study	Nutritional status was determined in 484 (326 women/158 men) aged individuals over 65 years old. EBI was used to assess body composition and the PUs were divided into Stages I-IV. The electric current used was 50 kHz. Four surface electrodes were placed on the wrist and ankle to take the measurements.	Nutrigard 2000-M	PU stages I-IV	PA showed effectiveness in wound reduction when compared to the Norton scale. Means of 3.4° in patients with lesion and of 3.8° in patients without lesion.
E4[18] Gonzalez-Correa et al., 2009. Colombia.	Case Control Study	A study conducted with 6 patients (3 men, 3 women) with a mean age of 71 years old, with unilateral diabetic foot ulcers in one of the legs treated with Triticum vulgare or with the measurements (resistance or R, reactance or Xc and phase angle or θ to	4000B – XITRON	Leg ulcers	PA was not effective in wound evaluation. Means of 3.85º in patients with lesions over 51 years old and of 7.4º in patients

		50 kHz) with a follow-up period of 5 weeks.			without lesion between 21 and 50 years old.
E5[19] Mota et al., 2019 Brazil	Cross-sectional study	A study conducted with 11 patients: 10 aged individuals over 65 years old and only 01 young person aged 21 years old, 6 being female. The frequency used by the device in this study was 50 kHz.	In Body S10	PU	PA was effective in indicating reduction of cellular integrity and, consequently, risk of pressure injuries. Overall mean of 3.18°, mean of 3.06° in aged individuals over 65 years old, and mean value of 4.3° in young patients.

Source: The author.

Chart 3 shows the risk of bias by using the JBI's critical analysis tools. All the studies presented items that were not attended and/or that were not clearly described in the studies, and Study E4 obtained the highest percentage of positive answers (87.5%) and Study E1, the lowest percentage (66.7%)[15-18].

E5 does not mention whether the groups were homogeneous in their characteristics. Therefore, the confusion factor cannot be clearly evaluated, as it occurs when the estimated effect of exposure to intervention is biased by the presence of some difference between the comparison groups[19]. In the evaluation of Study E2, as in Study E3, it was not clear who the control group were[16]. In addition to that, in studies E2 and E4 it was not possible to identify if there were confounding factors[16,18].

In Study E1, it was not clear whether the participants were included in similar comparisons[15]. The authors reported that the treatment was standard for all even in the use of supplementation, but lesions of various etiologies can contribute bias to the study.

Chart 3 – Analysis of the risk of bias in the studies. Niterói, RJ, Brazil, 2020.

Risk of Bias	Studies (percentage of positive answers)	
Cross-sectional study	**E5 (75%)**	
1. Were the inclusion criteria clearly defined?	Yes	
2. Were the subjects and scenario of the studies described in detail?	Yes	
3. Was exposure measured in a valid and reliable manner?	Unclear	
4. Were the criteria and standards used goals for assessing the condition?	Yes	
5. Were confounding factors identified?	Unclear	
6. Were there strategies to deal with confounding factors?	Yes	
7. Were the results measured in a valid and reliable manner?	Yes	
8. Was the appropriate statistical analysis used?	Yes	
Cohort	**E2 (72.7%)**	**E3 (81.8%)**
1. Were the two groups similar and recruited from the same population?	Unclear	Unclear
2. Were the exposures measured in a similar way to allocate people to exposed and unexposed groups?	Yes	Yes
3. Exposure was measured in a valid and reliable manner?	Unclear	Yes
4. Were confounding factors identified?	Unclear	No
5. Were the strategies to deal with confounding factors stated?	Yes	Yes
6. Were the groups/participants free from the outcome at the beginning of the study (or at the time of exposure)?	Yes	Yes
7. Were the results measured in a valid and reliable manner?	Yes	Yes
8. Was the follow-up time reported and sufficient to be long enough for the result to occur?	Yes	Yes
9. Was follow-up completed and, if not, were the reasons for its loss described and explored?	Yes	Yes
10. Were strategies used to deal with incomplete follow-up?	Yes	Yes
11. Was a proper statistical analysis used?	Yes	Yes
Case-control	**E4 (87.5%)**	
1. The groups were comparable, except in the presence of disease in cases or absence of disease in the controls?	Yes	
2. Were cases and controls matched properly?	Yes	
3. Were the same criteria used to identify cases and controls?	Yes	
4. Was exposure measured in a standard, valid and reliable manner?	Yes	
5. Was exposure measured in the same way for cases and controls?	Yes	
6. Were confounding factors identified?	No	
7. Were the strategies to deal with confounding factors stated?	Yes	
8. Were the results evaluated in a standard, valid and reliable manner for cases and controls?	Yes	
9. Was the exposure of interest period long enough to be meaningful?	Yes	
10. Was a proper statistical analysis used?	Yes	
Quasi-experimental	**E1 (66.7%)**	
1. Is it clear in the study what the 'cause' is and what the 'effect' is (i.e., there is no confusion regarding which variable comes first)?	Yes	
2. Were the participants included in similar comparisons?	No	
3. Were the participants included in any comparisons receiving treatment/similar care, in addition to the exposure or intervention of interest?	No	

4. Was there a control group?	No
5. Were there multiple measurements of the result before and after the intervention/exposure?	Yes
6. Has the follow-up been complete and, if not, were the differences between the groups in terms of their follow-up properly described and analyzed?	Yes
7. Were the participants' results included in any comparisons measures in the same way?	Yes
8. Were the results measured reliably?	Yes
9. Was the proper statistical analysis used?	Yes

Source: Adaptation from the *Joanna Briggs Institute*.

Chart 4 shows the quality of the evidence of the studies included in the review. For the "healing" outcome, the studies showed moderate evidence with a total of 529 participants. For the "risk of lesion" outcome, the evidence was weak, with a study of 11 participants.

Chart 4 – Quality of the evidence. Niterói, RJ, Brazil, 2020.

Outcomes	No. of participants (studies)	GRADE	Impact
Lesion healing evaluated with: PA by EBI	529 (3 observational studies and 1 quasi-experimental study)	⊕⊕⊕◯ MODERATE	The healing outcome was demonstrated in four studies using PA as a parameter in monitoring lesions.
Lesion Risk evaluated with: PA by EBI	11 (1 observational study)	⊕⊕ ◯◯ LOW	The risk of lesion outcome was demonstrated in a study with a small sample, which showed association of PA and risk for the development of pressure injuries.

Source: *GRADEpro Guideline Development Tool* software.

DISCUSSION

The treatment of skin lesions has already been undergoing profound transformations over time, challenging the technical-scientific knowledge of the health professionals who are responsible for this care, at any level of health care[20].

In several countries, studies have been developed to investigate not only the use of dressings, but also new technologies aimed at the treatment of skin lesions; for this reason, reviews on the scientific production in the health area that address this theme related to the types of technologies to support the care practice in preventive or curative care of skin lesions are important, as the implementation of care requires a combination of technologies that lead to the quality of life of human beings[20].

In this context, this systematic review gathered studies that addressed the use of the electrical bioimpedance technology and phase angle measurement associated with skin lesions. The use of this method employing measurement of the PA biomarker was suggested in this study to evaluate the effectiveness of predicting the risk of developing skin lesions and monitoring their healing, and only three scientific articles were able to demonstrate that the use of this biomarker was effective for these associations[15,17,19]. Although there are no reviews specifically with the focus of this study, some authors have already related the occurrence of pressure ulcer and changes in body composition[20]. This fact brings about new possibilities of the nurse' performance in the management of care in patients with skin lesions. However, so that such use can be recommended, new primary studies are necessary, with randomized and controlled experimental designs. Thus, it would be possible to conduct a meta-analysis to more accurately evaluate the measures of effect.

Through the data extracted in this review, it was identified that four scientific productions addressed chronic lesions. One study evaluated chronic wounds of varied etiologies (arterial, venous, neurotrophic, traumatic, surgical and infectious)[15]. The other evaluated patients with burns and two studies addressed PUs[17,18,19]. Only one scientific production addressed acute lesions caused by small burns of recent onset, less than four days. The diversity of skin lesions, in different stages and with different characteristics, contributed great heterogeneity to the review, making it impossible to perform a meta-analysis.

PA has been studied by a number of authors as a biological marker to evaluate prognoses of clinical pathologies, such as a cross-sectional and prospective study that evaluated the correlation between phase angle values and nutritional and clinical variables in cirrhotic patients with a sarcopenic profile[1]. In this study, it was concluded that low PA values can be good predictors for the diagnosis of cirrhosis and suggest its use as a viable marker for sarcopenia in patients with this profile because, in addition to being an easy-access method, it offers good reproducibility and low cost[21]. Corroborating the studies, for the "healing" outcome, a group of authors showed a positive relationship between healing and increased PA measures in patients with skin lesions[15,17]. Acquiring this technology in the health services can assist nurses in decision-making, together with other risk assessment measures, such as the scales already validated.

There was also an age difference between the populations of the studies, where it was possible to perceive that the PA value can be influenced by age and gender, corroborating other authors who discuss the need for reference values to be adjusted for gender and age as a possible limitation of the use of PA as a prognostic marker in several contexts of the clinical practice[22]. In the same study, the authors argue that, in a healthy individual, PA can present values between 4 and 10 degrees. Other authors found values that oscillated from 5 to 15 degrees[23]. In view of these references, we observed in the results obtained in this systematic review that the means of the values found in the studies were below the reference values of the respective authors.

Some studies included in the review were able to define cutoff points for PA in each study[17,19]. It was identified that aged patients over 65 years old with PUs had a mean PA value of 3.4°, and of 3.8° without PUs[17]. The study by Mota et al.[19], who also evaluated PU, showed that the cutoff point of an overall PA mean was 3.18° for young individuals and adults. In the study that evaluated chronic skin lesions, the PA cut-off point for patients over 51 years old was 3.85°[18]. Future primary studies on PA and skin lesions may use these values as a basis for a cutoff point, highlighting three studies that showed to be effective for monitoring lesions as predictors for risk assessment (E5)[19]. The development and/or healing of skin lesions (E1, E3)[15,17]. Thus, it is possible to corroborate studies that evaluate the relationship of the phase angle as a prognostic biomarker of clinical outcomes[1,24,25].

With the data analyzed in this study, it was possible to perceive that PA measured by electrical bioimpedance has a behavior of responding to the improvement or worsening of skin lesions, which can be explained by the fact that PA is associated with cell health, both in relation to the amount of intra- and extra-cellular fluid and to the integrity of the phospholipid membrane[26].

This systematic review fully complied with methodological rigor; however, it has some limitations related to the included studies. Few studies were found with themes that addressed PA and skin lesions (skin wounds and/or injuries) and that met the inclusion criteria. The included studies presented methodological weaknesses, with reduced samples and different forms of PA measurement. This fact was evidenced in the analysis of the risk of bias, and in the analysis of the quality of the evidence for the healing and risk outcomes. The comparison of the results by means of a meta-analysis would increase sampling power; however, the studies showed great heterogeneity, due to the differences in the results and in the equipment used. Due to the small number of studies that met the eligibility criteria, it is proposed to conduct new research studies with the theme addressed in this study, because it is important to enhance the health care provided to patients who are affected by skin lesions.

CONCLUSION

This review provided a synthesis of the evaluation of the effectiveness of phase angle to assess the risk of developing skin lesions and, in the case of lesions already installed, to evaluate the effectiveness in monitoring the healing process. Although there are few scientific papers with the theme proposed, it was possible to demonstrate moderate evidence for the "healing" outcome and low evidence for the "risk of lesion" outcome. It was impossible to perform a meta-analysis in this study.

The study brings about contributions, with innovation potential for the Nursing area, through the possibility of incorporating a new technology in the evaluation of skin lesions, including more accurate measures that translate the cellular state in these evaluations, being able to equip nurses in the best decision-making and planning of care management actions in order to minimize harms to the patients.

REFERENCES

1. Pena NF, Mauricio SF, Rodrigues AMS, Carmo AS, Coury NC, Correia MITD et al. Association Between Standardized Phase Angle, Nutrition Status, and Clinical Outcomes in Surgical Cancer Patients. Nutr Clin Pract. 2019;34(3):381-386.
2. Alves FD, Souza GC, Clausell N, Biolo A. Papel prognóstico do ângulo de fase em pacientes hospitalizados com insuficiência cardíaca descompensada. Nutrição. 2016;35:1530-4.
3. Jansen AK, Gattermann T, Fink JC, Saldanha MF, Rocha CDN, Moreira THS et al. Low standardized phase angle predicts prolonged hospitalization in critically ill patients. Clin Nutr ESPEN. 2019;34:68-72.
4. Mattiello R, Amaral MA, Mundstock E, Ziegelmann PK. Reference values for the phase angle of the electrical bioimpedance: Systematic review and meta-analysis involving more than 250,000 subjects. Clin Nutr. 2020;39(5):1411-7.
5. Pileggi VN, Scalize ARH, Camelo Junior JS. Ângulo de fase e critérios da Organização Mundial de Saúde na avaliação do estado nutricional em crianças com osteogênese imperfeita. Rev Paul Pediatr. 2016;34(4):484-8.
6. Silva JG, Oliveira KF, Ferreira MBG, Pacheco FA, Calegari IB, Barbosa MH. Composição corporal e ocorrência de lesão por pressão: revisão integrativa. Rev Baiana Enferm. 2019;33:e28790.
7. Kekonen A, Bergelin M, Eriksson JE, Vaalasti A, Ylänen H, Viik J. Bioimpedance measurement based evaluation of wound healing. Physiol Meas. 2017;38(2017):1373-83.
8. Oliveira FP, Oliveira BGRB, Santana RF, Silva BP, Candido JSC. Classificações de intervenções e resultados de enfermagem em pacientes com feridas: mapeamento cruzado. Rev Gaúcha Enferm. 2016;37(2):e55033.
9. Zimmermann GS, Cremasco MF, Zanei SSV, Takahashi SM, Cohrs CR, Whitaker IY. Predição de risco de lesão por pressão em pacientes de unidade de terapia intensiva: revisão integrativa. Texto & Contexto Enferm. 2018;27(3):e3250017.
10. Borghardt AT, Prado TN, Araújo TM, Rogenski NMB, Bringuente MEO. Avaliação das escalas de risco para úlcera por pressão em pacientes críticos: uma coorte prospectiva. Rev Latino-Am Enferm. 2015; 23(1):28-35.
11. Kekoren A, Bergelin M, Johansson M, Joon NK, Bobacka J, Viik J. Bioimpedance Sensor Array for Long-Term Monitoring of Wound Healing from Beneath the Primary Dressings and Controlled Formation of H2O2 Using Low-Intensity Direct Current. Sensors (Basel). 2019;19(11):2505.
12. Vieira CPB, Araújo TME. Prevalence and factors associated with chronic wounds in older adults in primary care. Rev Esc Enferm USP. 2018;52:e03415.
13. Aromataris E, Munn Z. (Editors). JBI Manual for Evidence Synthesis. Adelaide: JBI; 2020.
14. Galvão TF, Pansani TSA, Harrad D. Principais itens para relatar Revisões sistemáticas e Meta-análises: A recomendação PRISMA. Epidemiol Serv Saúde. 2015;24(2):335-42.
15. Moore MF, Dobson N, Castellino L, Kapp S. Phase Angle, an Alternative Physiological Tool to Assess Wound Treatment in Chronic Nonhealing Wounds. J Am Col Certif Wound Spec. 2011;3(1):2-7. [included in the review]
16. Gamerith C, Luschnig D, Ortner A, Pietrzik N, Guse J-H, Burnet M et al. Monitoring wound healing in minor burns: a novel approach. Burns. 2018;44(1):70-6. [included in the review]
17. Hengstermann S, Fischer A, Steinhagen-Thiessen E, Schulz RJ. Nutrition status and pressure ulcer: what we need for nutrition screening. JPEN J Parenter Enteral Nutr. 2007;31(4):288-94. [included in the review]
18. Gonzalez-Correa CA, Rivera-Garzón RA, Martínez-Táutiva S. Electric impedance and the healing of diabetic foot ulcers. J. Phys. 2019;1272:012009. [included in the review]

19. Mota RF, Christovam BP, Norberto ZN, Nascimento DC, Xavier MPSA, Nascimento Júnior SS et al. Há relação entre baixos valores de ângulo de fase e desenvolvimento de lesão por pressão? In: Strickler A. Ciência, tecnologia e inovação: desafio para um mundo global. Ponta Grossa, PR: Atena; 2019. [included in the review]
20. Vieira CPB, Pinheiro DMP, Luz MHBA, Araújo TME, Andrade EMLR. Wound care technologies used by nurses. Rev Enferm UFPI. 2017;6(1):65-70.
21. Silva DES, Waitzberg DL, Jesus RP, Oliveira LPM, Torrinhas RS, Belarmino G. Phase angle as a marker for sarcopenia in cirrhosis. Clin Nutr ESPEN. 2019;32:56-60.
22. Bosy-Westphal A, Danielzik S, Dörhöfer RP, Later W, Wiese S, Müller MJ. Phase angle from bioelectrical impedance analysis: population reference values by age, sex, and body mass index. JPEN J Parenter Enteral Nutr. 2006;30(4):309-16.
23. Barbosa-Silva MC, Barros AJ, Wang J, Heymsfield SB, Pierson RN Jr. Bioelectrical impedance analysis: population reference values for phase angle by age and sex. Am J Clin Nutr. 2005;82(1):49-52.
24. Silva TK, Perry IDS, Brauner JS, Weber OCB, Souza GC, Vieira SRR. Performance evaluation of phase angle and handgrip strength in patients undergoing cardiac surgery: Prospective cohort study. Aust Crit Care. 2018;31(5):284-290.
25. Martin L, Lagergren J, Blomberg J, Johar A, Bosaeus I, Lagergren P. Phase angle as a prognostic marker after percutaneous endoscopic gastrostomy (PEG) in a prospective cohort study. Scand J Gastroenterol. 2016;51(8):1013-6.
26. Gonzalez MC, Barbosa-Silva TG, Bielemann RM, Gallagher D, Heymsfield SB. Phase angle and its determinants in healthy subjects: influence of body composition. Am J Clin Nutr. 2016;103(3):712-6.