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REVIEW ARTICLE

MOBILE TECHNOLOGY TO PROMOTEFOOT MANAGEMENT AMONG PEOPLE WITH DIABETES MELLITUS: AN INTEGRATIVE REVIEW

Antonia Fabiana Rodrigues da Silva*
Francisco João de Carvalho Neto**
Mayla Rosa Guimarães***
Raissy Alves Bernardes****
Vicente Rubens Reges Brito*****
Ana Roberta Vilarouca da Silva******

ABSTRACT

Objective: Analyze the scientific literature addressing mobile technologies to prevent and diagnose diabetic foot ulcers and studies addressing foot care among individuals with diabetes mellitus. **Method**: this integrative literature review was conducted in the PubMed, LILACS, and BDENF databases in September 2019. The full texts of six studies were analyzed. **Results**: The studies date back to 2015, and all were identified in PubMed. Experimental studies stood out, totaling three (50%). As for the mobile technologies directed to prevention and self-care, two papers used mobile phone text messaging to reinforce the learning and practice of diabetic foot care, reporting satisfactory results. Four studies adopted technologies to diagnose foot ulcers. Although they used different methods, almost all of the studies monitored plantar foot temperature increases, which can serve as an alert system to detect foot ulcers early on. **Conclusion**: even though few studies were found, mobile technologies were effective to prevent and diagnose foot ulcers, and to promote foot care among individuals with diabetes.

Keywords: Diabetic Foot. Mobile health. Prevention. Self care. Diagnosis.

INTRODUCTION

Diabetes *mellitus* (DM) is one of the most significant global health emergencies of the 21st century. It is among the ten leading causes of death around the world, and together with the other three main Noncommunicable Diseases (NCDs) (cardiovascular diseases, cancer, and respiratory diseases) represents over 80% of all premature NCD deaths[1].Individuals with DM may experience various complications, which may be acute or chronic; one of the most severe and most frequent complications is diabetic foot[2].

Diabetic foot is characterized as infection, ulceration, and/or soft tissue damage associated with neurological abnormalities and various degrees of peripheral arterial disease in the lower limbs. It accounts for 40% to 70% of all non-traumatic lower-limb amputations in the general population,while ulcers precede 85% of the lower limb amputations among DM patients[3].

The role of diabetes self-management education is emphasized as the primary tool to promote patient self-care and is even enhanced with the use of strategies to instruct patients about risk factors and behaviors, in addition to basic foot care[4]. Among these strategies, telephone support services stand out[5].

People are currently enjoying increased access to mobile devices and are more interested in the mobility this technology provides. Thus, such devices became allies in health education as they enhance and speed up communication between healthcare workers and patients or those accessing health services[6]. For this reason, the following question emerged: what is the effect of mobile technologies directed to prevention and foot care among people with DM and to diagnose diabetic foot ulcers?

[1]Extracted from the Master's thesis named: "Análise do uso de intervenção telefônica na prática de autocuidado com os pés em pessoas com diabetes mellitus tipo 2" [Analysis of an telephone intervention on the foot care practice of individuals with type 2 diabetes mellitus] defended for the Sciences and Health Program in 2020.

*RN. MSc in Sciences and Health by the Federal University ofPiauí-UFPI.Doctoral student in the Nursing Program at the Federal University of Ceará (UFC).Member of the Collective Health Research Group – GPeSC.Picos, Piauí, Brazil. E-mail: fabi_enfer@hotmail.com. ORCID iD: http://orcid.org/0000-0002-2851-2767
**Nursing undergraduate student at UFPI. Member of the GPeSC.Picos, Piauí, Brazil. E-mail: franciscojoaodecarvalhoneto@gmail.com. ORCID iD: https://orcid.org/0000-0002-2011-5900
***RN. MSc in Sciences and Health by UFPI.Substitute Lecturer, Department of Nursing at UFPI. Member of the GPeSC.Picos, Piauí, Brazil. E-mail: m_aylaguimaraes@hotmail.com. ORCID iD: orcid.org/0000-0002-6501-7883
****Nursing undergraduate student at UFPI. Member of theGPeSC.Picos, Piauí, Brazil. E-mail: raissy.bernardes62@gmail.com. ORCID iD: https://orcid.org/0000-0002-0054-357X
*****Nursing undergraduate student at UFPI. Member of the GPeSC.Picos, Piauí, Brazil. E-mail: vicentereges@yahoo.com.br. ORCID iD: https://orcid.org/0000-0002-6231-4246
******RN. PhD in Nursing. Associate Professor, Department of Nursing at UFPI. Leader of the GPeSC.Picos, Piauí, Brazil. E-mail: robertavilarouca@yahoo.com.br. ORCID iD: http://orcid.org/0000-0001-5087-4310

Telephones are considered a strategy that favors the treatment and counseling of DM patients, enabling health workers to closely monitor patients, preventing chronic complications, encouraging health promotion, and promoting self-care and decision-making to improve these individuals' quality of life[7].

Therefore, this integrative review's objective was to analyze the scientific literature addressing mobile technology as a tool to prevent and diagnose diabetic foot and promote foot care among DM patients.

METHOD

This integrative review was based on the six steps proposed by Ganong[8], namely: identification of hypothesis or guiding question; selection of studies using inclusion and exclusion criteria; establishment of information to be collected from the studies and/or study categorization; assessment of studies; interpretation of results; and synthesis of knowledge.

Two guiding questions were established: 1) What is the effect of mobile technologies addressed by the literature on actions intended to prevent foot ulcers and promote foot care among individuals with DM? and 2) What is the effect of mobile technologies on actions intended to diagnose diabetic foot?

A search was conducted in September 2019 in the following databases: National Library of Medicine (PubMed/Medline), Latin American and Caribbean Health Sciences Literature (LILACS) and Database of Nursing (BDENF). The health terminology provided by the Health Sciences Descriptors (DeCS/BIREME) and Medical Subject Headings (MeSH/PubMed) was used, combining the following descriptors (in Portuguese, Spanish and English) and using the Boolean marker "and": pé diabético/pie diabético/diabetic foot; saúde móvel/saludmóvil/mobile health; prevenção/Prevención/ prevention; autocuidado/autocuidado/self care; diagnóstico/diagnóstico/diagnosis.

Two researchers conducted three searches in each database. Fifteen studies addressing foot care were found in the first search, 26 studies addressing diabetic foot prevention were identified in the second search, and 51 studies were found in the third search addressing diabetic foot diagnosis. All of these were identified in PubMed/Medline. The selection of studies was not restricted to any publication period so that all papers addressing the subject would be identified.

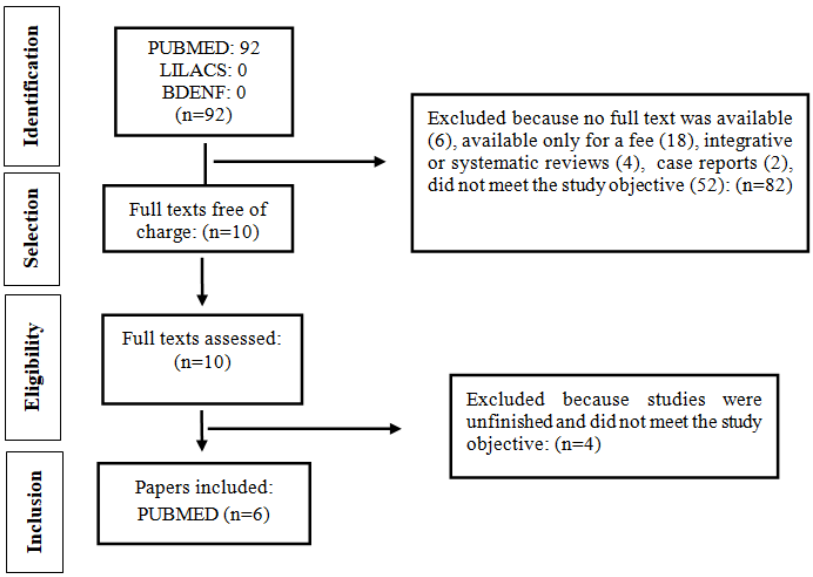

Figure 1. Flowchart of the study selection process.
Source: Study's data, 2019.

The full texts of studies addressing mobile technology in diabetic foot prevention and diagnosis, and promotion of foot care among individuals with type 1 and type 2 DM, available online and free of charge, written in English, Spanish or Portuguese, were included in this study. Exclusion criteria were: papers accessible for a fee, editorials, reflective studies, unfinished studies, experience reports, and integrative reviews.

The final sample was composed of the full texts of six papers published from 2015 to 2018, found in the PUBMED database. No papers that met the inclusion criteria were identified in LILACS or BDENF.

The Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA)[9] was used to organize and present a summary of the study selection process(Figure 1).

Seven levels of evidence were considered in the assessment of results[10]:

- Level 1: Systematic review or meta-analysis of all relevant randomized clinical trials;
- Level 2: Well-designed randomized clinical trial;
- Level 3: Well-designed controlled trials without randomization;
- Level 4: Well-designed case-control or cohort studies;
- Level 5: Systematic reviews of descriptive and qualitative studies;
- Level 6: Descriptive or qualitative study:
- Level 7: Opinion of authorities and/or reports of expert committees.

Note that this study did not involve human subjects. As for the studies composing the sample, the authorship of each paper was properly cited.

RESULTS

Six papers met the inclusion criteria. Table 1 presents the results of the studies concerning identification, design, level of evidence, objective, mobile technology used, country/periodical, year, and results concerning the use of technologies.

Table 1. Characterization of papers according to identification, design, level of evidence, objective, and interest variables, Picos, PI, Brazil.

Reference	Design	Level of evidence	Objective	Mobile technology used	Results	Country/periodical/Year
HannsamZM[11]	Intervention study	IV	To test the feasibility and efficiency of mobile phone text messaging in promoting diabetic foot care knowledge.	Mobile phone text messaging.	A “good” level of knowledge was found among n=51(23%) participants before the intervention, while n=149(66%) presented a “good” level of knowledge after the intervention. “Good” foot care practice before the intervention was presented by n=55(24%) participants, while n=223(99.1%) presented “good” foot care practice after the intervention.	Jordan, Int J NursPract, 2017.
Naghibi AS, Moosazadeh M, Zhyanifard A, CheratiJY[12].	Intervention study	IV	SMS to promote self-care among DM patients.	Mobile phone text messaging.	The mean and standard deviation of scores concerning foot care performance obtained by the intervention and control groups before the intervention were 22.90 ± 7.95 and 32.94 ± 6.14, respectively. These parameters after the intervention were 41.36 ± 5.0 and 32,76 ± 5.59 (p <0.001), respectively.	Iran,Int J PrevMed, 2015.

To be continued.

Reference	Design	Level of evidence	Objective	Mobile technology used	Results	Country/periodical /Year
Liu C, Netten JJV, Baal JGV, Bus AS[13].	Experimental study	III	To develop an automatic foot assessment technology to detect diabetic foot complications.	IR and RGB cameras were used to acquire infrared thermographic images. Mobile phone images were used to assess diabetic foot ulcers.	Thermal images acquired through an experimental set up detected diabetic foot complications. The mobile phone images presented low validity and reliability for remotely assess diabetic foot ulcers and should not be used as an independent diagnostic tool.	The Netherlands, J BiomedicalOptics, 2015.
				A thermal camera was connected to a Samsumg smartphone.	A mobile detection system using an automated thermal imaging method was used to identify potential ulcers among diabetic patients.	
Van Netten JJ, Clark D, Lazzarini PA, Janda M, Reed LF[14].	Experimental study	III	To determine the validity and reliability of remote diabetic foot ulcer assessment using mobile phone imaging.	IR and RGB cameras were used to acquire infrared thermographic images.	Thermal images acquired through an experimental set up detected diabetic foot complications.	Australia, ScientificReports, 2017.
Fraiwan L, AlKhodari M, Ninan J, Mustafa B, Saleh A, GhazalM[15].	Experimental study	III	To develop an ulcer detection system based on a mobile thermal camera and a mobile application.			United Arab Emirates, BiomedEng Online, 2017.
Reyzelman AM, Koelewyn K, Murphy M, Shen X, Yu E, Pillai R, *et al*[16].	Observation study	VII	To assess the accuracy of daily-wear socks with embedded sensors, verify whether recorded temperatures were correlated with clinical observations, and obtain the users' feedback on how comfortable socks were for home use.	Mobile phone images were used to assess diabetic foot ulcers.	The mobile phone images presented low validity and reliability for remotely assess diabetic foot ulcers and should not be used as an independent diagnostic tool.	United States, J Med Internet Res, 2018.

Source: Study's data, 2019.

All the papers were identified in the PubMed database (100%) and were published between 2015 and 2018. No Brazilian studies addressing the subject were found. The papers selected were conducted in Jordan, Iran, Australia, the Netherlands, the United Arab Emirates, and the United States. Even though DM complications are a concern worldwide, few studies addressing the use of mobile technologies aimed at the prevention, self-care, and diagnosis of diabetic foot ulcers were found.

As for the design, the following designs were identified: intervention studies without randomization, observational, and experimental studies. Experimental studies stood out; three (50%) of the studies were experimental. These studies presented positive results concerning the development and assessment of the effectiveness of mobile technologies.

Regarding studies addressing mobile technology aimed at prevention and self-care, only two papers met the inclusion criteria. One

paper was conducted in Jordan and the one in Iran. Both were intervention studies and addressed the use of mobile phone text messaging, intended to reinforce the learning and practice of foot care among individuals with diabetes[11,12].

A total of 255 people composed the sample in the study conducted in Jordan, and a little more than half the participants (n=118; 52.4%) were men[11]. This study lasted seven months, and each participant received a pamphlet addressing foot care. Later, the primary author sent four messages to the participants per week, addressing foot care.

The participants (n=228 people) in the study developed in Iran[12] were assigned to two groups: intervention group (n=114) and control group (n=144). Almost half of the sample, 49%, was composed of women. The intervention group received pamphlets addressing the intervention in the context of diabetes. The intervention lasted four weeks, and three messages were manually sent through a mobile phone every 48 hours (concerning exercise, foot care, and medications). No intervention was implemented in the control group.

Both studies report satisfactory results. The first of these studies report that "good" levels of knowledge were presented by n=51 (23%) participants before the intervention, while n=149 (66%) participants presented "good" levels of knowledge after the intervention. "Good" foot care practice was found among n=55 (24%) participants before the intervention, while n=223 (99.1%) presented "good" foot care practice after the intervention[12]. The second study assessed the mean and standard deviation of the scores obtained by the intervention and control groups concerning foot care performance before the intervention, 22.90±7.95, and 32.94±6.14. The scores obtained by the intervention and control groups after the intervention were 41.36±5.0 and 32.76±5.59, respectively ($p<0.001$)[12].

Four papers were found addressing the use of mobile technologies to diagnose foot ulcers among patients with diabetes and the mobile technologies used were: infrared thermography using RGB and IR cameras (The Netherlands)[13]; diabetic foot was remotely assessed using mobile phone images (Australia)[14];a thermal camera connected to a Samsung smartphone (United Arab Emirates)[15]; and socks with built-in wireless sensors combined with a mobile application (United States)[16].

The study developed in the Netherlands[13] involved 76 patients, 64 of whom were men. The method used was a simple asymmetric analysis combined with foot segmentation using color images and non-rigid landmark-based registration between the left and right feet. Optimized registration was used to map foot segments onto the thermal image. The final sensitivity and specificity of the foot segmentation in the thermal images were 97.9% ± 1.1 % and 98.3% ± 0.5%, respectively.

The study conducted in the United Arab Emirates[15] used a thermal camera connected to a Samsung smartphone, which was used to collect thermal images. The system was implemented under the MATLAB Mobile platform. Four test feet images were used to test the procedure: one image with foot temperature variation and three images with skin temperature increased by more than 2.2ºC. This mobile thermal imaging system, which includes an automated method to identify potential ulcers in patients with diabetes, enabled patients to self-assess potential ulcers[14].

The study conducted in Australia[14] included 50 participants, 80% of whom were men. The validity of the remote mobile phone assessment of diabetic foot ulcers was analyzed by calculating the following diagnostic parameters: sensitivity, specificity, positive (LLR+) and negative (LLR-) likelihood ratios between an in-person clinical assessment and the first assessment performed by one of the individual remote observers. LLR+ ranged from 1.3 to 4.2, with no items presenting "strong" or "convincing" diagnostic evidence. LLR ranged from 0.13 to 0.88, with an item presenting "strong" diagnostic evidence for LLR. The remaining LLR-ranged from 0.33 to 0.88, which did not present strong diagnostic evidence[14].

The study conducted in the United States[16] addressed 35 patients; 25 were men. The participants received socks with six built-in sensors, a small label on the sock contained a microcontroller unit, battery, and a Bluetooth chip. They also received an Android mobile

phone with the application needed for temperature monitoring.

The six sensors took temperature measurements at 10-second intervals to screen for increases in the temperature of the bottom of the participants' feet, specifically in the following sites: hallux, metatarsal points (MTPs) 1, 3, and 5; midfoot and heel. The mobile application displayed temperature readings to the patients. The patients wore the socks at home and reported they were safe, comfortable, useful, and well-designed[16].

To better discuss the mobile technologies adopted in the studies, we grouped the papers into two categories: Category 1 – mobile technologies used to promote prevention and self-care, and Category 2 – mobile technologies used to diagnose diabetic foot.

DISCUSSION

Recently, technologies used to promote self-care in diabetes have become one of the fastest-growing areas in the health field. The reason is that technologies improve communication and allows health workers to monitor individuals with chronic conditions, enabling patients to acquire greater confidence in theirautonomy, in the implementation of guidelines, and self-care[4]. The studies' results are discussed below, emphasizing the mobile technologies for individuals with DM and their effectiveness.

Category 1. Mobile technologies used to promote prevention and self-care

Analysis of the studies assessing the effect of the Short Message Service (SMS) on DM patients' self-careshowed that the SMS was efficient in promoting self-care. The self-care performance of these patients significantly improvedbetween the times before and after the intervention[11,12].

A three-month randomized controlled trial conducted in Egypt[17] also sent daily messages and weekly reminders to the intervention group addressing various categories of treatment for diabetes. In the end, decreased glycated hemoglobin (HbA1c) levels, greater adherence to medication, and higher scores were obtained regarding knowledge of the disease, eliciting considerable improvements in the treatment.

Text to Move (TTM) was a six-month randomized controlled trial developed in the United States[18]. It involved individuals with type 2 DM and was intended to promote the practice of physical exercise. The intervention group received text messages, adapted to each participant's change of behavior, twice a day. In the end, the participants were satisfied with the TTM program. They reported the messages were educational, informative and motivational, improving glucose monitoring, self-care behavior, attendance to appointments, and adherence to the pharmacological treatment.

Other studies corroborate these findings and report positive results using text messaging in promoting self-care in the context of DM. The studies report decreased HbA1c levels[19,20]; decreased fasting blood sugar levels; fewer obstacles to managing the disease; improved self-care[21]; greater adherence to medication; higher scores of knowledge regarding the disease; considerable improvement obtained with the treatment; and higher rates of physical exercise[20].

Mobile technologies are recommended to meet patients' needs concerning diabetes guidance because remote communication enables health workers to intervene at a distance, using SMS as an educational methodological strategy, successfully promoting self-care in diabetes[22].

Category 2. Mobile technologies used to diagnose diabetic foot

This category gathers four studies[13-16]with something in common. Although these studies adopted different methods, almost all of them focused on screening increased temperature at the bottom ofDM patients' feet.

Studies show that a routine skin foot temperature assessment can interrupt the occurrence of conditions that compromise foot health, such as foot ulcers or amputation of lower limbs. Thus, thermography is currently a widely adopted practice[23].

Additionally, various digital techniques are currently available to classify the plantar skin thermogram of patients with DM. The plantar

skin temperature of these patients may be symmetrically or asymmetrically distributed, presenting cold or hot spots. Thus, thermography is an appropriate technique to monitor the feet of these patients[24].

A recent study[25] used a "smart sock" with seven thermal sensors knitted with the sock fibers designed to measure foot temperature in everyday life conditions. The sock's upper part is connected to a central unit, through which changes in the resistance are converted into changes in temperature captured by the sensors. The temperature of the patients' feet was measured at 10-minute intervals and the authors verified that changes in plantar temperatures were correlated with plantar pressure distribution.

As previously described, socks with embedded wireless sensors, combined with a mobile device[16], were designed for daily use within and outside the home. These socks, made of smart fabric and manufactured in standard industrial equipment, are machine-washed, do not require assistance or recharge, and can be worn anywhere.

The studies discussed here show that the continuous monitoring of temperature is a promising strategy and can serve as an alert system for preventing and diagnosing foot ulcers early.

This review presents some limitations that should be noted, among which the scarcity of studies addressing the subject and the fact that studies published in paid journals were excluded.

CONCLUSION

Despite the few studies identified, this review's results show the effective use of mobile technologies. Mobile phone text messaging was useful in preventing and promoting foot care among DM patients, while the methods used to track increased temperature in the sole of the patients' feet, were also successful in preventing and early diagnosing foot ulcers, in addition to promoting self-care. These tools may not replace in-person appointments, however, with the increased use and easy access to digital devices, these methods can complement care delivery.

Finally, the studies' results show that mobile technologies in the health field can improve foot care, promote the autonomy of DM patients, and support the early diagnosis of foot ulcers; if left untreated, foot ulcers can compromise the quality of life of patients. Thus, further research is needed to seek innovative solutions for this population, with strategies that involve diabetic foot management outside the clinical setting.

TECNOLOGIA MÓVEL NO CUIDADO COM OS PÉS EM PESSOAS COM DIABETES MELLITUS: REVISÃO INTEGRATIVA

RESUMO

Objetivo: Analisar produções científicas sobre o uso das tecnologias móveis na prevenção e diagnóstico do pé diabético, bem como publicações que abordem o autocuidado com os pés em pessoas com diabetes *mellitus*. **Métodos**: Revisão integrativa realizada nas bases de dados PubMed, LILACS e BDENF, em setembro de 2019, com uma amostra de seis artigos analisados na íntegra. **Resultados**: As publicações datam desde o ano 2015, todas na PubMed. Destacaram-se os estudos experimentais, totalizando três (50%) publicações. Com relação às tecnologias móveis voltadas para a prevenção e autocuidado, dois artigos foram encontrados, ambos usaram mensagens de texto por telefone celular para reforçar o aprendizado e a prática de cuidados com os pés dos diabéticos e trouxeram resultados satisfatórios. Quanto às tecnologias voltadas para o diagnóstico de úlceras nos pés, identificaram-se quatro artigos e, apesar de terem utilizado métodos diferentes, quase todos eram voltados para rastrear aumentos de temperatura na parte inferior dos pés, podendo servir como um sistema de alertapara a detecção precoce de úlceras nessa região. **Conclusão**: Apesar da escassez de estudos, o uso de tecnologias móveis voltadas para a prevenção e autocuidado com os pés em pessoas diabéticas e as voltadas para diagnóstico de úlceras nos pés, mostraram-se efetivas.

Palavras-chave: Pé diabético. Saúde móvel. Prevenção. Autocuidado. Diagnóstico.

TECNOLOGÍA MÓVIL EN EL CUIDADO CON LOS PIES EN PERSONAS CON DIABETES MELLITUS: REVISIÓN INTEGRADORA

RESUMEN

Objetivo: analizar las producciones científicas sobre el uso de tecnologías móviles en la prevención y en el diagnóstico del pie diabético, así como publicaciones que traten el autocuidado con los pies en personas con diabetes *mellitus*. **Métodos**: revisión integradora realizada en las bases de datos *PubMed, LILACS* y *BDENF*, en septiembre de 2019, con una muestra de seis artículos analizados en su totalidad. **Resultados**: las publicaciones datan desde el año 2015, todas en la *PubMed*. Se destacaron los estudios experimentales, totalizando tres (50%) publicaciones. Respecto a las tecnologías móviles dirigidas para la prevención y autocuidado, dos artículos fueron encontrados, ambos usaron mensajes de texto por teléfono celular para reforzar el aprendizaje y la práctica de cuidados con los pies de los diabéticos y trajeron resultados satisfactorios. En cuanto a las tecnologías dirigidas para el diagnóstico de úlceras en los pies, fueron identificados cuatro artículos y, apesar de haber utilizado métodos diferentes, casi todos eran dirigidos para rastrear aumentos de temperatura en la parte inferior de los pies, pudiendo servir como un sistema de alerta para la detección precoz de úlceras e nesta región. **Conclusión**: Apesar de la escasez de estudios, el uso de tecnologías móviles dirigidas para la prevención y el autocuidado con los pies en personas diabéticas y las dirigidas para el diagnóstico de úlceras en los pies se mostraron efectivas.

Palabras clave: Violencia contra la mujer. Violencia por compañero íntimo. Salud de la mujer. Pandemias. Enfermería.

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Corresponding author: Antonia Fabiana Rodrigues da Silva. Rua Arão José Ferreira, 325, ap. 102, Bairro Junco. Picos, Piauí, Brasil. (89) 999252994. E-mail: fabi_enfer@hotmail.com

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