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DIABETIC FOOT SYNDROME: MULTIDISCIPLINARY ASPECTS AND THE ROLE OF NURSES

Sholpan Batarbekova¹, <https://orcid.org/0000-0001-9715-1742>

Dinara Zhunussova¹, <https://orcid.org/0000-0003-3851-3728>

Gulmira Derbissalina¹, <https://orcid.org/0000-0003-3704-5061>

Zhanagul Bekbergenova¹, <https://orcid.org/0000-0002-6146-3784>

¹ «Astana Medical University», Astana, Republic of Kazakhstan.

Abstract

Background. Diabetic foot ulcers are a common complication of diabetes that can lead to limb amputation. Effective treatment of this condition requires in-depth knowledge of risk factors, regular medical monitoring, and careful prevention.

Aim: to analyze current understanding of the pathogenesis, diagnosis, and prevention of diabetic foot.

Search strategy. We conducted a literature search and included articles published between 2014 and 2024. Search queries were regularly performed in academic databases (PubMed, MEDLINE, CINAHL, Embase). No gender filters were used in the search, only patients over 18 years of age were included by age, observational, experimental, and secondary studies were included by study type. In addition to the main search, references of relevant publications were analyzed, international and national guidelines were analyzed to include current approaches to the diagnosis, treatment, and prevention of diabetic foot.

Results. The analysis showed that the pathogenesis of diabetic foot involves complex processes associated with impaired microcirculation, neuropathy, and infection. Teaching patients proper foot hygiene, nail care, and choosing the right footwear plays a key role in reducing the risk of injury. Diagnostic approaches continue to improve, allowing for early detection of pathology and increased treatment effectiveness. Following a systematic approach to diagnosis and classification improves communication between physicians and specialists, simplifying the treatment of complications. Such a coordinated approach may ultimately lead to a reduction in the number of diabetes-related lower limb amputations.

Conclusions. Foot changes in patients with diabetes have become one of the most common complications and the main reason for hospitalization. Treatment should be comprehensive, including hyperglycemia control, wound care, and infection therapy. Effective care should be multidisciplinary and personalized according to the patient's condition and needs. It is important to provide prevention education, emotional support, and encourage the patient to follow recommendations, including regular foot care and blood glucose monitoring.

Keywords: type 2 diabetes mellitus, diabetic foot syndrome, primary health care, multidisciplinary team, nurse.

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Резюме

СИНДРОМ ДИАБЕТИЧЕСКОЙ СТОПЫ: МЕЖДИСЦИПЛИНАРНЫЕ АСПЕКТЫ И РОЛЬ МЕДСЕСТЕР

Шолпан Батарбекова¹, <https://orcid.org/0000-0001-9715-1742>

Динара Жунусова¹, <https://orcid.org/0000-0003-3851-3728>

Гульмира Дербисалина¹, <https://orcid.org/0000-0003-3704-5061>

Жанагуль Бекбергенова¹, <https://orcid.org/0000-0002-6146-3784>

¹ НАО «Медицинский университет Астана», г. Астана, Республика Казахстан.

Актуальность. Диабетические язвы на стопе – частое осложнение при диабете, которое может привести к ампутации конечности. Эффективное лечение этого состояния требует глубоких знаний о факторах риска, регулярного медицинского наблюдения и тщательной профилактики.

Цель: проанализировать современные представления о патогенезе, диагностике и профилактике синдрома диабетической стопы.

Стратегия поиска. Нами был проведен поиск литературы и в описательный обзор включены статьи, опубликованные в период с 2014 по 2024 год. Поисковые запросы регулярно выполнялись в академических базах данных (PubMed, MEDLINE, CINAHL, Embase). При осуществлении поиска фильтры по полу не применялись, по возрасту включались только пациенты старше 18 лет, по типу исследований включались обсервационные, экспериментальные исследования, а также вторичные исследования. В дополнение к основному поиску был

проведен анализ ссылок релевантных публикаций и анализ международных и национальных рекомендаций с целью включения актуальных подходов к диагностике, лечению и профилактике диабетической стопы.

Результаты. В результате проведенного анализа установлено, что патогенез диабетической стопы включает сложные процессы, связанные с нарушением микроциркуляции, развитием нейропатии и инфекционного процесса. Обучение пациентов правильной гигиене стоп, уходу за ногтями и выбору правильной обуви играет ключевую роль в снижении риска получения травм, которые могут вызвать появление язв. Диагностические подходы продолжают совершенствоваться, что позволяет выявлять патологию на ранних стадиях и повышать эффективность терапии. Следование систематическому подходу к диагностике и классификации способствует улучшению взаимодействия между врачами и специалистами, что упрощает лечение осложнений. Такой согласованный подход в конечном итоге может привести к сокращению числа ампутаций нижних конечностей, связанных с диабетом.

Выводы. Изменения стоп у пациентов с сахарным диабетом 2 типа стали одним из наиболее часто встречающихся осложнений, являются главной причиной госпитализации. Лечение должно быть комплексным, включая контроль гипергликемии, обработку ран, терапию инфекций. Эффективный уход должен быть мультидисциплинарным и персонализированным в соответствии с состоянием и потребностями пациента. Важно проводить обучение по профилактике, обеспечивать эмоциональную поддержку и стимулировать пациента следовать рекомендациям, включая регулярный уход за ногами и контроль уровня глюкозы в крови.

Ключевые слова: сахарный диабет 2 типа, синдром диабетической стопы, первичная медико-санитарная помощь, мультидисциплинарная команда, медицинская сестра.

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Түйіндеме

ДИАБЕТТІК ТАБАН СИНДРОМЫ: МУЛЬТИДИСЦИПЛИНАРЛЫҚ АСПЕКТІЛЕР ЖӘНЕ МЕЙІРГЕРЛЕРДІҢ РӨЛІ

Шолпан Батарбекова¹, <https://orcid.org/0000-0001-9715-1742>

Динара Жунусова¹, <https://orcid.org/0000-0003-3851-3728>

Гульмира Дербисалина¹, <https://orcid.org/0000-0003-3704-5061>

Жанагуль Бекбергенова¹, <https://orcid.org/0000-0002-6146-3784>

¹ "Астана медицина университеті" КеАҚ, Астана қ., Қазақстан Республикасы

Өзектілігі. Диабеттік аяқтың жарасы қант диабетінің жиі кездесетін асқынуы болып табылады және ампутацияға әкелуі мүмкін. Бұл жағдайды тиімді емдеу қауіп факторларын терең білуді, тұрақты медициналық бақылауды және мұқият алдын алуды талап етеді.

Мақсаты: диабеттік табан синдромының патогенезі, диагностикасы және алдын алу туралы заманауи идеяларды талдау.

Іздеу стратегиясы. Біз әдебиеттерді іздестірдік және 2014–2024 жылдар аралығында жарияланған мақалаларды әңгіме шолуына қостық. Іздеу жүйелі түрде академиялық деректер қорларында жүргізілді (PubMed, MEDLINE, CINAHL, Embase). Іздестіру кезінде жынысы бойынша сүзгілер пайдаланылмаған, жас бойынша тек 18 жастан асқан емделушілер, ал зерттеу түрі бойынша бақылау, эксперименттік және қайталама зерттеулер енгізілген. Негізгі іздестіруден басқа, диабеттік табан диагностикасына, емдеуге және алдын алуға қазіргі көзқарастарды қамту үшін тиісті басылымдардың сілтемелеріне шолу және халықаралық және ұлттық ұсыныстарды талдау жүргізілді.

Нәтижелер. Талдау нәтижесінде диабеттік табанның патогенезі микроциркуляцияның бұзылуымен, нейропатияның дамуымен және инфекциялық процеспен байланысты күрделі процестерді қамтитыны анықталды. Науқастарды аяқтың дұрыс гигиенасы, тырнақ күтімі және дұрыс аяқ киім туралы үйрету ойық жара тудыруы мүмкін жарақаттар қаупін азайтудың кілті болып табылады. Диагностикалық тәсілдер жетілдірілуде, бұл патологияны ерте кезеңде анықтауға және терапияның тиімділігін арттыруға мүмкіндік береді. Диагностика мен жіктеуге жүйелі көзқарасты ұстану дәрігерлер мен мамандар арасындағы байланысты жақсартады, асқынуларды басқаруды жеңілдетеді. Бұл үйлестірілген тәсіл, сайып келгенде, қант диабетімен байланысты төменгі аяқтардың ампутациясын азайтуға әкелуі мүмкін.

Қорытындылар. 2 типті қант диабеті бар науқастарда аяқтың өзгеруі жиі кездесетін асқынулардың біріне айналды және ауруханаға жатқызуудың негізгі себебі болып табылады. Емдеу гипергликемияны бақылауды, жараларды емдеуді және инфекцияларды емдеуді қамтитын кешенді болуы керек. Тиімді күтім науқастың жағдайы мен қажеттіліктеріне сәйкес мультидисциплинарлы және дербестендірілген болуы керек. Профилактикалық білім беру, эмоционалды қолдау көрсету және науқасты ұсыныстарды орындауға ынталандыру, соның ішінде тұрақты аяқ күтімі және қандағы глюкоза деңгейін бақылау маңызды.

Түйін сөздер: 2 типті қант диабеті, диабеттік табан синдромы, алғашқы медициналық көмек, көпсалалы команда, мейіргер.

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Introduction

Diabetes, a disease of the endocrine system, is defined by abnormally high levels of glucose in the blood and is one of the most common and rapidly developing diseases in the world [79]. The tenth edition of the International Diabetes Federation Atlas notes that type 2 diabetes accounts for more than 90% of all diabetes cases worldwide. Diabetes remains a major public health problem and compared to 2019, the overall incidence of diabetes worldwide has increased by 73.6 million, the number of undiagnosed cases by 7.8 million, and the number of diabetes-related deaths by 2.5 million. The Republic of Kazakhstan ranks 116th out of 214 in terms of diabetes incidence [34]. It is projected to affect 693 million adults worldwide by 2045, more than 50% more than the number of cases in 2017, and by 2050, more than 1.31 billion people are expected to suffer from diabetes [21,28].

The increase in the number of patients with type 2 diabetes directly leads to an increase in the number of patients with diabetic complications. Diabetes affects the heart, kidneys, eyes and nerves, leading to complications such as heart attack, stroke, blindness, renal failure, and amputation of the lower limbs. An unhealthy lifestyle and metabolic dysfunction syndrome lead to an increase in the concentration of triglycerides and non-esterified fatty acids. Excess lipids accumulate in non-adipose tissue, blocking insulin signaling pathways and causing insulin resistance. This leads to an increase in glucose formation in the liver and a decrease in its ability to absorb glucose, which contributes to an increase in blood glucose levels and an increase in basal insulin concentrations [59]. Increased insulin levels promote lipid accumulation, worsening insulin resistance and creating a vicious circle. Elevated glucose and lipid levels cause hyperglycolipotoxicity of islet β -cells, which damages their secretory function and quantitative composition, further increasing glucose levels [44, 26]. Diabetic foot is a chronic destruction of deep tissues caused by neurological dysfunctions, vascular diseases, and bacterial infections. [24, 73]. Patients suffering from diabetic foot syndrome, at the initial stage of development, often experience intense manifestations of sensitivity in the feet, such as a sensation of burning or stabbing pain, tingling, and in the later stages - numbness, paresthesia, impaired walking and the presence of long-term non-healing wound defects.

The objective of the review is to analyze modern concepts of pathogenesis, diagnosis and prevention of diabetic foot syndrome.

Search strategy and data sources

We conducted a literature review including articles published between 2014 and 2024. Academic databases such as PubMed, MEDLINE, CINAHL, and Embase were searched routinely. The main keywords used in the search included "diabetic foot syndrome", "diabetic foot ulcers", "multidisciplinary approach", "nursing role", "nursing education", "nursing care", "nursing interventions", "classification of diabetic foot", "economic impact", "pathogenesis of diabetic foot", and "prevention of diabetic foot". To cover different aspects of the topic, these terms were combined with "clinical guidelines", "management", "interprofessional collaboration". No gender filters were used in the search, and the age criterion was limited to

patients over 18 years. Observational, experimental, and secondary studies were included in the study. Studies focusing on the pathogenesis, classification, and prevention of diabetic foot, publications on the role of nurses and multidisciplinary teams, and clinical guidelines on a multidisciplinary approach were considered. Materials without mentioning the role of health care professionals, reports with an insufficient evidence base, articles that were not peer-reviewed, publications in languages other than English, and studies with little statistical information or highly specialized clinical cases were excluded. Guidelines from leading professional associations such as the International Diabetic Foot Working Group, the International Diabetes Federation, and the World Health Organization were analyzed, which provided up-to-date information on the diagnosis, treatment, and prevention of diabetic foot, as well as recommendations on the role of health care professionals in caring for such patients. A search for systematic reviews and meta-analyses on the topic of diabetic foot provided structured and summarized evidence to facilitate the assessment of the outcomes and effectiveness of different treatments, including the role of the multidisciplinary team and nurses.

Mechanisms of diabetic foot formation

There are four main aspects of diabetic foot formation: peripheral arterial disease, peripheral neuropathy, bacterial infection and cellular dysfunction. Hyperglycemia that occurs in diabetes mellitus stimulates non-enzymatic glycation of collagen with amino acids of proteins, mainly with lysine and arginine, which leads to the formation of advanced glycation end products [10]. Hyperglycemia, insulin resistance, excess free fatty acids, and advanced glycation products inhibit the production of nitric oxide synthase and reactive oxygen species, thereby reducing oxidative stress. These products reduce the solubility of the extracellular matrix, which leads to an increase in the number of pro-inflammatory factors. In conditions of intense inflammation, leukocytes adhere to the inner lining of arteries, migrate to the site of inflammation, absorb fatty deposits and turn into foam cells, which contributes to the development of atherosclerosis [22]. Atherosclerosis plays a key role in the pathological processes associated with peripheral vascular disease. Atherosclerotic plaque rupture can trigger thrombus formation in the peripheral arteries, which directly leads to arterial occlusion and ischemia of the lower extremities. The lower knee arteries (posterior tibial artery and anterior tibial artery) are most often affected, while the femoral and lower leg arteries (superficial femoral artery and popliteal artery) are affected less frequently [11]. There is a poor arterial blood supply, making peripheral ischemia one of the main causes of ulceration in 35% of cases. Restriction of blood flow in peripheral vessels leads to poor wound healing. Reduced arterial perfusion leads to weakening of the peripheral pulse, increasing the risk of ulcers, infections and delayed healing, leading to chronic conditions with gangrene and possible amputation [55].

Different types of diabetic neuropathy can be classified according to various criteria: anatomical distribution (proximal, distal, symmetrical, asymmetrical, focal, multifocal, diffuse), clinical course (acute, subacute, chronic), characteristic features (painful, painless, sensory, motor, autonomic) or pathophysiology [2]. Sensory

neuropathy is characterized by decreased or lost proprioception, superficial sensation, pain and temperature sensation. Burning feet syndrome is considered particularly severe, usually occurring at night and accompanied by intense pain. The pain subsequently decreases due to chronic sensory neuropathy. Due to the lack of pain, serious lesions or minor injuries may remain unnoticed, people with diabetes may not feel a sharp object in their shoes, which increases the risk of re-injury and often goes unnoticed for several weeks. Peripheral autonomic neuropathy can lead to vasomotor paresis, promotes the formation of arteriovenous shunts in the subcutaneous vascular network. Neuropathy can cause decreased function of sweat glands, leading to dry and fragile skin prone to cracking, decreased ability to vasoconstriction controlled by the sympathetic nervous system, and impaired regulation of skin microvessels, which contributes to local edema. Motor neuropathy contributes to accelerated depletion of the extensor muscles, manifested in atrophy of the small muscles of the foot. Imbalance between flexors and extensors leads to incorrect positioning of the toes, foot deformities, and an unstable gait. Incorrect distribution of weight on the foot, long periods of stress on the foot when walking, or minor injuries can cause the formation of a callus, which progresses to an ulcer [76, 47, 75, 77, 61].

Foot ulcers caused by inadequate blood sugar levels lead to diabetic foot infections. Infections occur when there are open wounds and begin with a breakdown of the protective layer of skin at the site of injury or ulcer. In diabetics, signs and symptoms of inflammation may be hidden by the presence of peripheral neuropathy, peripheral arterial disease, or immune dysfunction. Because wounds are colonized by microorganisms, infection cannot be determined based on wound culture alone [43, 16]. The infection may manifest as a localized superficial skin lesion or as deeper structural lesions that extend beyond the initial site. Such infections can involve joints, bones, and the circulatory system [57]. In the meta-analysis by *Macdonald K.E. et al.*, the most common microorganism was *Staphylococcus aureus*, of which 18.0% (95% CI 13.8–22.6%; I² = 93.8% [93.0–94.5%]) were methicillin-resistant *Staphylococcus aureus*. Common microorganisms included *Pseudomonas spp.*, *Escherichia coli*, and *Enterococcus spp* [45]. Diabetics were found to be 4.75% more likely to be colonized with methicillin-resistant *Staphylococcus aureus* ($p < 0.0001$). The data showed that the prevalence of methicillin-resistant *Staphylococcus aureus* was 16.78% (95% CI, 13.21–20.68%). Among 2147 cases of skin and soft tissue infections not associated with foot infections, the proportion of methicillin-resistant *Staphylococcus aureus* was 18.03% (95% CI, 6.64–33.41) [71]. It has been proven that methicillin-resistant *staphylococcus aureus* infection does not increase mortality, is associated with an increased frequency of hospitalizations and an increased risk of limb amputation [63]. In polymicrobial infections, identifying the specific microorganism causing the infection can be difficult because of the presence of multiple pathogens. Synergistic interactions between different microbial species can enhance their virulence or antibiotic resistance, making it difficult to isolate and identify the infectious agent. The composition of microbes in polymicrobial infections can vary from patient to patient and over time within the same

patient, making it difficult to identify the main pathogen responsible for the infection. Many microorganisms can form biofilms that protect them from antibiotics and the body's immune responses. Biofilms may include multiple microbial species, making it difficult to identify the dominant pathogen [7].

The wound healing process is a complex process and involves a sequence of interrelated stages, starting with the hemostatic phase, the inflammatory phase, the proliferation phase and the remodeling phase, which results in the formation of a scar [12]. Macrophages play a key role in the wound healing process. In the early stages, they promote inflammation, eliminate pathogens, and remove apoptotic cells. In the later stages of the healing process, they reduce inflammation and produce factors that control the proliferation, differentiation, and migration of keratinocytes, fibroblasts, and endothelial cells, which promotes neovascularization and wound healing. Macrophages in diabetics exhibit changes that affect their ability to engulf pathogens and remove apoptotic cells. This leads to a weakening of the body's ability to fight infections, since the process of efferocytosis is important for the transition of macrophages to the reparative M2 phenotype at the site of injury. Insufficient numbers of M2 macrophages lead to delayed wound healing and, in many cases, to further tissue damage. Another complication is a decrease in the body's ability to fight infection, which increases the likelihood of amputation [1, 80, 60].

Classification is a key factor in determining treatment strategy

To ensure widespread use of a classification system, it is necessary that it be easy to use and not require specialized equipment. For convenience, it is important that the system contains the necessary information for effective categorization of patients and is sufficiently reliable [53]. Classification is usually used for description, while scoring is a numerical indicator that reflects severity. It is difficult to imagine how one classification system can simultaneously serve both functions. The choice between descriptive and numerical classification depends on the clinical situation [27].

The Meggitt-Wagner classification, originally introduced by Meggitt and later expanded by Wagner, is a linear, six-tiered classification system for diabetes. The first three tiers of the system focus on the depth of foot involvement. Despite its limitations, the classification is popular due to its intuitive simplicity and ease of use [27, 78, 50]. Although the validation of the Wagner classification was insufficient and unable to clearly differentiate between different types of ulcers, it became the first widely used classification and continues to classify patients according to the Meggitt-Wagner scale and even provides compelling arguments that such systems can be successfully applied by practitioners regardless of their experience in wound care [18]. A study by *Shah P. et al.* evaluated various diabetic foot lesions according to the Wagner classification. The most common lesion among 50 patients was Wagner grade 2 foot ulcer, which was observed in 42% of cases, grade 3 lesions were found in 34% of patients, and grade 4 lesions in 12% of patients. The study found a strong positive correlation between Wagner grade and age [68].

The University of Texas system is designed to assess the depth of a wound, classify it according to the presence

of infection and ischemia. The system does not consider neuropathy or ulcer areas; it offers grades from 0 to 3 and stages from A to D. Its complexity lies in various degrees and stages, which can make it difficult to memorize and apply in everyday practice [29]. The aim of the study was *Santema T.B. et al.* It consisted of assessing the agreement between observers on two classifications: Meggitt-Wagner and the University of Texas. The consistency of the Meggitt-Wagner classification between the observers was moderate, amounting to 0.415 (95% CI 0.413–0.418). Nurses demonstrated slightly but statistically significantly ($p=0.006$) a higher level of agreement between observers (0.423; 95% CI 0.420–0.426) compared with doctors (0.404; 95% CI 0.392–0.417). The agreement between the observers according to the University of Texas classification was also moderate, amounting to 0.462 (95% CI: 0.445–0.479) among doctors and 0.451 (95% CI 0.447–0.456) among nurses, with no significant differences between the observer groups ($p=0.238$). It follows from the results that both classifications cannot be used as a single tool for selecting treatment methods or comparing them with research data. It is recommended to use them together with additional clinical information [64].

The Society for Vascular Surgery of the Lower Extremities Guidelines Committee has introduced WiFi (Wound, Ischemia, and Foot Infection System). The system addresses three key risk factors that can lead to the need for lower extremity amputation [78]. Wounds are classified into four grades, from zero to three, based on size, depth, severity, and prognosis for healing. Zero grade means the patient has no wound. Grade I wounds are characterized by minor tissue loss that can be repaired with simple techniques such as digital amputation or skin grafting. Grade II wounds are more severe but can be treated with multiple digital amputations or a standard transmetatarsal amputation. If there is extensive tissue loss requiring amputation closer to the level of a standard transmetatarsal amputation or the need to use a free flap, or if there is a deep heel ulcer that extends through the entire thickness of the foot, this is considered a grade III wound. Advanced gangrene that does not allow the functional foot to be saved is excluded from the classification [49]. An additional harmonized notation for re-evaluation of WiFi during treatment of a compromised limb is proposed. To correctly assess the increase or decrease in Wifi, the time frame of events and associated interventions must be considered to reflect the actual status of the limb. This division includes four stages: initial presentation, during therapy, recovery, and relapse. When assessing an index ulcer, the clinician should begin with an assessment of the initial presentation that is associated with the risk of severe lower limb ischemia and/or the possibility of revascularization, which will be the preliminary Wifi or "pWifi" score. During and after treatment, regardless of the type and number of procedures and the follow-up time, the score can be re-evaluated as many times as necessary using the post-treatment Wifi or "tWifi" score. Re-evaluation remains important since the ischemic component may persist. Therefore, the user should designate the status with "hWifi" [14].

The S(AD) SAD - Size, (Area, Depth), infection (Sepsis), ischaemia (Arteriopathy) and neuropathy (Denervation) system consists of five main components,

each of which is rated on a scale from 0 to 3. Criticisms that the system attracted concerned the lack of detail in key clinical categories and the inclusion of Charcot neuropathy as a degree of neuropathy severity. It was because of these concerns that the system was improved and transformed into the SINBAD system [27].

The SINBAD (Site, Ischemia, Neuropathy, Bacterial infection, Depth) scoring system includes six criteria, each of which is scored as present or absent (0 or 1) during the examination of the ulcer and foot [30]. The classification is easy to use, yet reliable, and provides the required information without the need for specialized equipment, except for routine clinical examinations. The system uses complex parameters with clear criteria, which facilitate rapid and accurate clinical decision-making to prevent lower limb amputation [15].

The PEDIS system (Perfusion (ischemia), Extent (area), Depth, Infection, Sensation (neuropathy)) developed by the International Diabetic Foot Working Group includes five domains. Unlike SINBAD, PEDIS does not take location into account. It differs from the University of Texas system and S(AD) SAD in that it is specifically designed for the selection of participants in prospective studies. PEDIS uses clear definitions for different degrees of peripheral arterial disease and infection, which gives it the character of complexity [27, 19].

Fife C.E. et al. created the Wound Healing Index (WHI) to predict the likelihood of wound healing in patients with diabetic foot disease based on individual characteristics of both the patient and their wound. The WHI is composed of 10 variables: wound area, patient mobility (ability to walk without assistance, with a cane, on crutches, with a walker, in a wheelchair, or confined to bed), hospitalization status (whether the patient was hospitalized on the day of care), wound count (the total number of ulcers or wounds the patient has), infection status (evidence of bacterial contamination in the wound), renal status (whether the patient is on dialysis or has had a transplant), and ulcer grade according to the Wagner scale [25].

The Diabetic Foot Ulcer Assessment Scale (DFUAS) developed by *Arisandi D. et al.* is designed to monitor the progression of diabetic ulcers over time and to assess the effectiveness of interventions. It includes 11 items, with a minimum and maximum score of 0 and 98, with a higher score indicating severe wound disease [8].

The Diabetic Foot Risk Assessment (DIAFORA) tool includes eight variables. The tool is divided into two parts: the first four variables are designed to predict the likelihood of ulcer development, the full version, considering all eight variables, is used to assess the risk of amputation in people with an existing diabetic foot. The scoring system includes points: 4 points for the presence of neuropathy, 1 point for foot deformity, 7 points for peripheral arterial disease, 3 points for a history of diabetic foot ulcer or lower limb amputation, 4 points for multiple ulcers, 4 points for infection, 10 points for gangrene and 7 points for bone damage in diabetic foot. The scale used is less than 15 points - low risk, from 15 to 25 points - average risk, more than 25 points - high risk [51].

Chetpet A. et al. developed a scale to assess the risk of amputation in patients with diabetic foot ulcers. It includes 13 parameters: sensory neuropathy (according to the

Semmes-Weissman test), motor neuropathy (deep tendon reflexes and muscle strength level), ulcer grade according to the Rutherford classification, diabetes duration, age, glycated hemoglobin level, foot deformities, history of previous amputations, ankle-brachial index, ulcer depth, assessment according to the criteria of the Infectious Diseases Society of America, habit of walking barefoot outdoors and the presence of comorbidities. The score ranges from 3 to 41 points, where higher values indicate a worse prognosis [20].

Jun D. et al. developed the DIRECT (Debridement of necrosis, Infection control, Revascularization, Exudate control, Chronicity, and Top surface) coding system as a simple, systematic, and standardized tool for evaluating all types of wounds. The system includes six scoring components, each based on pathophysiological aspects that influence the healing process: debridement of necrosis, infection control, revascularization, exudate control, chronicity, and top surface analysis [40].

The new SHID model (Suriadi, Haryanto, Imran, and Defa) was developed based on the authors' clinical observations of patients with diabetic ulcers in Indonesia. It not only covers the levels from skin tissue to bone, but also includes elements aimed at preventing complications. The first classification describes the superficial layer covering the epidermis and/or dermis, the second considers the occurrence of one or more signs or symptoms of infection and/or inflammation, ischemia, or osteomyelitis. The third class covers injuries involving the lower layers of the dermis (subcutaneous) that extend to tendon but do not reach bone; the fourth class covers injuries to subcutaneous, muscular, fascial, and tendinous tissues with one or more signs of inflammation, infection, ischemia, or osteomyelitis; the fifth class describes injuries to all skin tissue that reach bone, including areas with localized and extensive gangrene; the sixth class is similar to the fifth class but is supplemented by one or more of the following signs: inflammation, infection, ischemia, or osteomyelitis [72, 36].

The authors Monteiro-Soares M. et al. [52], Oe M. et al. [56] presented a scale for assessing the condition of the diabetic foot, including seven parameters: depth, maceration, inflammation/infection, size, type of tissue in the wound, type of wound edge and tunneling/subcutaneous emphysema. The total score can range from 0 to 34

Despite the existence of classification and grading systems, existing systems suffer from insufficient validation in specific populations, inadequate consideration of regional differences, and incomplete assessment of risk factors and outcomes [4, 6].

Interdisciplinary approach and the role of nurses

Since the disease itself, type 2 diabetes, and consequently its complication, diabetic foot, cannot be completely cured, correct and timely education of patients at the stage of primary care is of paramount importance [70]. Effective and timely treatment of foot lesions require a comprehensive approach, including accurate diagnosis and classification, systematic assessment of risk factors, and appropriate selection of treatment tactics. A diabetic foot care team that takes a comprehensive approach, viewing foot changes as an indicator of a systemic disease, and integrates various related medical fields plays a leading role

in care planning, patient management, and delivery of care [67]. According to a systematic review by Musuza et al., the composition of healthcare teams for diabetic foot care varies widely across the world. A review of studies found that major limb amputations due to diabetic foot care were reduced by 94% when patients in this category were cared for by a multidisciplinary team. Teams should include representatives from medical and surgical specialties, have a clear structure with core and additional members, follow care algorithms to ensure timely and comprehensive care, and address four key tasks: blood glucose control, wound and vascular care, and infection control [54]. According to practical recommendations for the prevention and treatment of diabetic foot diseases, in all countries of the world for optimal work there should be at least three levels of care organization with the participation of interdisciplinary specialists. The first level should include: a general practitioner, an orthopedist and a nurse, the second level - a diabetologist, a surgeon, a vascular specialist, an infectious disease specialist or a clinical microbiologist, an orthopedist or prosthetist and a nurse. The third is a specialized reference center focused on the treatment of foot diseases associated with diabetes, in which several experts from related disciplines work [66]. Wound care specialists play an important role in a multidisciplinary team committed to achieving positive outcomes. Their in-depth knowledge of chronic wound care is based on certification and years of training, giving them the knowledge, skills, and abilities to develop an effective, evidence-based patient care plan [31]. Most often, the multidisciplinary team includes: an endocrinologist, a vascular surgeon, a podiatrist, and nurses, who have a special key role in the team. Due to the long-term care and treatment, nurses interact with the patient longer, determine his primary needs, make a nursing diagnosis using their clinical thinking and combining clinical, social, behavioral and other data, and create long-term and short-term care plans [46]. Nurses provide standard patient education on foot care, proper shoe selection, daily examination, wound care, dressing, and reduction of factors that contribute to decreased quality of life, which can delay the progression of foot ulcers, which is a key primary prevention strategy to reduce the overall disease burden and overall morbidity [69]. Thus, a prospective study analyzed changes in the feet of patients with type 2 diabetes mellitus who attended a nursing appointment lasting from 30 minutes to an hour. During the appointment, during the foot examination, patients were advised to carefully monitor any changes, and were given recommendations on foot care, including the rules for washing and drying feet, cutting nails, and choosing suitable socks and shoes. At the end of each appointment, patients were given written recommendations on prevention, as well as a folder containing data on glucose levels, lipid profile, blood pressure, and weight. After multivariate analysis, it was found that the only factor that reduced the risk of death was the time spent under the supervision of nurses (95% CI 0.66 (0.61–0.71)). Each year of patient supervision by nurses reduced the risk of death by 34% across all classifications of diabetic foot. The study found that patients who had their feet checked regularly by nurses and who attended appointments over many years lived longer due to a reduced risk of complications [65]. The

study by *Mekonen E.G. et al.* showed the following results: patients who had not previously received information about foot care rules had an 88% higher risk of poor foot care than those who had been informed [AOR = 0.12, 95% CI (0.06, 0.24)]. Patients who received good support from family had a 57% lower likelihood of poor foot care than those who faced insufficient support [AOR = 0.57, 95% CI (0.34, 0.94)] [48].

Comprehensive nursing intervention is an integrated and multidisciplinary approach to care that includes health education, nutritional advice, physical activity, medication therapy and other aspects of nursing care. This approach helps improve patients' awareness of diabetic foot disease and their self-management skills, which allows them to manage the disease more effectively, reducing the incidence of diabetic foot disease and amputation rates [81]. A study by *Ren M. et al.* included 185 patients with diabetes at high risk for foot disease. They underwent intensive nurse education, which included individual counseling on diabetes and foot disease, as well as education on foot care. According to the results, toe ulcers were found in 24 cases, which accounted for 48.0% of the total number of ulcers, of which 70.8% were located on the big toe. The incidence of foot ulcers decreased from 41.2% to 11.1% after nurse education, but the location of the ulcers did not change: half of them were still on the toes. [62].

There are a widespread belief that systematic, organized and regular education plays a key role in preventing diabetes-related foot changes, so effective patient education on foot care includes specific, clear and understandable information about their condition to enable patients to be active participants in their own care [3]. Education should be culturally sensitive, gender sensitive, appropriate to health literacy, and personal circumstances. It is important to assess how clear the recommendations are to the patient, family members, or caregivers, how motivated they are to follow the recommendations, and whether the patient has sufficient self-care skills. Traditional didactic education, a classic approach that focuses on imparting knowledge and convincing patients to follow certain rules, often has little impact on their self-care habits. In contrast, modern strategies such as open-ended communication, interview style, and collaborative approach have been shown to be more effective in changing behavior. These new approaches better engage patients in the treatment process and promote intrinsic motivation to change health-related behavior. The study by *Heng M.L. et al.* analyzed modern communication approaches and their impact on improving patient education outcomes. Participants were randomly assigned to either collaborative patient education or traditional didactic education. Participants in the experimental group showed greater improvement in knowledge retention and self-care behaviors compared to the control group. There was a significant increase in scores at post-study compared to baseline ($p < 0.001$) [33]. Education about proper diabetic foot care and practicing self-care are key to preventing diabetic foot disease [58]. In a study by *Alrashed F.A. et al.*, it was found that among patients with good knowledge of proper foot care, 44% inspected their feet daily, while only 13% did not. Among patients with diabetes who inspected

their shoes before using them (always - 44% and sometimes - 31.6%), 75.6% had good knowledge of proper foot care [5]. In this context, the knowledge and skills of the professionals themselves will be a decisive factor. The medical staff who provide such instructions should undergo regular training to improve their skills in caring for patients [67]. For greater efficiency, it is recommended that medical workers themselves take part in organizing and conducting theoretical and practical training programs without interruption from work, considering the needs for training. As is known, the correct balance between theory and practice not only contributes to an increase in the level of knowledge but also improves skills that will contribute to improving the behavior of patients in caring for themselves and improving their quality of life [41]. A qualitative analysis of participants' perceptions identified four key themes influencing foot care: personal knowledge of people with similar problems had a positive impact on care, while the emotional impact of diabetes and physical, social and everyday limitations made it difficult [39].

Economic Impact

There is a global effort to develop and implement effective treatments that can heal ulcers and prevent serious sequelae. There are many treatments for diabetic foot disease, and access to these treatments remains a challenge, particularly in low- and middle-income countries. Information on ulcer management in health care settings and outcomes related to amputation prevention are widely available. However, information on interventions to prevent diabetic foot disease is rare. With new factors such as the global epidemic of infectious diseases, diabetes outcomes may be even more important and should be considered in planning future public health interventions [23]. It is therefore important to conduct well-designed clinical trials to confirm the effectiveness of new treatments, management, diagnosis and prevention [37]. There is currently significant investment in clinical practice, clinical research and public health interventions, but there is no sign of a slowdown in the growth of chronic diseases [42]. The high frequency and difficulty of treating foot lesions require significant financial resources and increased medical care costs. It is natural that under such conditions there will be a significant financial burden on the country's health care system, which includes direct and indirect costs such as lost wages, disability, and the burden on the few medical personnel [74]. Costs include direct costs such as hospitalization, medical supplies, medications, and surgeries, as well as indirect costs associated with the social and psychological consequences of diabetic foot complications. In a study on the productivity and work capacity of patients with diabetic foot, patients were divided into three groups. The results showed that patients with diabetic foot experienced more difficulties in time management, planning, and performing tasks requiring physical strength, mobility, endurance, coordination, and flexibility. This group also reported limitations in performing cognitive tasks and interacting with colleagues, and a reduced ability to complete work within the established deadlines and to the required volume and quality. Regarding absenteeism, patients reported the greatest number of workdays missed due to health problems [17]. The burden associated with diabetic foot care is difficult to quantify accurately, and cost estimates

vary widely across sources. For example, researchers in New Zealand found that the economic burden was significantly higher than they had expected [38]. In a study by *Barshes N.R. et al.*, the authors found that the costs of treating diabetic foot disease were three times greater than the costs of treating colorectal cancer [13]. The average cost of the United Kingdom National Health Service for wound treatment over 12 months was 7,800 pounds for a diabetic foot ulcer, with 13% of this amount accounted for amputations. Treatment of a non-healing diabetic foot was four times more expensive than that of a healed one (2,140 pounds for a healed one and 8,800 pounds for an unhealed one). The cost of treatment for an amputated limb was 16,900 pounds, not including rehabilitation after amputation [32]. According to the study by *Armstrong et al.*, the overall economic impact of diabetic foot disease is comparable to cancer in all respects, and yet assistive technologies that can predict and prevent the disease could lead to potential savings in health care costs, but only in the short term. An emphasis on early preventive treatment and long-term maintenance therapy for diabetic foot lesions during remission would lead to increased life expectancy and improved health outcomes. And the financial savings from shifting focus from treatment to prevention could be used as investments to find and address the causes of diabetes complications, thereby reducing future suffering [9]. In a study by *Jais S. et al.*, wound care specialists in private hospitals in Indonesia demonstrated greater cost-effectiveness in treating diabetic foot ulcers. Their cost was IDR 2,804,423.3, significantly lower than IDR 6,483,493.4 for nurses in public hospitals. The incremental cost-effectiveness ratio was -165,723.9 [35].

Conclusions

The review analyzes key aspects of diabetic foot syndrome development, its mechanisms, and major risk factors. The results of the analysis indicate that the pathogenesis of diabetic foot includes complex processes associated with impaired microcirculation, development of neuropathy, and infectious diseases. Timely identification of risk factors and implementation of educational programs for patients and their families on self-care and foot care play an important role in prevention, helping to reduce the incidence of complications. Effective care should be individualized according to the patient's condition and needs. It is important to conduct prevention education, provide emotional support, and motivate the patient to follow recommendations, including regular foot care and blood glucose monitoring. Treatment should be comprehensive and include hyperglycemia control, wound care, infection therapy, and arteriopathy correction, since developing tissue necrosis can lead to a reduction in life expectancy due to the need for amputation, deterioration in quality of life, and increased health care costs.

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Author Information

Dinara Zhunussova - PhD, Department of General Medical Practice with a course of Evidence-Based Medicine, Astana Medical University, Astana, Kazakhstan, E-mail: zhunussova.d@amu.kz, OrcidID: 0000-0003-3851-3728

Gulmira Derbissalina - PhD, Associate Professor, Department of General Medical Practice with a course of Evidence-Based Medicine, Astana Medical University, Astana, Kazakhstan, E-mail: derbissalina.g@amu.kz, OrcidID: 0000-0003-3704-5061

Zhanagul Bekbergenova - MSc, Research Assistant, Department of General Medical Practice with a course of Evidence-Based Medicine, Astana Medical University, Astana, Kazakhstan, E-mail: bekbergenova.zh@amu.kz, OrcidID: 0000-0002-6146-3784

Corresponding author:

Sholpan Batarbekova, the second-year PhD-student of the educational program "Nursing Science", Astana Medical University, Astana, Kazakhstan

Postal code: 010000

Address: 47, Abai Street

Phone: +7 702 47 42 36

E-mail: bksholpan@gmail.com