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Estimated costs of treating two standardised diabetes-related foot ulcers of different severity – A comparison of 7 global regions

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ABSTRACT

Aims: To determine estimated costs to treat two hypothetical diabetes related foot ulcers of differing severity in different World Health Organization regions.
Methods: Descriptions of two standardised diabetes related foot ulcers of differing severity were sent to foot teams. Each centre was sent a picture and description of the ulcers, and a series of potential interventions. Respondents were asked to estimate how much each intervention would cost in their centre, and how many times each would be required before the ulcer would heal. These estimated costs were converted to US dollars.
Results: Responses were received from 51 centres. Estimated costs for treating each wound were highest in the North America and Caribbean region. The average estimated cost of treating the milder wound was $2,942, (range $79–$17,758). Relative costs compared to those of North America and the Caribbean ranged from 0.36 to 0.75. The average time needed to cover the estimated costs of treating the wound was 8.6 (0.3–62.3) months' salary. The average estimated cost of treating the more severe wound was $17,403, ($546-$67,178). Relative costs ranged from 0.06 to 0.69. The average time needed to cover the estimated costs of treating the wound was 22.7 (0.2–98.3) months' salary.
Conclusions: The estimated costs of treating ulcers vary widely across the world.

1. Introduction

Diabetes related foot ulcers (DFU) remain a significant cause of morbidity and mortality around the world, with an estimated prevalence of over 20 million people [1–3]. Just under half of those with DFU require hospitalisation for treatment of infection or the effects of peripheral arterial disease, with an estimated 2 million people per year requiring an amputation [2–4]. The annual incidence of DFU globally is estimated to be between 2.5% and 5%, with a lifetime risk of developing a DFU ranging between 15% and 34% in those with diabetes. This translates to hundreds of millions of individuals affected when considering the people with diabetes and their families [1–8]. Beyond the immediate effect of the individuals' increased risk of complications and subsequent diminished quality of life, there is often also a significant financial burden accompanying DFU.

In 2015 diabetes mellitus (DM) is estimated to have cost the global economy about US$1.3 trillion [9]. If past trends persist, the same authors estimated the global burden to increase to US$2.5 trillion by 2030 [9]. In the USA, direct expenditure on DM was estimated at US$237 billion 2017, with 30% of this being attributed to DFU management [10]. Similarly, it has been calculated that 0.9% of the entire UK National Health Service budget was attributed to DFU management [11]. In developing countries, data on the financial burden of DFU is scarce, despite the reported high prevalence [2,8,12,13]. It is reported that

Abbreviations: DM, Diabetes mellitus; DFU, Diabetes related foot ulcer; MENA, Middle East and North Africa; NAC, North America and the Caribbean; SACA, South and Central America; SEA, South-East Asia; WP, Western Pacific.

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approximately 6% of the National Health Budget for Barbados was allocated for DFU management [14]. A Brazilian study highlighted the shift for more outpatient care to reduce the financial burden of DFU on the individual and healthcare system [15]. The authors calculated that $333.5million was spent on outpatient care of DFU compared to $27.7million for inpatient care. However, these calculations did not represent the entirety of the expenses, because indirect costs were not accounted for [15].

In 2012, Cavanaugh *et al* published findings on the estimated costs of treating DFU in five countries – Chile, China, India, Tanzania, and the USA [16]. Using the 2010 Purchasing Power Parity (PPP) tool published by the world bank to account for the economic differences, the study showed substantial disparities in management strategies, and treatment costs for standardised (hypothetical) ulcers [17]. The World Bank and the *Economist* magazine define purchasing power parity asa way of comparing the price of specific goods in different countries using the absolute costs in that countries' currency. They are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries The PPP is the ratio of the cost of good in one economy compared to another economy [18]. The reference value for the current study and for the 2012 study was the costs of treating an ulcer in the USA. In 2012, the relative costs when compared to the USA ranged from markedly low (0.37 in India and Tanzania) to moderately low (0.53 in China) and low (0.71 in Chile) [16]. The objective of the current study was to expand this analysis to all seven World Health Organization (WHO) regions, namely Africa, Europe, Middle East and North Africa (MENA), North America and the Caribbean (NAC), South and Central America (SACA), South-East Asia (SEA), and the Western Pacific (WP). We aimed to evaluate the costs across the world of treating two hypothetical ulcers of different severity.

2. Materials and methods

In May of 2023 at the International Symposium for the Diabetic Foot meeting in the Hague, and other subsequent national and international foot meetings delegates were invited to register their interest in the study. Invitations were also sent out via the regular D-Foot International electronic newsletters. Interested centres were sent details on 2 hypothetical ulcers of highly different severity (Table 1, and Supplementary Figures). They were also sent out a list of multiple possible interventions (Table 2). Centres were asked to determine which interventions each wound would need, and how frequently each intervention would be needed at their centre before the wound would heal. Finally, they needed to find out the cost or reimbursement value of each intervention. The estimated costs of treating the wound were then calculated. A currency calculator was included (https://www.xe.com), to allow conversion to US dollars for each intervention. The Gross Domestic Product (US dollars per capita) was calculated using data from the International Monetary Fund website (https://www.imf.org/external/datamapper/NGDPDPC@WEO/OEMDC/ADVEC/WEOWORLD). Data were used for 2024 (except Pakistan, where 2023 data were used). The use of these standardised ulcers and interventions was to minimise the uncertainty and variations in analysis.

The data from each region were pooled for comparison. Using the United States as the reference value, we calculated the purchasing power parity of each region. This was the same analysis plan used by Cavanaugh et al [16]. We used the Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) guidance for health economic evaluations (given in the supplementary materials) [19]. Patients, or other service recipients, the general public, communities, or stakeholders (including payers) were not included in this exercise on the treatment of hypothetical ulcers.

Clinical Audit & Improvement, and Information Governance Departments of the Norfolk and Norwich University Hospitals NHS Foundation Trust deemed this to be a service improvement exercise and thus did not need ethical approval.

Table 1
The 2 hypothetical scenarios.

	Case 1	Case 2
Age	55 years old	75 years old
BMI	28 Kg/m^2	40 Kg/m^2
Sex	Female	Male
Smoker	No	Yes
Site	1st metatarsal head	Heel
HbA$_{1c}$	8.5 % (69 mmol/mol)	10 % (86 mmol/mol)
Lesion size	4 cm^2	20 cm^2
SINBAD score		
• **S**ite	Forefoot	Midfoot and hindfoot
• **I**schaemia	Pedal blood flow intact: at least one pulse palpable	Clinical evidence of reduced pedal blood flow
• **N**europathy	Protective sensation lost	Protective sensation lost
• **B**acterial Infection	None	Present
• **A**rea	Ulcer $\geq$ 1 cm^2	Ulcer $\geq$ 1 cm^2
• **D**epth	Ulcer confined to skin and subcutaneous tissue **= 2/6**	Ulcer reaching muscle, tendon or deeper **= 6/6**
Duration of wound	6 weeks	6 months
Prior ipsilateral amputation	No	Yes – loss of 1st ray
Prior contralateral amputation	No	Yes – previous *trans*-tibial (below knee) amputation
Renal status	Microalbuminuria – urinary albumin/creatinine ratio 54.7 mg/mmol/l (normal < 3.5)	Renal impairment – urinary albumin/ creatinine ratio 354.7 mg/ mmol/l (normal < 2.5), creatinine 220 μmol/L (2.49 mg/dL) (normal 45–84 μmol/L, 0.51–0.95 mg/dL)

Table 2
The list of treatment options.

Treatment options	
Out-patient clinic visits	Out-patient debridement
Hospitalization	Operating room debridement
Offloading footwear	Plain x-ray
Total contact cast	MRI scan
Below knee removable walker	CT scan
Dermal replacement	External fixation
Renal consult	Soft tissue flap
Vascular consult	Hyperbaric oxygen
Orthopaedic consult	Trans-tibial amputation
Angioplasty	Prosthesis
Open bypass surgery	Rehabilitation
Oral antibiotics	GP visits / home nurse visits
IV antibiotics	Other (please specify)
Dressings	Other (Please specify)

3. Results

Data were returned from 51 centres: 4 from NAC, 9 from Africa, 11 from Europe, 9 from the MENA, 4 from SACA, 6 from SEA (all from India), and 8 from the WP region.

The estimated costs of treating hypothetical wound 1 and 2, and estimated costs relative to the NAC are shown and Tables 3 and 4.

The average estimated cost of treating wound 1 was $2,942, ranging from $79 in Vellore, India to $17,758 in Greece, with the relative costs compared to those of NAC ranging from 0.36 in SACA to 0.75 in Europe. The average time in months of salary needed to cover the estimated costs of treating the wound was 8.6 months ranging from 0.3 months in Romania to 62.3 months in Egypt.

The average estimated cost of treating wound 2 was $17,403,

Table 3
The estimated costs of treating hypothetical wound 1, and costs relative to the North America and the Caribbean (NAC). Data on average salary from the International Monetary Fund: (https://www.imf.org/external/datamapper/NGDPDPC@WEO/OEMDC/ADVEC/WEOWORLD).

Region	Mean estimated cost of treating wound 1 ($) (range)	Cost relative to NAC	Average annual salary ($) (range)*	Average time in months to cover estimated cost (range)
North America and Caribbean	4,606 (640–9,922)	–	55,400 (23,600–85,370)	1.0 (0.3–1.4)
Africa	2,381 (1,125–4,082)	0.52	1,113 (952–1,730)	30.0 (11.1–53.8)
Europe	3,462 (379–17,758)	0.75	25,176 (7,240–52,430)	1.6 (0.3–8.9)
Middle East and North Africa	2,514 (175–16,720)	0.55	3,503 (526–6,360)	10.6 (0.7–62.3)
South and Central America	1,663 (606–3,707)	0.36	13,025 (7,750–17,250)	1.7 (0.5–3.8)
SE Asia	2,763 (79–8,988)	0.60	2,850 (2,850)	12.1 (0.3–39.5)
Western Pacific	3,202 (259–12,690)	0.70	20,466 (4,640–91,730)	2.9 (0.4–11.4)

Table 4
The estimated costs of treating hypothetical wound 2, and costs relative to the North America and the Caribbean (NAC). Data on average salary from the International Monetary Fund: (https://www.imf.org/external/datamapper/NGDPDPC@WEO/OEMDC/ADVEC/WEOWORLD).

Region	Mean estimated cost of treating wound 2 ($) (range)	Cost relative to US	Average annual salary ($) (range)*	Average time in months to estimated cover cost (range)
North America and Caribbean	41,062 (9,225–38,717)	–	55,400 (23,600–85,370)	7.7 (2.5–13.2)
Africa	2,394 (1,125–4,082)	0.06	1,113 (952–1,730)	30.1 (11.1–53.8)
Europe	16,919 (4,215–50,201)	0.43	25,176 (7,240–52,430)	7.5 (2.7–12.2)
Middle East and North Africa	6,512 (546–18,635)	0.16	3,503 (526–6,360)	23.6 (2.0–56.9)
South and Central America	28,484 (8,604–67,178)	0.69	13,025 (7,750–17,250)	26.9 (6.8–68.5)
SE Asia	7,726 (813–22,367)	0.19	2,850 (2,850)	34.0 (3.6–98.3)
Western Pacific	18,725 (178–56,399)	0.46	20,466 (4,640–91,730)	31.9 (0.2–86.7)

ranging from $546 in Sudan to $67,178 in the Dominican Republic, with the relative costs compared to those of NAC ranging from 0.06 in Africa to 0.69 in SACA. The average time in months of salary need to cover the estimated costs of treating the wound was 22.7 months, ranging from 0.2 months in Malaysia to 98.3 months in Chennai, India.

4. Discussion

This worldwide study has shown very large variations in the estimated costs of treating two diabetes related foot ulcers at different end of the severity spectrum. In addition, the very large disparities in average income per head, meant that the time taken to cover the estimated costs of treating each wound (assuming the individual had to pay for their own treatment) varied vastly. North America and the Caribbean remained the most expensive region.

Previous work has look at the estimated costs of DFU, with many (but not all) having largely been from developed nations [20–24]. Data from the United States suggested that just under 50 % of the estimated $306.6 billion dollars spent in 2022 on medical expenditure attributable to diabetes was related to peripheral arterial disease [10]. There no data comparing costs across the world.

The strengths of our study lie in the global nature of the data collection over a fixed time period. We provided descriptions and images of standardised ulcers. Together, these allowed direct comparisons of estimated costs. In addition, rather than use absolute costs, we used the purchasing power parity to be able to directly compare costs across different countries relative to costs in the United States. This can be likened to the 'Big Mac Index' first established by '*The Economist*' magazine in 1986 [18].

We acknowledge that our study has several limitations. We did not involve a health economist. One of the authors (KD) is the co-chair of the EASD Health Services Research and Health Economics Study Group. The analysis presented was done according to their recommendations. Furthermore, our methodology followed the same process as outlined in the 2012 paper by Cavanaugh et al [16]. We relied on centres that returned data, and thus may not be representative their countries or regions. The rate of reply varied between region, from 4 in NAC, to 11 from Europe. Only Indian centres replied from the SEA region. In addition, these centres are likely to be from those with an interest in diabetes related foot disease. The data presented do not account for the subjectivity of the interventions, or their cost-effectiveness. In addition, our results may have influenced by misunderstandings by those who returned data. To try and minimise this, our initial invitations to take part in this study were sent to all centres / individuals on several mailing lists from the IWGDF and D-Foot International. We worked on the assumption that those who replied had, by the fact they were on a diabetes foot related mailing list, at least a basic knowledge of foot disease. However, we also gave them images, and detailed descriptions of the wounds. Despite their being several evidence-based guidelines on the management of DFU (https://iwgdfguidelines.org/guidelines-2023/), we do not know how many of the centres follow them and thus, where practices differ from those recommended, estimated costs may vary. In addition, these data are reliant on the subjective opinions of the investigators who returned data and is thus open to bias. Another factor we have not been able to account for is the level of income of those presenting with DFU. With data suggesting that the development of DFU is dependent to some extent on socio-economic factors this may have had an impact of the likelihood of someone presenting to a specialist clinic, and to decide what treatment they could have or afford. We appreciate that reimbursement varies across countries, with some countries, e.g., the UK, having a health service that is free to all users, being paid for by a general tax (National Insurance). In the United States, some people under the age of 65 years may or may not have some form of health insurance. Those that do, may require a percentage co-pay, but those over 65 years of age have Medicare, where the co-pay contribution may also be different. In other countries, e.g., India, healthcare costs are almost always fully borne by the individual with diabetes, with very few having health insurance. A myriad of other reimbursement methods exists across the world and thus costs may also vary as a result.

Similarly, medical expenses are not only related to the level of medical services, but also related to the national economic development and to the price of drugs and equipment and other factors. We have not taken these into account. Because we did not carry out any further modelling, an estimate of cost effectiveness was not possible.

In summary we have found that the estimated costs of treating diabetes related foot ulcers vary vastly across the world. More work needs to be done to help reduce these variations.

CRediT authorship contribution statement

Ketan Dhatariya: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Zulfiqarali G. Abbas:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Availability of data and materials

The datasets generated and/or analysed during the current study will be made available from the corresponding author on reasonable request, provided appropriate credit is attributed to the original authors and the data source.

Author's contributions

KD and ZA developed the initial idea for the manuscript. Both authors critically reviewed and revised the manuscript for important intellectual content. Both authors read, amended, and approved final manuscript. No AI was used in the writing of this manuscript. The authors named in Appendix 1 contributed their costs data from each centre.

Appendix 1

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List of contributing authors and centres of 7 Regions Foot Ulcer Costs Study Group.

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Appendix A. Supplementary data

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