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[Tshifhiwa Mukheli](#) , Anschen Fourie , Tshepo Polly Mokoena , [Shingirai Brenda Kagodora](#) , [Thifhelimbilu Emmanuel Luvhengo](#) *

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Article

Risk Factors and Prevention of Diabetic Foot Ulcer: A Cross-Sectional Survey of Healthcare Practitioners in a South African Setting

Tshifhiwa Mukheli ¹, Anschen Fourie ², Tshepo Polly Mokoena ³, Shingirai Brenda Kagodora ⁴ and Thifhelimbilu Emmanuel Luvhengo ^{5,*}

¹ Oral Health and Therapeutic Services of Gauteng Province

² Department of Physiotherapy, Charlotte Maxeke Johannesburg Academic Hospital

³ Department of Podiatry, Charlotte Maxeke Johannesburg Academic Hospital

⁴ Department of Nuclear Medicine, Charlotte Maxeke Johannesburg Academic Hospital

⁵ Department of Surgery, Charlotte Maxeke Johannesburg Academic Hospital, University of the Witwatersrand

* Correspondence: thifhelimbilu.luvhengo@wits.ac.za; Tel.: +27-839952552

Abstract: Background/Objective: Prevention of foot ulceration is critical to reduce the rate of amputation in individuals with diabetes mellitus (DM). We investigated knowledge of risk factors and prevention of diabetic foot ulcer (DFU) among healthcare practitioners (HCPs). **Methods:** This was a prospective cross-sectional observational study using a self-administered questionnaire. Participants were HCPs involved in management of patients with DM. The questionnaire investigated professional background, prior education, knowledge of risk factors DFU, foot care and appropriate footwear. Participants were asked to indicate if they agreed or disagree with a statement. Scores were based on percentage response by each category of HCPs. Knowledge level was classified as very poor if less than 50% of participants from a category of HCPs answered appropriately, reasonable for 50%-59%, average at 60%-69%, above average from 70%-79% and excellent when $\geq 80\%$. The chi-square test to compare the knowledge levels across the categories of HCPs. **Results:** 449 HCPs participated and 48.1% (216/449) were therapeutic health practitioners (THPs), 37.4% (168/449) nurses and 14.5% (65/449) medical doctors. 36% (162/449) of participants had prior education on DFU. Overall knowledge level among participants of risk factors of DFU was 80%, appropriate technique of foot examination 80%, identification of limb-threatening conditions 82%, proper foot care 77% and selection of appropriate footwear 65%. Differences in knowledge levels across HCPs was statistically significant ($P < 0.05$). **Conclusion:** Majority of HCPs had no prior education on prevention of DFU. The level of knowledge regarding foot care, risk factors and prevention of DFU among HCPs was mostly insufficient.

Keywords: diabetes mellitus; foot care; healthcare professionals; knowledge; neuro-ischaemic ulcer; prevention; risk factors

1. Introduction

Most non-traumatic lower amputations worldwide result from complications of diabetes mellitus (DM). Diabetic foot infection (DFI) is among the common reasons for admission to hospital of patients with DM and is usually preceded by diabetic foot ulcer (DFU) [1–6]. Diabetic foot ulcer may be neuropathic, ischaemic or mixed. Risk factors of DFU include male gender, age above 60 years, poor glycaemic control, smoking and longer duration of DM [7–9]. Other risk factors of DFU are peripheral neuropathy, peripheral artery disease (PAD), retinopathy, nephropathy, foot deformities, blistering of the skin, callosities, in-grown or thickened toenails and fungal infections [7,9,10]. Early identification of a foot at risk and timely implementation of preventive or corrective

measures lowers the chance of developing DFU and subsequently DFI [11–17]. In some cases, over 80% of patients admitted to a hospital with DFI end up with an amputation, and 30-50% are dead within 5 years following the amputation [17].

Management of patients with DM must be by a multi-disciplinary team, involving almost all categories healthcare practitioners (HCPs). It is therefore important for all HCPs to have enough knowledge of factors of DFU and, how to conduct a proper foot examination, identification of foot at risk, practise good foot care including selection and use of appropriate footwear [18,19]. It is recommended that every individual with DM must have at least one comprehensive foot examination yearly [18,19]. Healthcare practitioners are encouraged to implement the 10 key strategies in improving diabetic footwear practice to decrease the burden of DFU [20]. Diabetic foot care (DFC) is a key component of DM self-management and therefore all HCPs who interacts with patients with DM must educate them on how to take care of their feet to prevent DFU [21].

Appropriate footwear is one of the key strategies to prevent development or recurrence of DFU and, patients with DM must wear shoes that are safe and fit, and comfortable as inappropriate footwear to prevent DFU. Inappropriate footwear may increase plantar pressures and mechanical stress [22–24]. Moreover, wearing of appropriate footwear relieves plantar pressure during walking or standing and reduces the risk of development or recurrence of DFU [23,25–27]. This study investigated the level knowledge among categories of HCPs regarding risk factors of DFU and how to prevent or timeously identify foot complications in individuals with DM.

2. Materials and Methods

This was a descriptive cross-sectional observational study conducted at public healthcare facilities within the Charlotte Maxeke Johannesburg Academic Hospital Cluster (CMJAH). Charlotte Maxeke Johannesburg Academic Hospital is one of the central academic hospitals in the Gauteng Province of South Africa. The CMJAH Cluster is the largest cluster comprising of 14 hospitals with nine hospitals and three district health services involved in the care of patients with DM. The nine hospitals are East Rand Hospital, Helen Joseph Hospital, Rahima Moosa Hospital, Pholosong Hospital, Tambo Memorial Hospital, Bertha Gxowa Hospital, Dr. Yusuf Dadoo Hospital, Leratong Hospital, Edenvale Hospital, Carletonville Hospital, Sizwe Hospital and South Rand Hospital. The three district health services are the Ekurhuleni Health District, West Rand Health District and Johannesburg Health District.

Participants included podiatrists, physiotherapists, occupational therapists, dieticians, medical orthotists, prosthetists, nurses and medical doctors. Data from pharmacists were excluded during analysis because a low response rate. Podiatrists, physiotherapists, occupational therapists, dieticians, medical orthotists and prosthetics were grouped together as therapeutic health practitioners (THPs). Convenient sampling was followed, and participants were invited using forums, meetings and online communication systems. Participants completed a self-administered questionnaire online or a hard copy. Participation was voluntary.

The questionnaire had three sections with the first section covering socio-demographic parameters and professional category of the participant. The second section had questions on history and type of prior education including format and training platform, and participant's training needs. The last section of the questionnaires assessed knowledge regarding foot care and had five subthemes with a total of 67 questions. The 67 questions included 10 on risk factors of DFU, 16 on elements of a proper foot examination, 27 on the do's and don'ts regarding foot care, 9 on the selection and correct use of footwear and 5 identification of limb-threatening conditions. Participants were asked to indicate if they agree or disagree with a posed statement. The statements were a mixture of appropriate and inappropriate knowledge or practice. Expected response was either agreeing when the statement is correct or not disagreeing if incorrect. Questionnaires were completed electronically via a survey link sent to the participants by email or on hard copies distributed to participating hospitals and all clinics within the three districts. Participants completed the survey anonymously after signing an informed consent. The estimated time for participants to complete the survey was 20

minutes. Hard copies of completed questionnaires were collected from the participants by the researchers assisted by the delegated HCPs in each of the participating facilities.

We captured and entered the data onto an MS Excel spreadsheet and thereafter used STATA version 15 for analysis. After capturing the data, the total scores for an individual participant for the themes in Section 3 were re-coded and converted it into a metric ranging from 0 to 100. The scores were categorized as very poor if less than 50, reasonable if 50-59, average from 60-69, above average if 70-79 and excellent when above 79. The level of knowledge was insufficient if the individual, group or overall score in a theme was less than 80. We captured the data to provide a view on knowledge of each participant and professional group regarding appropriate foot care independently to avoid bias. Analysing the three groups of THPs independently to avoid biases was important in our study, especially considering the assumption that education levels differ significantly among HCPs. Among the assumptions in the survey was that all HCPs involved in the day-to-day prevention and management of DFU would be more knowledgeable of prevention and care diabetic foot regardless of their education level and their scope of practice.

Findings were presented in a way that facilitated comparison of individual scores and scores across professional groups, and to provide a holistic view of combined scores of participating professions. We used a box and whisker plot to depict the range of scores for each of category of healthcare professions, highlighting variability and median score for a visual summary of the data. We used the chi-square test to assess the significance of differences between groups. Statistical significance was set at a p-value less than 0.05. Ethical clearance to conduct the study was received from the Human Research Ethics Committee (Medical) of University of the Witwatersrand (M190563), and followed the guidelines contained in 2024 revised Declaration of Helsinki of the World Medical Association.

3. Results

Four hundred and forty-nine completed questionnaires were returned and 48.1% (216/449) participants were THPs, 37.4% (168/449) nurses and 14.5% (65/449) medical doctors. Majority, (320/449) of participants of participants were female (Table 1).

Table 1. Socio-demographic characteristics of participants (N=449).

Variables	Number
<i>Profession</i>	
Medical doctors	65(14.5%)
Nurses	168(37.4%)
Therapeutic health practitioners	216(48.1%)
<i>Sex</i>	
Male	120(26.7%)
Female	320(71.3%)
Not specified	9(2%)
<i>Service unit</i>	
Polyclinic	70(15.6%)
Rehabilitation unit	150(33.4%)
Therapeutic unit	56(12.5%)
Medical-related unit	90(20%)
Surgical-related unit	32(7.1%)
Not specified	51(11.4%)

Prior Training and Provisioning of Health Education to Patients

Two hundred and eighty-seven (63.9%:287/449) participants had no training on foot care or risk factors of DFU. Sixty-eight (41%: 68/168) of the nurses and 40% (26/65) of the medical doctors had

had specific training on foot care and prevention of DFU compared to 29% (63/216) of THPs, and the difference was statistically significant ($P = 0.032$). Two hundred and twenty (49%:220/449) participants had had general education on DM and diabetic foot during their undergraduate training. Overall, 65% (284/449) of the participants educated their patients with DM on foot care during consultation. Fifty-two (80%: 52/65) medical doctors educated their patients foot care compared to 66.5% (107/161) and 59.2% (125/211) of nurses and THPs, respectively; and the difference across the three professional groups was statistically significant ($P = 0.008$) (Table 2).

Table 2. Healthcare professional prior education and platform and nature of training on diabetic foot care management, and involvement in patients’ education (N = 449).

Variable	Total	Medical doctors	Nurses	Therapeutic Health Practitioners	P-value
<i>Prior training in diabetic foot care</i>					
No	284(63.3%)	37(57%)	96(59%)	151(71%)	0.032
Yes	157(35%)	26(40%)	68(41%)	63(29%)	
Not specified	8(1.8%)	2(0.4%)	8(4.8%)	2(0.9%)	
<i>Training platform and nature</i>					
Undergraduate	78(17.3%)	30(46.2%)	24(14.3%)	24(11.1%)	
Short course	36(5.8%)	5(7.7%)	18(10.7%)	13(6%)	
Workshops, in-service training, seminars, symposium or CPD activities	17(3.8%)	0(0%)	4(2.4%)	11(5.1%)	
On-site training or self-training	19(4.2%)	0(0%)	9(5.4%)	10(4.6%)	
<i>Education of patients on foot care</i>					
No	153 (35%)	13(20%)	54(34%)	86 (41%)	0.008
Yes	284 (65%)	52(80%)	107(66%)	125 (59%)	

Overall, participants scored a median of 82 (range: 0-100) on knowledge of limb-threatening conditions, 80 (range: 20-100) on risk factors of DFU, 80 (range: 30-90) on how to conduct a proper foot examination, 78 (range: 40-100) on appropriate foot care and 65 (range: 38-100) on selection and appropriate use of footwear (Figure 1).

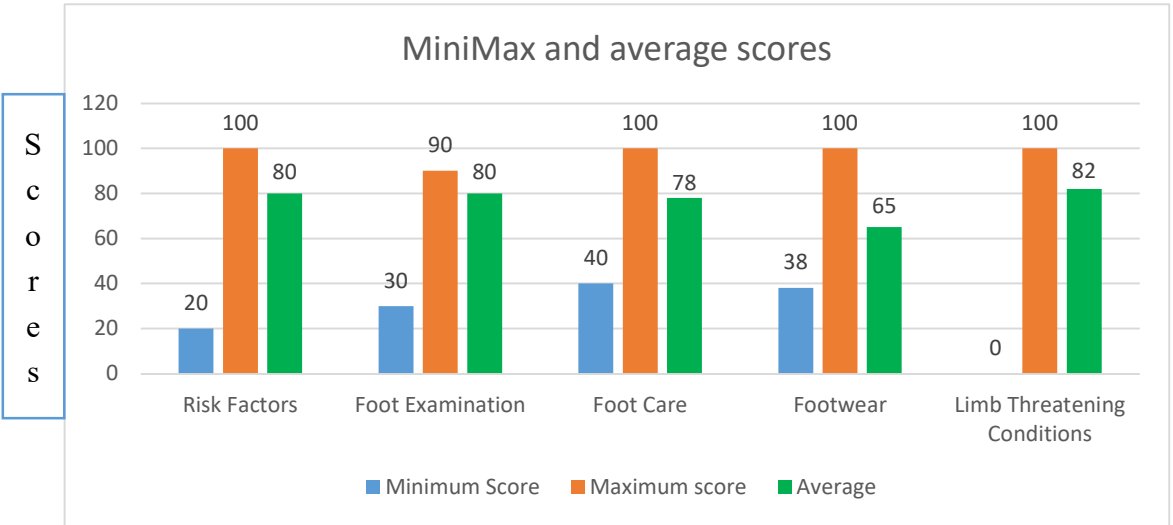


Figure 1. Comparison of minimum, average and maximum scores of knowledge of diabetic foot care management variables by all participants (N = 449).

The median scores of medical doctors on knowledge of risk factors of DFU was 85 and 72 on selection and use of appropriate footwear, which was higher than that of THPs (Figure 2).

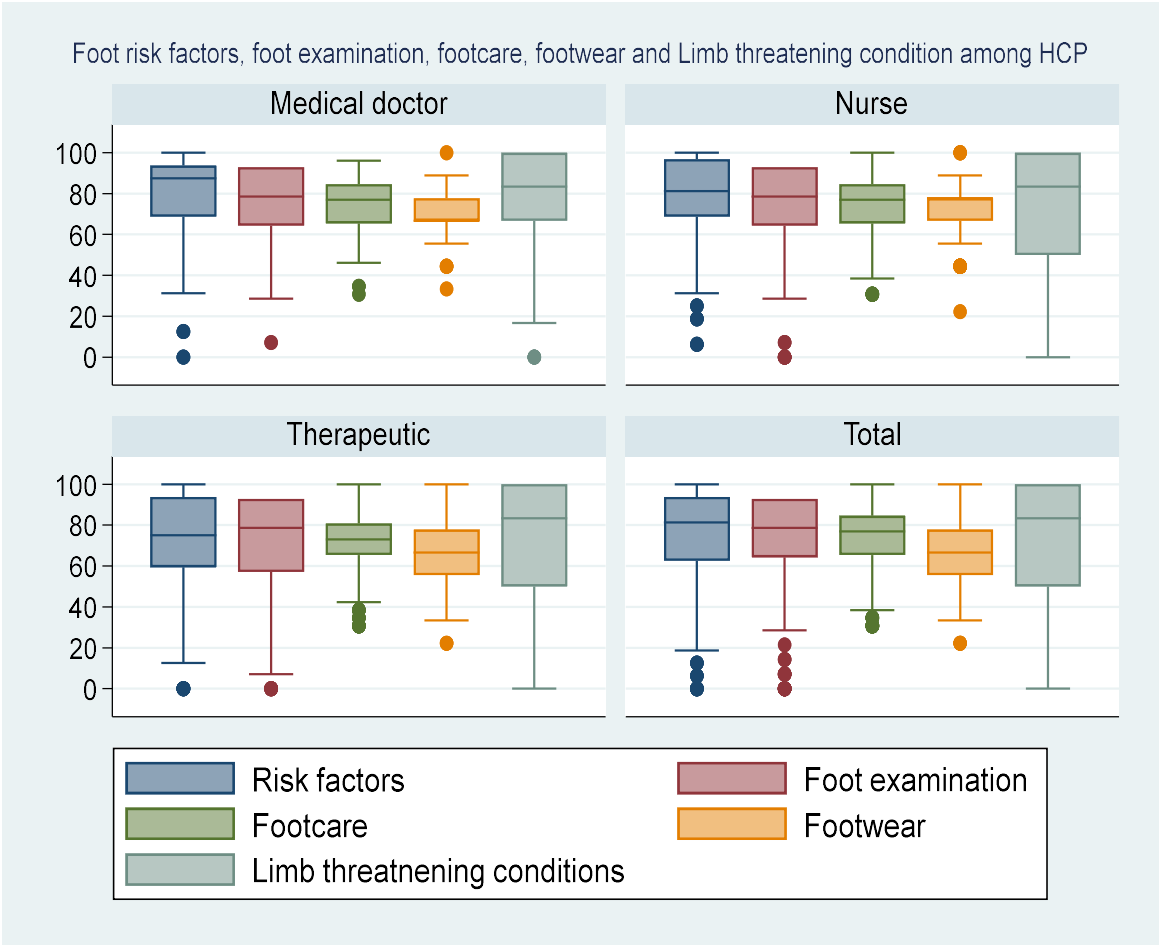


Figure 2. Box-and-whiskers plot comparing knowledge levels among medical doctors, nurses and THPs regarding risk factors, proper foot examination, foot care, selection and appropriate use of footwear and identification of limb-threatening conditions .

Hundred and sixty-eight (78%: 168/216) of THPs were aware that poor glycaemic control was a risk factor for the development of DFU, which was statistically significantly lower than 82% (137/168) of nurses and 95% (62/65) of medical doctors ($P = 0.002$). Similarly, differences in the level of knowledge among the HCPs that PAD, callosities and foot deformities are risk factors of DFU were statistically significant with p-values of 0.038, 0.029 and 0.044, respectively (Table 3).

Table 3. Comparison of levels of knowledge of risk factors among the categories of HCPs (N = 449).

Risk Factors Variables	Total	Medical doctors	Nurses	Therapeutic Health practitioners	P-value
Poor glycaemic control					
No	82(18%)	3(5%)	31(18%)	48(22%)	0.002
Yes	367 (82%)	62(95%)	137(82%)	168(78%)	
Pain, burning, tingling, or tenderness of foot					
No	69(15%)	10(15%)	21(13%)	38(18%)	0.390
Yes	380(85%)	55(85%)	147(87%)	178(82%)	
Peripheral vascular disease					
No	85(19%)	5(8%)	35(21%)	45(21%)	0.044
Yes	364(81%)	60(92%)	133(79%)	171(79%)	
Presence of callus					
No	201(45%)	24(37%)	67(40%)	110(51%)	0.038
Yes	248(55%)	41(63%)	101(60%)	106(49%)	
Dry or cracked skin					

No	154(34%)	16(25%)	47(28%)	91(42%)	0.003
Yes	295(66%)	49(75%)	121(72%)	125(58%)	
Previous DFU on same foot or opposite extremity					
No	95(21%)	8(12%)	40(24%)	47(22%)	0.149
Yes	354(79%)	57(88%)	128(76%)	169(78%)	
Evidence of infection like redness, tenderness, and temperature increase					
No	67(15%)	4(6%)	23(14%)	40(19%)	0.037
Yes	382(85%)	61(94%)	145(86%)	176(81%)	
Walking barefoot, bad shoes, foreign object inside shoes					
No	99(22%)	9(14%)	31(18%)	59(27%)	0.026
Yes	350(78%)	56(86%)	137(82%)	157(73%)	
Mallet or claw toes, hallux valgus, previous amputation, Charcot deformity or low foot					
No	189(42)	18(28)	71(42)	97(58)	0.029
Yes	260(58)	47(72)		116(54)	
Neuropathic foot					
No	44(10)	2(3)	21(13)	21(10)	0.077
Yes	405(90)	63(97)	147(87)	195(90)	

Three hundred and seventy-four (83%: 374/449) participants agreed that smoking is a risk factor of DFU, which included 59% (126/216) of THPs and 76% (128/168). The difference in the level of knowledge regarding smoking and DFU was statistically significant ($P = 0.001$). Fifty-three (82%: 53/65) of medical doctors agreed that gait should be assessed during foot examination compared to 60% (100/168) of nurses, and the difference was statistically significant ($P = 0.006$). Furthermore, 91% (59/65) of medical doctors and 48% (81/168) of nurses agreed that assessment of proprioception should be included during foot examination, and difference was statistically significant ($P < 0.0001$) (Table 4).

Table 4. Comparison of level of knowledge of risk factors of DFU and elements of proper foot assessment (N = 449).

Foot examination	Total	Medical doctors	Nurses	Therapeutic health practitioners	P-value
Cigarette smoking					
No	75(17%)	4(6%)	32(19%)	39(18%)	0.033
Yes	374(83%)	61(94%)	136(81%)	177(82%)	
Age of 65 and over					
No	133(30%)	14(22%)	53(32%)	66(31%)	0.289
Yes	315(70%)	51(78%)	114(68%)	150(69%)	
Obesity					
No	93(21%)	13(20%)	33(20%)	47(22%)	0.869
Yes	356(79%)	52(80%)	135(80%)	169(78%)	
Patients not trained/educated in diabetic foot					
No	7(22%)	9(14%)	42(25%)	46(21%)	0.177
Yes	352(78%)	56(86%)	126(75%)	170(79%)	
Oedematous, atrophic or dry skin, fissures and calluses					
No	36(8%)	1(2%)	16(10%)	19(9%)	0.093
Yes	413(92%)	64(98%)	152(90%)	197(91%)	
Pale, red or cyanotic skin					

No	40(9%)	3(5%)	19(11%)	18(8%)	0.273
Yes	409(91%)	62(95%)	149(89%)	198(92%)	
Foot that is warm or cold to touch					
No	58(13%)	5(8%)	25(15%)	29(13%)	0.341
Yes	391(87%)	60(92%)	143(85%)	187(87%)	
Pain, tingling or burning, tenderness, sensory loss					
No	44(10%)	2(3%)	21(13%)	21(10%)	0.077
Yes	405(90%)	63(97%)	147(87%)	195(90%)	
Muscle atrophy due to damage in muscles					
No	118(26%)	15(23%)	39(23%)	64(30%)	0.300
Yes	331(74%)	50(77%)	129(77%)	152(70%)	
Palpation of posterior tibial and dorsal pedis pulse					
No	84(19%)	7(11%)	30(18%)	47(22%)	0.129
Yes	365(81%)	58(89%)	138(82%)	169(78%)	
Feel for temperature increase, redness or edema					
No	47(10%)	4(6%)	14(8%)	29(13%)	0.145
Yes	402(90%)	61(94%)	154(92%)	187(87%)	
Checking for foot deformities like hammer or claw toes and hallux valgus					
No	126(28%)	12(18%)	43(26%)	71(33%)	0.051
Yes	323(72%)	53(82%)	125(74%)	145(67%)	
Assessment of toenails for thickening, ingrown, and length of the nails					
No	147(33%)	18(28%)	40(24%)	89(41%)	0.001
Yes	301(67%)	47(72%)	128(76%)	126(59%)	
Shoe suitability assessment					
No	83(18%)	9(14%)	25(15%)	49(23%)	0.086
Yes	366(82%)	56(86%)	143(85%)	167(77%)	
Foot joints ranges of motion					
No	121(27%)	14(22%)	47(28%)	60(28%)	0.560
Yes	327(73%)	51(78%)	120(72%)	156(72%)	
Gait assessment					
No	154(34%)	12(18%)	68(40%)	74(34%)	0.006
Yes	295(66%)	53(82%)	100(60%)	142(66%)	
Proprioceptive assessment					
No	153(34%)	6(9%)	87(52%)	60(28%)	0.000
Yes	295(66%)	59(91)	81(48%)	155(72%)	

Fifty-two (80%: 52/65) medical doctors indicated that the spaces between the toes must be kept moist compared to nurses 64% (107/168), and the difference was statistically significant ($P = 0.044$). Of nurses and THPs, 83% from each agreed with doing daily exercises by patients to improve the circulation compared to 64% (44/65) of medical doctors, and the difference was also statistically significant ($P = 0.017$). The difference in level of knowledge among nurses regarding washing of the feet with warm water of 83% (139/168) and 64% (43/65) for doctors was statistically significant ($P = 0.016$). Of the THPs, 80% (172/216) supported checking the temperature of the water before washing the feet compared to 92% 154/168 of nurses, and the difference statistically significant ($P = 0.002$).

Among the THPs, 65% 140/216 agreed to preventing foot corn and callus formation to medical doctors on compared to 80% (52/65) of medical doctors. From nurse participants, 64% (106/168) agreed that socks should be worn for warmth while only 39% (84/216) of THPs agreed. The difference

in the level of knowledge regarding daily change of socks, not wearing torn, wrinkled or oversized socks, and that socks should be checked for wetness and colour change and that socks must be changed every day was statistically significant ($P = 0.007$). The difference in level of knowledge regarding avoiding walking barefoot, prolonged standing and crossing the legs while sitting were statistically significant (Table 5).

Table 5. Comparison of level of knowledge among categories of HCPs regarding foot care (N = 449).

Foot care	Total	Medical Doctors	Nurses	Therapeutic Health Practitioners	P-value
Daily check of foot by patient or a relative for callus or cracks					
No	38(8%)	4(6%)	12(7%)	22(10%)	0.511
Yes	411(92%)	61(94%)	156(93%)	194(90%)	
Feet should be washed daily with warm water					
No	108(24%)	22(34%)	29(17%)	57(26%)	0.016
Yes	341(76%)	43(64%)	139(83%)	159(74%)	
Temperature for washing feet should be checked before hand					
No	64(14%)	6(9%)	14(8%)	44(20%)	0.002
Yes	385(86%)	59(91%)	154(92%)	172(80%)	
Feet, especially spaces between toes, should be dried after each wash					
No	44(10%)	4(6%)	13(8%)	27(13%)	0.189
Yes	405(90%)	61(94%)	155(92%)	189(87%)	
Moisturising cream must be applied to feet					
No	83(18%)	18(28%)	22(13%)	43(20%)	0.028
Yes	366(82%)	47(72%)	146(87%)	173(80%)	
Moisturising cream must be applied to toes					
No	247(55%)	31(48%)	100(60%)	116(54%)	0.230
Yes	202(45%)	24(52%)	68(40%)	100(46%)	
Toes must be kept dry to prevent fungal infections					
No	65(14%)	10(15%)	19(11%)	36(17%)	0.326
Yes	384(86%)	55(85%)	149(89%)	100(83%)	
Cutting tools and chemicals should not be used to remove calluses or hardened skin areas					
No	171(38%)	21(32%)	59(35%)	91(42%)	0.218
Yes	278(62%)	44(68%)	109(65%)	125(58%)	
Callus stiffness should be thinned with a pumice stone					
No	190(42%)	26(40%)	77(46%)	87(40%)	0.506
Yes	259(58%)	39(60%)	91(54%)	129(60%)	
Exercise in the form of twisting and stretching toes several times a day should be done					
No	263(59%)	30(46%)	115(68%)	118(55%)	0.002
Yes	186(41%)	35(54%)	53(32%)	98(45%)	

Prevention of foot corn and callus formation					
No	126(28%)	13(20%)	37(22%)	76(35%)	0.005
Yes.	323(72%)	52(80%)	131(78%)	140(65%)	
There is no inconvenience to use callus band and plaster					
No	143(32%)	22(34%)	70(42%)	51(24%)	0.001
Yes	305(68%)	43(66%)	97(58%)	165(76%)	
Only socks should be worn to warm the feet					
No	227(51%)	34(52%)	61(36%)	132(61%)	0.000
Yes	222(49%)	31(48%)	106(64%)	84(39%)	
Direct heat sources like radiators, hot-water bottle and electrical appliances should be used to warm feet					
No	88(20%)	11(17%)	41(24%)	36(17%)	0.140
Yes	361(80%)	54(83%)	127(76%)	180(83%)	
Socks should not be torn, wrinkled or oversized, and should be checked for wetness and colour change, and changed everyday					
No	112(25%)	23(35%)	29(17%)	60(28%)	0.007
Yes	337(75%)	42(65%)	139(83%)	156(72%)	
Tight rubber socks should be avoided					
No	164(37%)	26(40%)	48(29%)	90(42%)	0.025
Yes	285(63%)	39(60%)	120(71%)	126(58%)	
Walking bare feet is prohibited					
No	167(37%)	19(29%)	35(21%)	113(52%)	0.000
Yes	282(63%)	46(71%)	133(79%)	103(48%)	
Pressure on feet should be removed by not standing for long periods					
No	143(32%)	23(35%)	35(21%)	85(39%)	0.000
Yes	306(68%)	42(65%)	133(79%)	131(61%)	
Legs should not be crossed when sitting on a chair					
No	220(49%)	41(63%)	60(36%)	119(55%)	0.000
Yes	229(51%)	24(37%)	108(64%)	97(45%)	
If there is clawing of toes, massage should not be done to prevent joint stiffness					
No	133(30%)	12(18%)	66(39%)	55(25%)	0.001
Yes	316(70%)	53(82%)	102(61%)	161(75%)	
Toenails should be controlled in terms of thickening, ingrowth, and length, they should be cut flat and, in the corners					

No	117(26%)	24(37%)	34(20%)	59(27%)	0.029
Yes	332(74%)	41(63%)	134(80%)	157(73%)	
The thickened nails should be cut with a special scissors after being softened in warm water					
No	132(29%)	19(29%)	44(26%)	69(32%)	0.470
Yes	317(71%)	46(71%)	124(74%)	147(68%)	
Toe web spaces need to be kept moist					
No	137(31%)	13(20%)	61(36%)	63(29%)	0.044
Yes	312(69%)	52(80%)	107(64%)	153(71%)	
Any changes to feet and toes of colour, temperature, or shape and signs of infection should be reported to the doctor immediately					
No	65(14%)	12(18%)	19(11%)	34(16%)	0.290
Yes	384(86%)	53(82%)	149(89%)	182(84%)	
Foot exercises should be done daily to help the circulation					
No	87(19%)	21(32%)	29(17%)	37(17%)	0.017
Yes	362(81%)	44(68%)	139(83%)	179(83%)	
In case of any foot lesion, shoes must be replaced to reduce the load on feet					
No	154(34%)	14(22%)	76(45%)	64(30%)	0.000
Yes	295(65%)	51(78%)	92(55%)	152(70%)	
Smoking is strictly forbidden since it reduces the amount of blood going to feet					
No	101(22%)	14(22%)	35(21%)	52(24%)	0.737
Yes	348(78%)	51(78%)	133(79%)	164(76%)	

Among medical doctors 51% agreed that shoes fitting and grasping feet should be worn and 22% that doctors should be consulted for foot deformities and 17% to preference of soft-skinned and comfortable shoes. More nurses (12%: 20/168) compared to the other groups disagreed with the use of high-heeled shoes but the difference was not statistically significant ($P = 0.117$). Other responses which did not yield statistically significant differences included allowing the feet to get used to new shoes ($P = 0.357$) and the importance of checking shoes for foreign bodies before wearing them ($P = 0.334$) (Table 6).

Table 6. Comparison of level of knowledge among categories of HCPs regarding selection and use of footwear (N= 449).

Footwear variables	Total	Medical doctors	Nurses	Therapeutic Health practitioners	P-value
Shoes should fit and grasp feet					
No	215(48%)	33(51%)	82(49%)	100(46%)	0.782
Yes	234(52%)	32(49%)	86(51%)	116(54%)	
High-heeled shoes should be preferred					
No	38(8%)	5(8%)	20(12%)	13(6%)	0.117
Yes	411(92%)	60(92%)	148(88%)	203(94%)	
New shoes should be worn and allow feet to get used to them					

No	194(43%)	29(45%)	79(47%)	86(40%)	0.357
Yes	255(57%)	36(55%)	89(53%)	130(60%)	
Shoes should be painted frequently					
No	62(14%)	8(12%)	23(14%)	31(14%)	0.915
Yes	387(86%)	57(88%)	145(86%)	185(86%)	
If there is a deformity in the foot, a doctor should be consulted for proper treatment or orthopaedic shoes					
No	89(20%)	14(22%)	27(16%)	48(22%)	0.303
Yes	360(80%)	51(78%)	141(84%)	168(78%)	
A shoe should not lose its exterior protection feature					
No	142(32%)	21(32%)	55(33%)	66(31%)	0.894
Yes	307(68%)	44(68%)	113(67%)	150(69%)	
Shoes should be worn without socks and, if shoe insoles are worn out, they should be replaced					
No	365(81%)	55(85%)	127(76%)	183(85%)	0.057
Yes	84(19%)	10(15%)	41(24%)	22(15%)	
Soft-skinned and comfortable shoes should be preferred					
No	71(16%)	11(17%)	27(16%)	33(15%)	0.944
Yes	378(86%)	54(83%)	141(86%)	183(85%)	
Shoes should be checked for foreign bodies such as nail, gravel, etc. before each wear					
No	59(13%)	5(8%)	25(15%)	29(13%)	0.334
Yes	389(87%)	60(92%)	142(85%)	187(87%)	

Fifty-seven (88%: 57/65) medical doctors, 65% (110/168) nurses and 54% (116/216) agreed that osteomyelitis should be worrisome of potentially limb-threatening DFI, and the difference was statistically significant ($P < 0.001$). The difference in knowledge level regarding the risk of rapidly spreading infection in DFS among categories of HCPs was not statistically significant (p -value = 0.992) (Table 7).

Table 7. Comparison of level of knowledge among HCPs regarding the signs of limb-threatening conditions (N = 449).

Variables for Limb threatening conditions	Total	Medical doctor	Nurses	Therapeutic Health practitioners	P-value
Chronic limb ischemia					
No	93(21%)	9(14%)	37(22%)	47(22%)	0.335
Yes	357(79%)	56(86%)	131(78%)	169(78%)	
Osteomyelitis					
No	166(37%)	8(12%)	58(35%)	100(46%)	<0.0001
Yes	283(63%)	57(88%)	110(65%)	116(54%)	
Extensive soft tissue loss					
No	107(24%)	7(11%)	41(24%)	59(27%)	0.023
Yes	342(76%)	58(89%)	127(76%)	157(73%)	
Rapid progression of infection					
No	156(35%)	23(35%)	58(35%)	75(35%)	0.992
Yes	293(65%)	42(65%)	110(65%)	141(65%)	
Extensive bony destruction of the foot					
No	128(29%)	15(23%)	49(29%)	64(30%)	0.574
Yes	321(71%)	50(77%)	119(71%)	152(70%)	

4. Discussion

Diabetic foot ulcer is serious health risks for people with DM. Our study examined the knowledge levels of medical doctors, nurses, and therapeutic health practitioners regarding foot care and prevention of DFU during the care of patients with DM. The main finding from the study is of varying levels of knowledge of risk factors and measures to prevent DFU among categories of

healthcare professionals (HCPs). Medical doctors scored highest on knowledge of risk factors and foot examination, while nurses led on foot care. Medical doctors and nurses were more knowledgeable in all areas of foot care than THPs except limb-threatening conditions, where all groups demonstrated enough knowledge. The knowledge differences among HCPs in most areas might have been due to lack of prior training as found in the study or varying scope of practice of the professions.

Overall, most HCPs have high level of knowledge in certain areas of diabetic foot care, but there are significant gaps, particularly in foot care and footwear, which may lead to suboptimal patient care and increase the risk of DFUs [28,29]. However, this study showed that THPs might not be as well-equipped to provide comprehensive diabetic foot care, potentially leading to higher risks of complications. A comprehensive approach for prevention of new or recurrent DFU requires a team approach with all HCPs involved in the management of patients with DM bringing his or her expertise [30–33]. Therefore, HCPs need to be well-trained in all aspects of diabetic foot care. Therapeutic health practitioners need specific additional education in risk factors and foot examination, while all groups need to improve their knowledge of foot care and footwear.

Health science faculties must include diabetic foot care management modules in their programs. By working together, doctors, nurses, and therapeutic health practitioners can improve their skills and provide better care for patients. Although some studies have looked at HCPs' knowledge, they have limitations and differ from our study [34–36]. To our knowledge, this study is the first to compare the knowledge of diabetic foot care management in preventing DFU among nurses, medical doctors, and therapeutic health practitioners, highlighting the need for targeted strategies to improve knowledge and patient care. Future studies should examine how well different educational programs improve HCPs' knowledge and practices related to diabetic foot care.

4.1. Healthcare Practitioners' Knowledge of Risk Factors

Our study revealed that nurses and medical doctors had enough knowledge of diabetic risk factors of DFU, which should lead to timely intervention and management of foot complications. Therapeutic health practitioners' knowledge regarding risk factors of DFU was however insufficient, with significant gaps in understanding of the link between poor glycaemic control and risk of DFUs. The above could be because diabetic foot is not included in the curriculum of most professions of the THPs group, except podiatrists. Furthermore, the scope of practice for THPs in most cases focuses primarily on therapeutic modalities and rehabilitation with minimal teaching and training on preventive strategies.

Considering their roles in the management of DFU, which include rehabilitation, therapeutic modalities (38,39), pressure offloading methods, exercise therapy and nutritional therapy, insufficient knowledge regarding the importance of good glycaemic control may have serious implications like increased risk of amputation, higher healthcare costs, reduced quality of life and increased mortality [37–54]. Practitioners may not be able to monitor, analyse and timeously refer patients with poor glycaemic control for treatment. Additionally, patients may also delay seeking medical intervention due to a lack of knowledge about the warning signs and implications of poor glycaemic control [54,55]. Therefore, all THPs need to have a comprehensive understanding of poor glycaemic control, its management, and prevention, as it is one of the key strategies to reduce the rate of occurrence of DFU [54,55]. Knowledge regarding the importance of good glycaemic control in the prevention of DFU may be enhanced by targeted educational programs like specialized training sessions, continuing medical education (CME) courses and distribution of educational materials detailing risk factors and management strategies for DFU.

4.2. Knowledge of Proper Foot Examination Among Healthcare Professions

A comprehensive foot examination can identify risk of DFU and help with early recognition of “foot at risk”. A comprehensive foot examination must include dermatologic, vascular, neurologic and musculoskeletal assessments [18,56]. In our study, THPs and nurses were less knowledgeable

about assessment of toe nails, gait and proprioception, likely due to limited training on the importance and technical methods of comprehensive foot examinations, and lack of inter-professional collaboration.

Surprisingly, THPs except dieticians are expected to excel in this area of foot examination. Podiatrists are key members in managing the diabetic foot and its complications) while the rest of THPs play a major role in the rehabilitation, therapeutic modalities, offloading therapy, exercise therapy [18,56]. Insufficient knowledge in these areas can lead to misdiagnosis and delayed intervention, increasing the risk of bad outcomes such as DFU, DFI or major amputation. For example, improper care of toe nails may predispose to bacterial or fungal infections [58,59]. Therapeutic health practitioners and nurses need to be knowledgeable about toenail assessment and educate patients and their caregivers to inspect their toe nails regularly for signs of infection or changes and provide appropriate treatments to maintain nail health [58].

Patients with diabetes mellitus often experience gait abnormalities due to neuropathy, limitation of joint movements, muscle dysfunction and foot deformities [60,61]. Because of peripheral neuropathy, patients with DM may not receive tactile information from the ground and lack proprioceptive inputs from their foot and ankle joints while walking [60–64]. Due to knowledge gaps, THPs and nurses may not implement appropriate preventive measures and therefore put patients at risk of injury from falls, and the development of DFU [63,64]. Early identification of gait changes is crucial as it reduces the development of DFU [61]. It is essential for THPs and nurses to augment their expertise in gait assessment and proprioception to facilitate early interventions and prevention of falls, which may lead to DFU and impair quality of life for patients with DM [61].

4.3. Knowledge Levels on Foot Care Among Professional Groups

The findings of our study highlight significant gaps in the knowledge of HCPs regarding foot care, which is a critical component of diabetic self-management and prevention of diabetic foot complications. While nurses demonstrated commendable knowledge, better than medical doctors and THPs in specific areas such as washing the feet with warm water, checking water temperature, and moisturizing the feet, their overall practical knowledge in all areas of foot care was still lacking and not as high as expected, similar to other studies [65–68]. These results are discouraging because nurses are in contact with patients more often than other HCPs and should be therefore be the cornerstones of management DM and its complications. A nurse should be the primary source of information on diabetic foot and their families. It is expected that nurses will have sufficient level of knowledge in foot care since educating patients is an integral part of their duties and responsibilities.

In our study, we found that nurses and THPs demonstrated excellent knowledge about foot exercises, while medical doctors were more knowledgeable about specific techniques such as twisting and stretching the foot. This difference may be attributed to the expertise of THPs in foot exercises and rehabilitation, whereas nurses play a crucial role in rehabilitation and promoting physical activity in the management and prevention of DFU [37,38,44–48,69,70]. On the other hand, medical doctors usually receive more comprehensive training that includes exercises as non-pharmacological strategies for preventing DFU and its complications. Since foot exercises are crucial in managing DM by improving blood circulation, reducing complications, and enhancing the overall quality of life, medical doctors, nurses, and THPs must integrate foot exercises into treatment plans and patient education programs [44–48]. Medical doctors can demonstrate techniques to patients and their families, ensuring accurate and effective implementation of diabetic foot exercises [48].

Conducting joint training sessions and workshops can help healthcare professionals understand each other's roles better and learn new skills that can enhance patient care. Conversely, THPs excluding podiatrists generally possess less knowledge than medical doctors in preventing foot corn and callus formation due to a lack of training in diabetic foot care, as was found in our study. Therapeutic health practitioners without prior training may not provide comprehensive education to patients about foot care as was shown in our study, resulting in poor self-management and foot complications. To better support patients with DM, these practitioners should enhance their

understanding of causes, risk factors and preventive strategies for corns and calluses [71,72]. Collaboration with podiatrists and working within multidisciplinary teams is essential for providing comprehensive care.

4.4. Knowledge of Appropriate Selection and Use of Footwear

Inappropriate footwear selection predisposes patients to DFU by increasing plantar pressure and causing mechanical stress on the dorsal and plantar regions of the foot [22–25]. Our study found that all healthcare professionals (HCPs) lacked sufficient knowledge regarding footwear, which would affect HCPs' ability to assess patient footwear and educate patients on appropriate selection and proper use of footwear. Footwear is a key preventative strategy for development or recurrence of DFU [22,23,26,27]. Without proper guidance, patients with DM are more likely to develop DFU if they wear shoes that cause pressure points and friction [24,25]. Poor choice of footwear may lead to infections, calluses and blistering of skin, which may progress to DFU and DFI, and subsequently amputation [23–26]. Prescribing appropriate footwear for diabetic patients relieves plantar pressure during walking and avoids recurring plantar ulcers in at-risk patients [23,26].

Our findings align with other studies that highlight a significant gap in knowledge and practices related to diabetic footwear among patients due to a lack of awareness [36,65,66,73]. The above strengthen the need to emphasize improved education and awareness among HCPs on footwear assessment and appropriate footwear. We recommend a multifaceted approach, including continuous medical education and specialised training on footwear. Implementing key factors for improving diabetic footwear practice and developing comprehensive training modules on footwear are essential steps [20]. Additionally, fostering partnerships with podiatrists, orthotists, prosthetists, and other foot specialists will enhance the overall quality of patient care.

4.5. Knowledge of Limb-Threatening Conditions Among Healthcare Professionals

Limb-threatening infections are severe diabetic foot complications that can quickly lead to tissue necrosis. Delays in treatment can rapidly worsen the infection, increasing the risk of amputation [2,4,17]. Our study found that all HCPs scored higher on limb-threatening conditions, demonstrating commendable knowledge levels that can foster better multidisciplinary collaboration, enabling the development of effective care plans for patients with DFI, which will be effective in improving limb salvage rates [3,4,16]. Furthermore, medical doctors exhibited greater knowledge about osteomyelitis as a life-threatening condition than nurses and THPs, likely due to their specialized training in infectious disease. This knowledge is essential for enhancing medical doctors' skills in educating patients and their families, conducting comprehensive evaluations such as assessing vascular status, neurological function and wound severity, inspecting wounds for signs of osteomyelitis, cellulitis, gangrene, necrosis, or infection, and timely referral to specialists for further intervention [2,4,5,17,74].

Therapeutic health practitioners and nurses showed insufficient knowledge on osteomyelitis, which can lead to delays in diagnosis and treatment, resulting in severe complications such as chronic infection, bone destruction, and amputation [3,75]. The knowledge gaps among THPs and nursed might have resulted from less specialized training in infectious diseases than medical doctors. The variation in training lead to a greater reliance on specialists, resulting in longer waiting times [74]. Patients may experience prolonged pain, disability, and reduced quality of life due to untreated or poorly managed osteomyelitis [5,75].

Unfortunately, we could not find a similar study to compare our findings. To address the significant differences in knowledge about osteomyelitis, we recommend targeted training programs for nurses and therapeutic health practitioners. Additionally, these practitioners should work closely with specialists like infectious disease experts and wound care nurses to enhance their understanding of diabetic foot infection management and prevention. More research is needed on diabetic foot infections and the knowledge of HCPs to address these gaps effectively.

4.6. *The Strength of the Study*

This study is the first to compare the knowledge of different categories of HCPs like medical doctors, nurses and therapeutic health practitioners—regarding diabetic foot care management. This comprehensive comparison provides valuable insights into the strengths and weaknesses of each group. By including various HCPs, the study highlights the importance of multidisciplinary collaboration in diabetic foot care, emphasizing how different professionals can contribute to better patient outcomes. The study includes HCPs from all levels of care (primary, regional, tertiary, and academic institutions), ensuring a broad and representative sample. This wide scope enhances the generalizability of the findings. The study identifies specific knowledge gaps among HCPs, which can inform targeted educational interventions and training programs to improve diabetic foot care. The findings have practical implications for improving diabetic foot care through enhanced education and training, ultimately leading to better patient outcomes. This study provides a foundation for future research to evaluate the effectiveness of educational programs and training methods in improving HCPs' knowledge and practices related to diabetic foot care.

4.7. *Study Limitations*

The data collection for the study was conducted during the COVID-19 pandemic, this could have limited availability and participation of some of the healthcare professionals due to surrounding circumstances associated with the pandemic. For the study, there were certain questions as well as specific physical examination questions that could not be asked because in-depth knowledge of the diabetic foot among healthcare professionals is not generic across the board, therefore the questionnaire needed to be kept as basic as possible and covering only the fundamental issues that can be considered generic. Good knowledge does not always ensure best practice and therefore future studies can look at healthcare professionals' practices when treating patients with diabetic foot ulcers. Furthermore, this study targeted hospitals and districts in the CMJAH cluster, and therefore the results cannot be used to generalise the findings to all healthcare professionals in South Africa. Although the study targeted all HCPs involved in the management of DM, the medical doctors, nurses, and therapeutic health practitioners should have been disaggregated further according to the healthcare professionals' fields and specialties. Future studies should be conducted to determine their level of knowledge in DF. There is a need to do a similar study on a national level and to include our foot soldiers of the healthcare system which are the Community Health Care Workers in the future study.

5. **Conclusions**

Our study highlights significant variations in the knowledge levels of healthcare professionals (HCPs) regarding diabetic foot ulcers (DFUs) and their prevention within the CMJAH cluster healthcare facilities. While medical doctors and nurses generally excel in understanding risk factors and conducting foot examinations, therapeutic health practitioners show notable gaps in several areas, particularly in risk factors and foot examination. These disparities can lead to suboptimal patient care and increased risk of complications. The findings emphasize the importance of a multidisciplinary approach to DFU care, where each HCP brings their expertise to the table. Despite some strengths, there are critical gaps in knowledge, especially in foot care and footwear, which need to be addressed to improve patient outcomes. Effective DFU management requires comprehensive training and education for all HCPs involved in diabetic foot care.

To address the knowledge gaps identified, we recommend implementing targeted educational interventions, including specialised training sessions and CME courses on diabetic foot care. Integrating diabetic foot care management modules into medical, nursing, and therapeutic health practitioner curricula is essential. Encouraging interprofessional collaboration through multidisciplinary teams and joint training sessions will enhance knowledge sharing. Providing detailed guidelines and resources for healthcare professionals, along with educational materials for

patients and caregivers, will support effective care. Continuous medical education programs should include footwear assessment training and regular updates. Finally, advocating for healthcare policies that prioritize diabetic foot care and support training programs will ensure sustained improvements in prevention and management. Conducting research to evaluate educational programs and investigating barriers to training will help refine these initiatives.

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Abbreviations

The following abbreviations are used in this manuscript:

DFI	Diabetic foot infection
DFU	Diabetic foot ulcer
DM	Diabetes mellitus
HCPs	Healthcare practitioners

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