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RESEARCH ARTICLE

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Weight-bearing physical activity in people with diabetes-related foot disease: A systematic review

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Abstract

Introduction: Weight-bearing physical activity is important for people with diabetes-related foot disease but may also contribute to ulceration or delayed ulcer healing. No overview of weight-bearing activity of people at different stages of foot disease is available. We aimed to summarise quantitatively measured daily activity levels in people with diabetes-related foot disease.

Methods: We systematically searched peer-reviewed literature for studies reporting objectively measured weight-bearing activity in people with diabetes-related foot disease. We calculated daily step counts' means (over studies) and weighted means (over participants). International Working Group on the Diabetic Foot (IWGDF) risk strata, different climates, and activity indoors versus outdoors were compared.

Results: From 1247 publications, 27 were included. Mean steps/day in people with IWGDF risk 1/2: 6125 (12 studies; 345 participants; weighted mean: 5384). In IWGDF risk 3: 6167 (8 studies; 291 participants; weighted mean: 6239). In those with a foot ulcer: 4248 (6 studies; 186 participants; weighted mean: 4484). People living in temperate oceanic climates are more active compared to those in hotter or more humid climates (mean steps/day for no ulcer: 7712 vs. 5224 [18 studies]; for ulcer: 6819 vs. 2945 [6 studies]). People are more active indoors than outdoors (mean 4047 vs. 2514 [3 studies]).

Conclusion: Levels of weight-bearing physical activity are similar between people with diabetes at various risk levels for foot ulceration but lower for those with a foot ulcer. Weight-bearing activity differs depending on the climatological environment and is higher indoors than outdoors. These findings provide reference for intervention studies or for clinicians aiming to provide mobility advice in this population.

KEYWORDS
diabetic foot disease, exercise, foot ulcer, physical activity, prevention

1 | INTRODUCTION

Physical activity is important for people with diabetes.[1] Adopting and maintaining physical activity are important for overall health, improving glycaemic control, and minimising complications.[1] However, for people with diabetes at risk of foot ulceration, weight-bearing physical activity may also cause foot ulceration.[2,3] During weight-bearing activity, the foot is repetitively loaded, and high mechanical loads on the foot lead to ulcer development and delay ulcer healing.[2,3] Such foot ulcers have a lifetime incidence of 19%–34% among people with diabetes, and are a leading cause of the global burden of disease.[4,5]

Weight-bearing physical activity has long been discouraged for people with diabetes and peripheral neuropathy, because of their increased risk of foot ulceration.[6] However, this mantra has changed as shown in recent international guidelines as a result of evidence from RCTs showing no increased risk following interventions that stimulate weight-bearing activity.[1,7] Contrary to this, for people with a foot ulcer, the recommendation is still to limit or refrain from weight-bearing activity,[1] although a recent systematic review concluded that the association between the level of weight-bearing activity and ulcer healing incidence is unclear.[2]

While guidelines[1] and literature reviews[8,9] frequently focus on specific physical activity or exercise interventions, physical activity concerns any bodily movement produced by skeletal muscles that requires energy expenditure.[10] The key physical activity for patients are their daily steps. Daily steps contribute to moderate-intensity physical activity as recommended by the World Health Organization,[10] and increases in such activity are associated with higher quality of life[1,11,12] and favourable physical outcomes, such as improved blood glucose control.[1,13] This explains the growing interest in developing interventions to stimulate people to be more active without having to participate in a specific physical activity intervention program,[14] to enhance people's 'activity-rich days'.[15]

Interventions aiming to improve the daily activity of people who are at risk of foot ulceration would benefit from reference data on the weight-bearing activity in this population, to help interpret individual or group outcomes. However, despite a variety of studies in the field reporting this outcome, no systematic overview of the weight-bearing activity in people with diabetes who are at risk of foot ulceration or who have a foot ulcer is available. Such an overview may identify ulcer-risk specific weight-bearing activity levels, or differences in activity between being indoors or outdoors or between different countries or climates, that may further help in the interpretation and generalisation of findings of future interventions. Therefore, our aim was to systematically review the literature for studies reporting on the amount of weight-bearing activity in people with diabetic foot disease, defined as those who are at risk of foot ulceration or who have a foot ulcer.

2 | MATERIALS AND METHODS

The systematic review was performed according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[16] The systematic review was prospectively registered in the PROSPERO database for systematic reviews (CRD42021227065). As a start, the population of interest (P), interventions (I), and outcomes (O) were defined, and research questions were formulated accordingly. Given the nature of the systematic review, ethical approval was not required by Dutch law.

Population (P): the population of interest was people with diabetes mellitus type 1 or 2 who are at moderate or high risk of developing a foot ulcer, defined as International Working Group on the Diabetic Foot (IWGDF) risk category 2 or 3,[7] or who have a foot ulcer, defined as a "full thickness lesion of the skin distal to the malleoli in a person with diabetes mellitus".[17] Interventions (I) and Comparators (C) were not applicable. Outcome (O) was the amount of weight-bearing physical activity. This includes any type of physical activity during which a person is weight-bearing on their feet, such as while walking, running, stair walking, and standing. These outcomes can be expressed quantitatively, for example, as the number of daily steps or strides during walking or the time spent during weight-bearing physical activities.

2.1 | Inclusion and exclusion criteria

We included original studies that reported on the population of interest and the outcome. We excluded studies that measured weight-bearing activity in a subjective manner (e.g. through a questionnaire or logbook) because of the lower reliability of this method.[18] We included all study designs with the exception of case reports and systematic reviews. We excluded conference proceedings. We included studies with at least an abstract in English and excluded studies in other languages.

2.2 | Search strategy

To develop the search strategy, we first created a validation set of 9 articles that, known to the authors, met our inclusion criteria.[19-27] The final search strategy had to include all these 9 articles to be considered valid. The search consisted of two elements: the first part concerned the population of interest and the second part the outcome. The final search, performed on 28 January 2022, was as follows:

> ((("Diabetic Foot"[Mesh]) OR (diabetic foot[tiab] OR diabetic feet[tiab] OR diabetic foot ulcer[tiab]) OR (diabet*[tiab] AND ulcer*[tiab]) OR (diabet*[tiab] AND foot[tiab]))

AND

((walking[tw] OR step[tw] OR steps[tw] OR step count[tw] OR stride*[tw]) OR (physical activity[tiab] OR physical activities [tiab] OR physical exercise[tiab] OR physical exercises[tiab] OR daily activity[tiab] OR daily activities[tiab])))

To broaden the search, reference checking of all included publications was done. In addition, while we excluded systematic reviews in the eligibility assessment following the search, they were kept apart and used for reference checking.

Data on weight-bearing activity was extracted from the included studies by one assessor and checked by a second assessor. If possible, data was converted to steps per day, for example,: if data was expressed in strides per day, it was multiplied by two, and if data was expressed in steps per 48h, it was divided by two, etc. We calculated the mean daily steps (over the total number of included studies, Equation 1); and weighted-mean daily steps (over the total number of participants included in these studies, Equation 2); per group.

$$\frac{\Sigma(\text{mean daily steps in each included study})}{\text{number of included studies}} \tag{1}$$

$$\frac{\Sigma(\text{mean daily steps in each included study} * \text{number of participants in that study})}{\text{number of participants in included studies}} \tag{2}$$

2.3 | Eligibility assessment

In the first step, publications were assessed for eligibility based on title and abstract. Two assessors independently scored 130 publications and found an agreement of 99%. Given the high agreement, one assessor screened all other publications. In the second step, full text publications were read and checked against the inclusion and exclusion criteria independently by two assessors (VF and JvN). If multiple publications from one study were found, they were grouped and included as one study. Publications excluded in the final step were listed.

2.4 | Assessment of included studies

Qualitative risk of bias assessment of the included studies was done with both a general instrument and a diabetic foot disease specific instrument. The general instrument was a checklist of 10 questions (for RCTs) or 7 questions (for cohort studies), developed by the Dutch Cochrane Centre (www.cochrane.nl), as also used in other systematic reviews.[28,29] Studies scoring positive on 8–10 out of 10 items (for RCTs) or 7 out of 7 items (for cohort studies) were considered very low risk of bias; with 6–7/10 or 5–6/7 low risk of bias; and 0–5/10 or 0–4/7 high risk of bias. Cross-sectional studies were considered high risk of bias by design.

The topic-specific instrument was developed for this study specifically and consisted of five questions. Three questions were obtained from the 21-item score for reporting standards of studies and papers on the prevention and management of foot ulcers in diabetes,[30] and two self-developed questions were added (Supplementary Appendix 1). A very low or low risk of bias assessment following the general instrument could be downgraded (from very low to low or from low to high risk of bias) if the topic-specific instrument had a score of 0–2/5.

Data were grouped based on IWGDF risk stratification,[7] based on the climate in which the participants were studied following the Köppen climate classification,[31] and based on being indoors or outdoors when reported in the publications. Data were analysed with Microsoft Excel (version 16.43).

3 | RESULTS

The search resulted in 1247 publications, of which 1146 were written in English. After screening the title and abstract, 1115 publications were excluded. After assessing the eligibility of the 31 remaining publications from a full-paper review, 24 publications from 20 unique studies were included for qualitative assessment. Reference checking resulted in an additional 3 publications, giving a total 27 publications from 21 studies.[14,19-27,32-48] In one publication, outcomes were reported as part of a guideline, yet without population characteristics.[47] We contacted the first author, who confirmed the correctness of the data and confirmed data was obtained from a subset of which population data were published elsewhere.[49] The PRISMA flow diagram is shown in Figure 1. Articles that were excluded after full-text assessment and the reasons for exclusion can be found in Supplementary Appendix 2.

Critical appraisal was done at the level of the studies, using information from all the included publications. We assessed two studies to have a very low risk of bias, six a low risk of bias, and fifteen a high risk of bias (Supplementary Appendix 1). Outcomes for people at low or moderate risk of ulceration (IWGDF risk 1 or 2) were mostly not reported separately (Table 1). We therefore combined these two groups, even though people at low risk of ulceration were not part of our population of interest as defined in the methods. Five studies did not report outcomes for people at high risk separate from those at low or moderate risk; we grouped

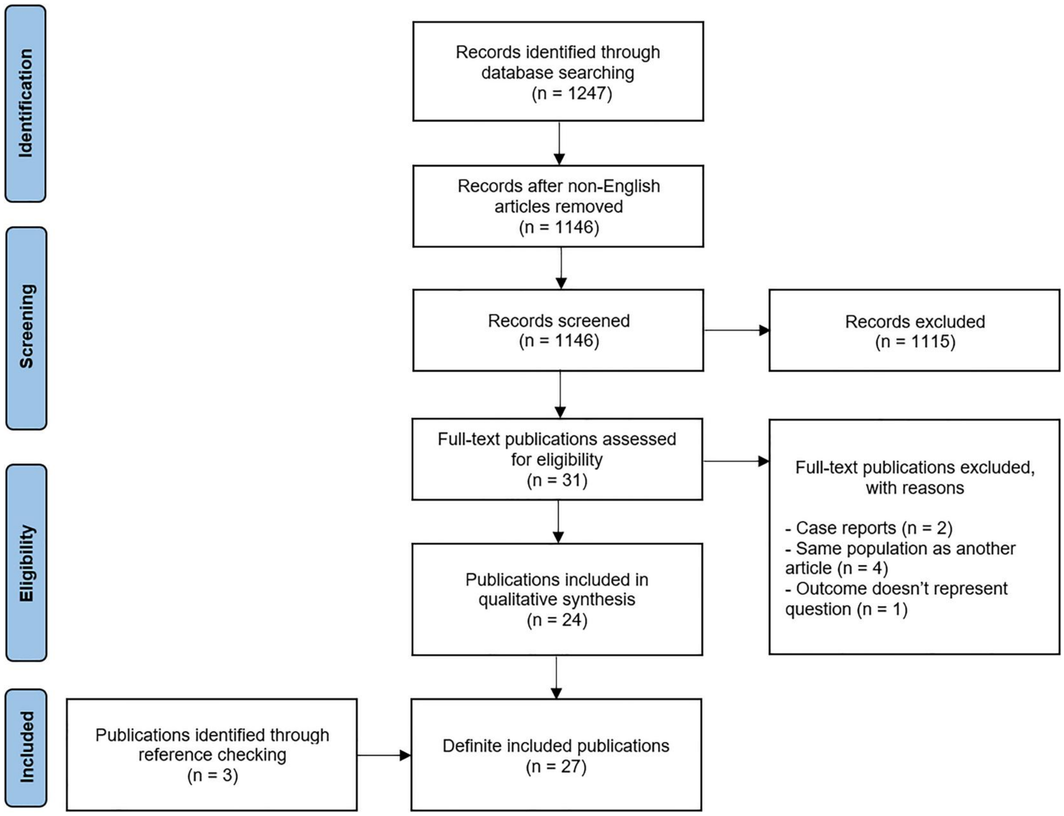

FIGURE 1 PRISMA flow chart

the study based on the largest group (low or moderate risk: $n = 5$; high risk: $n = 1$).

The outcomes of all the included publications are shown in Table 1 and Figure 2. Based on 12 studies with 345 participants,[14,19,21,23-25,27,32-35,45] we found a mean (over the total number of included studies) of 6125 steps per day (range: 3342 to 10,124) in people at low or moderate risk of ulceration (IWGDF risk 1 and 2); the weighted mean, over the total number of participants included in these studies, was 5384 steps. Based on 8 studies with 291 participants,[25,27,36-38,41,42,46] we found a mean (over the total number of included studies) of 6167 steps per day (range: 4548 to 8450) in people at high risk of ulceration (IWGDF risk 3); the weighted mean, over the total number of participants included in these studies, was 6239 steps. Finally, based on 6 studies with 186 participants,[20-22,25,43,47] we found a mean (over the total number of included studies) of 4248 steps per day (range: 1219 to 8153) in people with a foot ulcer; the weighted mean, over the total number of participants included in these studies, was 4484 steps.

When comparing weight-bearing physical activity in studies categorised based on climate, those people living in a temperate oceanic climate appeared to be more active compared to those living in hotter and more humid climates (Figure 3). This was seen in people who are at risk of foot ulceration (18 studies; means: 7712 vs. 5224 steps/day, respectively; weighted means: 7040 vs. 4742 steps/day, respectively; Figure 3). This was seen even more markedly in people with a foot ulcer (6 studies; means: 6819 vs. 2945 steps/day, respectively; weighted means: 7076 vs. 3328 steps/day, respectively; Figure 3).

The three studies[36,39,42] that separated weight-bearing activity between indoors and outdoors, all in people stratified as IWGDF risk 3, showed that people are more active when inside their house compared to when outside their house (mean 4074 vs. 2514 steps per day, respectively; weighted-mean: 3893 vs. 2566 steps per day, respectively; Table 1, Figure 4).

Two studies assessed the differences in weight-bearing activity between people who ulcerated and those who did not.[26,40] One found a slightly higher activity level in those who ulcerated (3437 vs. 3238 steps/day), while the other study found the opposite (809 vs. 1516 steps/day, respectively); see Table 1. Similarly, two studies assessed the differences in weight-bearing activity between those who healed and those who did not heal within 12 weeks.[22,44] One found a higher activity level in those who healed (5304 vs. 4312 steps/day), while the other found the opposite (7222 vs. 9706 steps/day); see Table 1.

4 | DISCUSSION

Based on a systematic review of the peer-reviewed literature, we provide an overview of weight-bearing physical activity in people with diabetes who are at risk of foot ulceration or who have a foot

TABLE 1 Outcomes of included publications

Study	Study participants	Steps/day in primary population	Steps/day in secondary populations
IWGDF risk 1 or 2			
Maluf et al. (2003)	IWGDF 1 + 2: *n* = 10	7816	Without diabetes: 10,074
Missouri, USA	Age = 57.9, M/F:7/3, BMI = 35.3; diabetes type 1/2: 1/9 diabetes duration = 8.6 years		
Humid subtropical climate (Cfa)	Without diabetes: *n* = 10; Age = 57.5, M/F:7/3, BMI = 35.1		
Armstrong et al. (2004)	IWGDF 2: *n* = 68; IWGDF 3: *n* = 32	NR	Developed ulcer: 809
Arizona, USA	Age = 68.5, M/F:95/5, BMI = 30.0		Did not develop ulcer: 1515.7
Tropical and subtropical desert climate (BWh)	Diabetes duration = 13.7 years		
Smith et al. (2004)	IWGDF 1,2 + 3: *n* = 57	3292.8	
Seattle, USA	Age = 68, M/F:57/0		
Dry-summer subtropical climate (Csb)			
Kanade et al. (2006)	IWGDF 1 + 2: *n* = 23	8818	
Cardiff, United Kingdom	Age = 64.5, M/F:20/3, BMI = 31.1		
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 12/11		
LeMaster et al. (2008)	IWGDF 1 + 2: *n* = 79 (Intervention: *n* = 41; control: *n* = 38)	3342.5	Intervention: 3350
Missouri, USA	Age = 65.7; M/F:39/40; BMI = 36.5		Control: 3335
Humid subtropical climate (Cfa)	Diabetes type 1/2: 5/74; diabetes duration = 11.0 years		
Najafi et al. (2010)	IWGDF 1 + 2: *n* = 13	7754	
Chicago, USA	Age = 59, BMI = 34.6		
Hot summer continental climate (Dfa)			
Van schie et al. (2011)	IWGDF 1 + 2: *n* = 24	10,124	
Amsterdam, NL	Age = 60, M/F:17/4		
Temperate oceanic climate (Cfb)	Diabetes duration = 18.1 years		
Mueller et al. (2013)	IWGDF 1 + 2: *n* = 29 (Intervention: *n* = 15; control: *n* = 14)	5711.3	Intervention: 4909
Missouri, USA	Age = 64.5, M/F:17/12, BMI = 35.0		Control: 6571
Humid subtropical climate (Cfa)	Diabetes duration = 12.4 years		
Grewal et al. (2015)	IWGDF 1 + 2: *n* = 25	4618	Intervention: 4328
Qatar and Arizona (USA)	Age = 64 years, M/F: 16/19, BMI = 30.8		Control: 4893
Tropical and subtropical desert climate (BWh)	Diabetes duration = 17 years		
Wijlens et al. (2017)	IWGDF 1 + 2: *n* = 20	6524	
Location: Hengelo, NL	Age = 73, M/F:8/12		
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 2/18		
Sheahan et al. (2017)	IWGDF 1 + 2: *n* = 23	3660	IWGDF risk 0: 5102
Brisbane, Australia	Age = 68, M/F:15/8, BMI = 32;		
Humid subtropical climate (Cfa)	Diabetes duration = 15 years		

(Continues)

TABLE 1 (Continued)

Study	Study participants	Steps/day in primary population	Steps/day in secondary populations
	IWGDF 0: *n* = 20; Age = 60, M/F:11/9, BMI = 32		
	Diabetes duration = 11 years		
Schneider et al. (2019)	IWGDF 1,2 + 3: *n* = 12	3867	Pre-intervention: 3825.3
Chicago, USA	Age = 59.9, M/F:4/8, BMI = 38.1		Post-intervention: 4707.2
Hot summer continental climate (Dfa)	Diabetes type 1/2: 1/11		
	Diabetes duration = 13.0 years		
Monteiro et al. (2020)	IWGDF 1,2 + 3: *n* = 30 (Intervention: *n* = 15; control: *n* = 15)	7972.7	Intervention: 7810.8
São Paulo, Brazil	Age = 63.6, M/F:16/14		Control: 8134.6
Humid subtropical climate (Cfa)	Diabetes type 1/2: 5/25		
	IWGDF risk 1 or 2: mean (over studies)	**6125**	
	IWGDF risk 1 or 2: weighted mean (over participants in studies)	**5384**	
IWGDF risk 3			
Armstrong et al. (2001)	IWGDF 2 + 3: *n* = 20	4548	At home: 2380.6
Arizona, USA	Age = 64.6, M/F:20/0		Away from home: 2167.4
Tropical and subtropical desert climate (BWh)	Diabetes duration = 13.4 years		
Maluf et al. (2003)	IWGDF 3: *n* = 10	5454	
Missouri, USA	Age = 54.5, M/F:7/3, BMI = 36.1		
Humid subtropical climate (Cfa)	Diabetes type 1/2: 3/7		
	Diabetes duration = 21.9 years		
Kanade et al. (2006)	IWGDF 3: *n* = 38	4831.4	
Cardiff, United Kingdom	Age = 62.6, M/F: 35/3, BMI = 31.0		
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 13/25		
Bus et al. (2012)	IWGDF 3: *n* = 14	8294	
Location: Amsterdam, NL	Age = 56.2, M/F:11/3		
Temperate oceanic climate (Cfb)			
Bus et al. (2013) and Waaijman et al. (2013) and Waaijman et al. (2014) and Keukenkamp et al. (2020)	IWGDF 3: *n* = 171 (Intervention: *n* = 85; control: *n* = 86; daily activity outcomes for *n* = 157)	6718	Intervention: 7287
Multicenter; NL	Age = 63.3, M/F:165/6, BMI = 30.6		Control: 6171
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 28/143		Ulcer recurrence: 3437
	Diabetes duration = 17.3 years		No ulcer recurrence: 3238
			Low adherence: 5849
			High adherence: 6885
			At home: 3959
			Away from home: 2604
			Charcot foot group: 6592

TABLE 1 (Continued)

Study	Study participants	Steps/day in primary population	Steps/day in secondary populations
			Non-charcot foot group: 6600
Najafi et al. (2017a)	IWGDF 3: *n* = 12 (Low alert group: *n* = 6; High alert group: *n* = 6)	5877	Low alert group: 5695
Arizona, USA	Age = 62, M/F:5/7, BMI = 33		High alert group: 6059
Tropical and subtropical desert climate (BWh)			
Keukenkamp et al. (2018)	IWGDF 3: *n* = 10 (intervention: *n* = 5; control: *n* = 5)	8450.5	Intervention: 10,788
Amsterdam, NL	Age = 59.5, M/F:9/1, BMI = 26		Control: 6113
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 2/8		At home: 6048.5
	Diabetes duration = 23 years		Away from home: 2759
Featherston et al. (2021)	IWGDF 3: *n* = 30	5410	Before 8 AM: 240
Greater Brisbane area, Australia	Age = 54, M/F:24/6		8 AM–12noon: 1438
Humid subtropical climate (Cfa)	Diabetes type 1/2: 5/25		12noon–6PM: 2902
			After 6 PM: 850
	IWGDF risk 3: mean (over studies)	**6176**	
	IWGDF risk 3: weighted mean (over participants in studies)	**6239**	
Foot ulcer			
Armstrong et al. (2003)	Foot ulcer: *n* = 20	1219.1	While using RCW: 345.3
Arizona, USA	Age = 65.0, M/F:14/6		While not using RCW: 873.7
Tropical and subtropical desert climate (BWh)	Diabetes duration = 12.5 years		
Kanade et al. (2006)	Foot ulcer: *n* = 23	5484	
Cardiff, United Kingdom	Age = 59.7, M/F:19/4, BMI = 31.5		
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 3/20		
Sheahan et al. (2017)	Foot ulcer: *n* = 30	2154	IWGDF risk 0: 5102
Brisbane, Australia	Age = 57, M/F:24/6, BMI = 33		
Humid subtropical climate (Cfa)	Diabetes duration = 13 years		
Najafi et al. (2017b)	Foot ulcer: *n* = 49 (iTCC: *n* = 23; RCW: *n* = 26)	4634.2	iTCC: 3912
Qatar and Arizona (USA)	Age = 53.7 years; M/F:45/4; BMI = 29.2.		RCW: 5273
Tropical and subtropical desert climate (BWh)	Healed ulcer after 12 weeks: *n* = 22		Healed: 5304
	Non-healed ulcer after 12 weeks: *n* = 21		Non-healed: 4312
Bus et al. (2018) and Van Netten et al. (2018)	*n* = 60 (BTCC: *n* = 20; cast shoe: *n* = 20; FOS: *n* = 20; daily activity measurements for *n* = 34)	8153	BTCC: 8300
NL and Germany	Age = 62.6, M/F:48/12, BMI = 29.9		Cast shoe: 7028
Temperate oceanic climate (Cfb)	Diabetes type 1/2: 8/52		FOS: 8894
	Diabetes duration = 12.7 years		Healed at 12 weeks: 7222
	Sub-analysis in Van Netten et al: *n* = 31		Non-healed at 12 weeks: 9706
	Healed ulcer after 12 weeks: *n* = 21		
	Non-healed ulcer after 12 weeks: *n* = 10		

(Continues)

TABLE 1 (Continued)

Study	Study participants	Steps/day in primary population	Steps/day in secondary populations
Fernando et al. (unpublished)	Foot ulcer: *n* = 16	3773	
Townsville, Australia	Subset from *n* = 21 with the following characteristics:		
Humid subtropical climate (Cfa)	Age = 66, M/F: 15:6, BMI = 32		
	Diabetes duration = 17 years		
	Foot ulcer: mean (over studies)	**4248**	
	Foot ulcer: weighted mean (over participants in studies)	**4484**	

Note: Age is expressed in mean years; BMI = body-mass index, expressed in mean kg/m2; diabetes duration = mean years; M/F = male/female; iTCC = instant total contact cast; IWGDF = International Working Group on the Diabetic Foot; RCW = removable cast walker; USA = United States of America; NL = the Netherlands; BTCC = bivalved total contact cast; FOS = forefoot offloading shoe; NR = not reported.

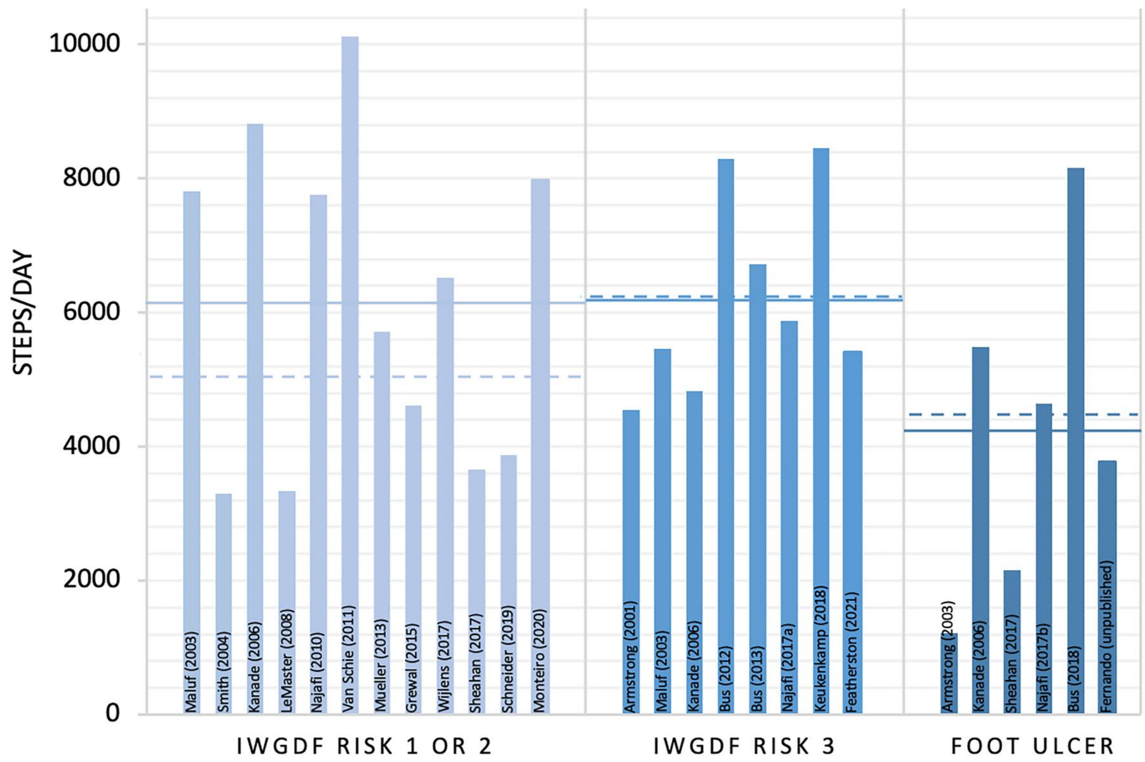

FIGURE 2 Mean steps/day in studies in people with diabetes at risk of or with a foot ulcer. Mean (solid line) and weighted mean (dashed line) are shown per group. IWGDF, International Working Group on the Diabetic Foot

ulcer. A total of 21 unique studies show that people at risk of foot ulceration take around 6000 steps/day, while this is around 4500 steps/day in those with a foot ulcer. People at risk take more steps inside their homes than outside their homes, and people at risk or with a foot ulcer in a temperate climate take more steps compared to those in hotter or more humid climates.

The average weight-bearing activity of 6000 steps/day found in this systematic review is similar to normative data reported for people with type 2 diabetes,[50,51] to the median 5000 steps/day found in a recent systematic review on daily step counts and health outcomes in a mixture of middle-aged or older nondiabetic populations,[52] and to the mean 5000–6000 steps/day seen in an analysis of largescale worldwide physical activity data.[53] However, we found large variations in mean daily steps between and within studies. Some of this variation could be explained by the climatological environment in which the study took place, but many unmeasured factors may play a role as well. Despite this, our findings seem to suggest that people with diabetes at risk of foot ulceration are not less active compared to people with diabetes without neuropathy and possibly not even to the general population, contrary to what has been suggested.[54]

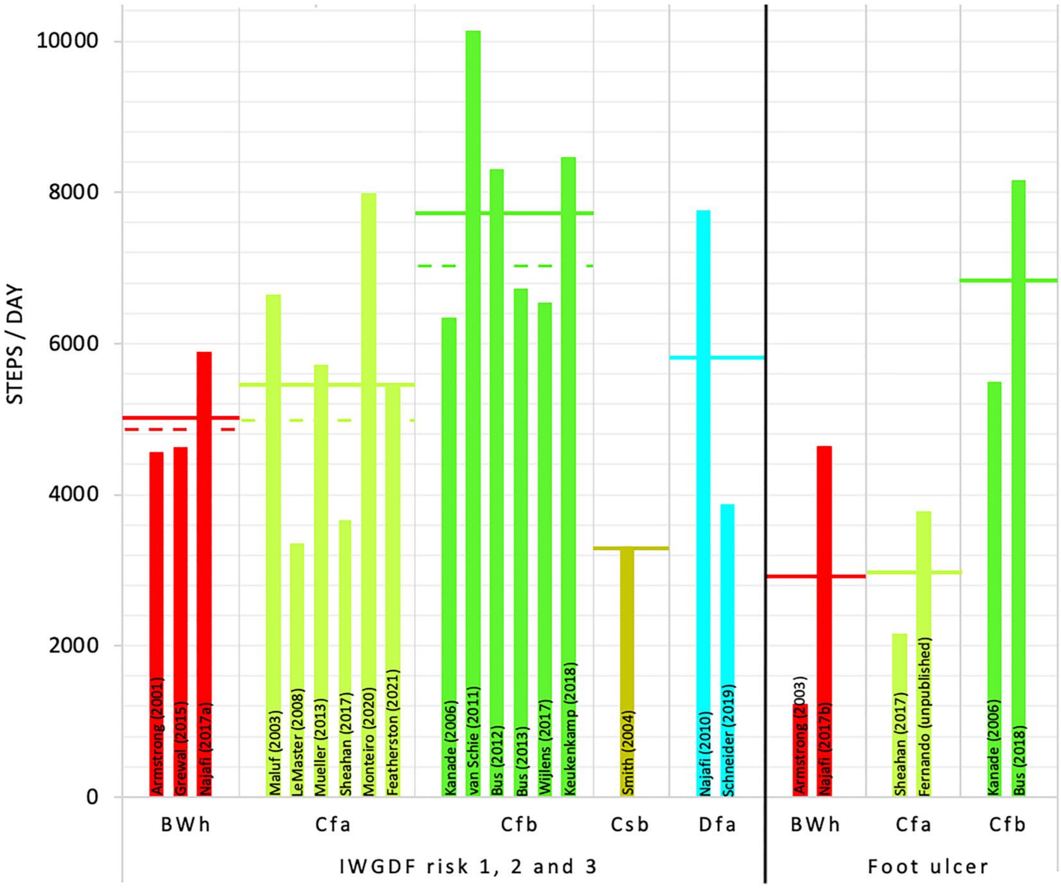

FIGURE 3 Mean steps/day in studies in people with diabetes at risk of or with a foot ulcer in different climates. Solid line represents the mean, dashed line the weighted mean (only applicable for groups with >2 studies); BWh = Tropical and Subtropical Desert Climate; Cfa = Humid Subtropical Climate; Cfb = Temperate oceanic climate; Csb = Dry-summer Subtropical Climate; Dfa = Hot Summer Continental Climate. IWGDF, International Working Group on the Diabetic Foot

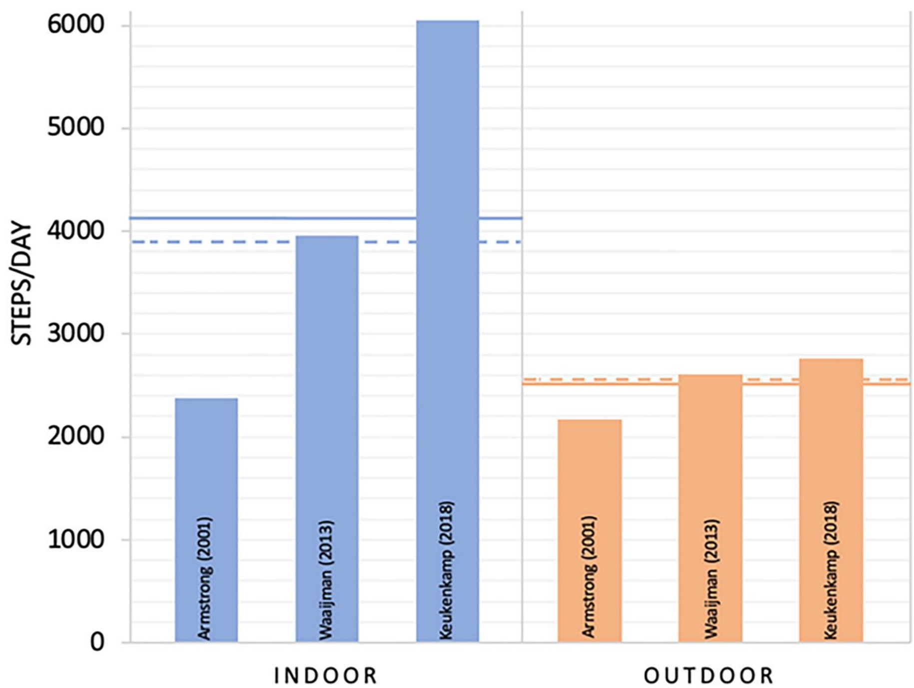

FIGURE 4 Mean indoor and outdoor steps/day in studies in people with diabetes at risk of or with a foot ulcer. Mean (solid line) and weighted mean (dashed line) are shown per group

People with a foot ulcer took an average one-fourth fewer steps compared to those without a foot ulcer but at risk of foot ulceration. With only 5 studies and 156 participants, investigations in this population were limited, and confirmation of these findings in more studies is necessary, although current findings were from a diverse population with studies done in five different regions and three different climates. A larger difference between those at risk and those with a foot ulcer was expected, based on activity advice for the population with a foot ulcer and the mobility restrictions caused by the offloading treatment required for plantar foot ulcers.[1,55] However, with an average of around 4500 daily steps found in people with a foot ulcer, these patients are still rather active. While positive from a general health standpoint, this is a reason for caution, as higher activity could be associated with slower healing rates.[56] On the other hand, this provides reason for optimism, as it suggests that people with a foot ulcer still retain a large portion of their daily weight-bearing activity. Mobility advice following prolonged offloading treatment recommends that the activity level should be slowly increased to pre-ulceration levels, with around 10% per 2 weeks.[54] If fewer steps are lost during the course of offloading treatment, patients can regain their normal activity levels sooner. With a 10% increase per 14 days as the suggested recommendation,[54] people may go from 4500 daily steps to 6000 daily steps in 4–6 weeks. Such a dosing of physical activity would be a new and awaited addition in the treatment and prevention of diabetic foot ulcers.[15,54,56,57]

Concerning the climatological environment, we found that people in temperate climates were more active compared to those in hotter or more humid climates. It can be hypothesised that cooler weather facilitates more weight-bearing physical activity, or hotter/humid weather serves as a barrier. However, other factors such as how cities or countries score on the 'walkability index'[53] or differences in populations with regard to BMI, age, and comorbidities might also play a role, but these could not be taken into account in our analyses. We do suggest that for benchmarking or comparison, researchers and clinicians take the climate-related differences found into account.

Concerning weight-bearing physical activity taking place inside or outside one's house, the only three studies that compared indoor versus outdoor activity all clearly found that people were much more active inside their houses.[36,39,42] This is relevant for patients and clinicians to realise, as it stresses the importance of having adequate protective footwear or offloading devices that can be used inside the house.[7]

A strength of this systematic review was using a validation set to validate the search. A limitation was the restriction to publications in the English language. However, checking the abstracts in other languages did not show potentially relevant publications that were missed by this criterion. Another limitation was performing our search in only one database (PubMed). While this was chosen because previous systematic reviews done by the authors showed that all relevant articles were found in this database,[28,29] including other databases to confirm that finding in this systematic review would have strengthened the methods. A limitation of the studies included in this systematic review was that most did not have weight-bearing physical activity as a primary outcome. It was frequently obtained as a secondary outcome in a randomised controlled trial or a noncontrolled study. However, we only included studies with an objective assessment of physical activity, to avoid including studies with a potentially biased outcome assessment.

Based on the findings of this systematic review, various suggestions for future research can be made. Firstly, it is important for studies in people with diabetes to report outcomes for the various risk strata separately. We found a number of studies where outcomes for people with different ulcer risks were amalgamated in one number, which limits interpretation and generalisability. Secondly, in this review, we focussed on daily steps in walking activity as the primary outcome, as that is the only weight-bearing physical activity that was consistently reported in studies. Outcomes such as daily variation in steps, time spent standing, or bouts of activity were only reported in one or sometimes two studies, limiting comparisons. As also suggested by others,[3] future studies should incorporate a variety of outcomes related to weight-bearing activity, as such outcomes can now be easily and reliably obtained with advanced sensors. Thirdly, almost all the included studies measured activity during one observational period only. Most observational periods were short (generally 1 week), but also studies with longer periods (e.g. 25 weeks in[26]) only reported one average outcome for that observational period; the exceptions were the studies that provided an intervention targeting this activity, as these also measured post-intervention.[14,19,23] However, it is unknown if daily steps in people with diabetes at risk of foot ulceration are consistent throughout the year and over prolonged periods of follow-up. We therefore suggest for future research to measure weight-bearing activity during various timepoints in longitudinal prospective cohort studies and analyse these periods separately.

In conclusion, we found that weight-bearing physical activity in people with diabetes who are at risk of foot ulceration shows to be similar between the various risk strata and is lower for those with a foot ulcer. Weight-bearing activity also differs depending on the climatological environment and is higher indoors than outdoors. This extensive overview based on all studies on weight-bearing activity in this population can serve as a benchmark or reference for future intervention studies in this population or for clinicians aiming to provide mobility advice to people with diabetes and peripheral neuropathy.

AUTHOR CONTRIBUTIONS

Jaap J. van Netten and Vera M. Fijen conceived the idea. Vera M. Fijen developed the search string; Jaap J. van Netten and Sicco A. Bus checked the search string. Vera M. Fijen performed the search and title/abstract screening. Jaap J. van Netten and Vera M. Fijen performed full-text screening. Vera M. Fijen assessed the included publications and extracted outcomes. Jaap J. van Netten and Sicco A.

Bus checked all the extracted outcomes. All authors contributed to the analysis and interpretation of outcomes. Jaap J. van Netten draughted the manuscript. Vera M. Fijen and Sicco A. Bus provided critical input to the manuscript. All authors agree with the final version of the manuscript.

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CONFLICT OF INTEREST

The authors do not declare any conflict of interest related to this manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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PEER REVIEW

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SUPPORTING INFORMATION

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