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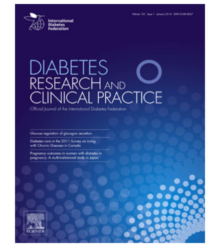

# The role of joint mobility in evaluating and monitoring the risk of diabetic foot ulcer

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ABSTRACT

*Aims:* Evaluation of how ankle joint mobility (AJM) can be useful in the identification of patients with diabetes at risk of foot ulcer (FU).
*Methods:* Plantar and dorsal flexion of foot were evaluated using an inclinometer in 87 patients (54 type 2 and 33 type 1), and 35 healthy sex- and age-matched control subjects. Patients with diabetes were followed up for diagnosis of FU over the next 8 years and subsequently, patients were subdivided into: those without a history of FU (18 type 1 and 33 type 2), those who had a history of FU detected before baseline evaluation (14 type 2) and those who had history of first ulceration detected by the 8th year of the evaluation period (7 type 2).
*Results:* Aging and diabetes caused a significant reduction in mobility of each of the movements investigated ($p < 0.001$), whereas after adjusting for the confounding effect of age, diabetes specifically reduced plantar flexion ($p < 0.0001$). AJM was significantly lower in those with history of previous FU compared to all the other groups ($p < 0.001$). The first ulceration was detected in the same foot presenting lower AJM in 17 of the 22 subjects with diabetes with history of ulcer (77.27%).
*Conclusions:* Diabetes and aging reduce AJM although diabetes seems to reduce plantar flexion to a more specific extent. Reduced AJM is mostly associated with a previous history of FU. The evaluation of AJM is a valid and reliable ulcer risk scale that indicates which foot is at higher ulcer risk.



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## 1. Introduction

Diabetic foot is one of the most ominous complications of diabetes [1]. Neuropathy, vasculopathy, minor foot trauma and foot deformities are individually or altogether the main etiological factors of diabetic foot ulcers. However, other factors, such as limited joint mobility (LJM) of the ankle, may contribute to the genesis of diabetic foot ulcer [2–5]. LJM is an important risk factor for plantar foot ulcer because it may induce abnormal distribution of foot plantar pressure in static and dynamic conditions [5–9].

In particular, diabetes may exacerbate reduced joint mobility that typically occurs with aging [10–12]. In clinical practice, the effect of diabetes on joint mobility may be difficult to prevent because it can induce a painless deficit in joint range of motion (ROM) with an insidious onset followed by asymptomatic progressive deterioration [5,7,13]. At the same time, it is well known that LJM can occur a few years after diagnosis, even in young patients [10,13–15].

It has been reported that LJM increases in relation to the diabetic peripheral neuropathy level in patients with diabetes and is related to the increase in peak plantar foot pressure, integral pressure–time and shear forces [5–7,9,16,17]. The significant correlation of LJM of the first metatarso-phalangeal, subtalar and ankle joints and diabetes is well known [7,16,18]. The overall thickening and stiffness in the main tendons and ligaments of the foot-ankle complex, *i.e.* the plantar fascia and Achilles tendons, can influence joint function and limit ankle ROM and foot joint mobility [19,20]. Reduced joint ROM can impair the performance of large movements such as gait in subjects with diabetes. [8,9,21,22]. Ankle and metatarso-phalangeal LJM alter foot propulsion and increase the load at the metatarsal heads [7,22]. The accumulation of forefoot loads in orthostatic posture and during the whole stance phase increases the risk of tissue breakdown [5–8,17,23].

Since LJM and ROM alterations can be evident in subjects with diabetes prior to the development of clinical neuropathy [7,9,24], it has been suggested for many years that the assessment of ankle and foot joint mobility can help to define the risk of ulcer and to monitor a patient's condition [6,7,9,18,25–28].

The aim of this study was to verify joint mobility changes during the lifetime of patients with diabetes and to use ankle joint mobility (AJM) to monitor the risk of foot ulcer. In addition, we investigated the presence of a direct relationship between limited AJM and a higher risk of foot ulcer in the same patient.

## 2. Patients and methods

Patients attending the St. Jacopo Hospital of Pistoia, Italy were consecutively recruited for evaluation of AJM in plantar and dorsal flexion by means of an inclinometer. A total of 87 patients with diabetes, 14 young and 73 adults, of whom 54 type 2 and 19 type 1, were evaluated and compared with 35 healthy control subjects, of whom 21 were adults and 14 were youths. Both young groups (patients with diabetes and control subjects) ranged in age from 11 to 17 years. The detailed clinical characteristics of the study participants are shown in Tables 1 and 2. Exclusion criteria were: presence of current foot ulcer at baseline, orthopedic and/or surgical complications or Charcot foot. Data were collected regarding type of diabetes, diabetes duration, and presence of neuropathy. The physical examination included foot inspection, evaluation of neuropathy by means of vibration perception threshold (VPT), 10 G Semmens Weinstein monofilament, and evaluation of patellar and ankle reflexes. Evaluation of vasculopathy included determination of peripheral pulses and transcutaneous oxygen tension (TcpO2). Hemoglobin A1c was measured at baseline by high performance liquid chromatography HPLC method. Weight, height and body mass index (BMI) were measured. BMI was expressed as body weight in kilograms divided by height in meters squared (kg/m$^2$). When patients had foot ulcers in the past or during follow-up, they were graded according to the University of Texas Wound Classification System [29].

Patients with diabetes were followed up from the diagnosis of foot ulcer and for 8 years thereafter. The adult group was

**Table 1 – Main characteristics and dorsal, plantar and total AJM (expressed as degrees) in type 1 patients with diabetes compared to age- and sex-matched controls.**

| | Controls | | Type 1 diabetes mellitus patients | | *p*-Value* |
|---|---|---|---|---|---|
| | Youths (*n* = 14) | Adults (*n* = 21) | Youths (*n* = 14) | Adults (*n* = 19) | |
| Age (yrs) | 14.4 ± 1.8 | 61.3 ± 4.7 | 14.1 ± 1.0 | 52.1 ± 12.8 | <0.0001 |
| Diabetes duration (yrs) | – | – | 6.1 ± 4.6a | 26.5 ± 11.0b | <0.0001 |
| Gender (M/F) | 6/8 | 10/11 | 7/7 | 10/9 | |
| HbA1c (% – mmol/mol) | – | – | 7.2 ± 0.7 to 56 ± 6a | 8.3 ± 1.4 to 67 ± 11.b | <0.02 |
| BMI (kg/m$^2$) | 21.5 ± 2.7a | 26.6 ± 3.7b | 20.4 ± 2.5a | 28.1 ± 3.5b | <0.0001 |
| Neuropathy at baseline no. (%) | – | – | 0 | 6 (31) | – |
| Plantar flexion (° – degree) | 38.5 ± 4.2a | 37.6 ± 7.4 | 28.0 ± 5.6b | 32.7 ± 9.8 | <0.0005 |
| Dorsal flexion (°) | 114.4 ± 10.8a | 94.5 ± 18.1a | 91.2 ± 12.3b | 76.7 ± 22.8b | <0.0001 |
| Total AJM (°) | 152.9 ± 13.2a | 131.6 ± 19.2a | 120.8 ± 15.3b | 109.4 ± 27.3b | <0.0001 |
| Δ Right–left (°) | 2.7 ± 1.9 | 6.5 ± 4.3 | 5.0 ± 3.7 | 5.8 ± 6.3 | NS |

Values are mean ± SD.
* By one-way ANOVA.
a *vs.* b in young and adult groups: $p < 0.001$.

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