Type 1 diabetes, sport practiced, and ankle joint mobility in young patients: What is the relationship?

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Background/Objective: It is known that patients with diabetes can develop limited joint mobility (LJM) and that this can depend on the metabolic control maintained and the duration of the disease. The aims of this study were to verify the presence of ankle joint mobility (AJM) deficits in both plantar and dorsiflexion in young type 1 diabetic patients (T1D) considering also the possible role of sport practiced as a further factor, able to modify AJM.

Methods: AJM was evaluated by an inclinometer in 82 T1D patients (M/F: 48/34), mean age 12.9 ± 2.6 years, body mass index (BMI) 19.7 ± 3.6 kg/m², duration of diabetes 5.6 ± 3.3 years, mean HbA1c 7.5 ± 1.0% and in 226 healthy controls (M/F: 146/80), age-, gender-, and BMI-matched practicing different sports (soccer, volleyball, basketball, and dance).

Results: The patients’ ankle range of motion was significantly lower than that in controls (132.7 ± 22.3° vs 126.1 ± 17.9°; P < .017). In particular, ankle plantar flexion was significantly lower in the patients group (31.6 ± 7.9° vs 28.5 ± 6.6°; P < .002). Soccer players showed lower AJM in both groups: patients (120.1 ± 15.9° vs 127.3 ± 18.1°) and controls (119.4 ± 21.1° vs 142.0 ± 18.1; P < .0001) than subjects practicing other sports or who were sedentary. In both groups, patients and controls, age, sex, duration of disease, hemoglobin 1Ac, and BMI have not been shown to be correlated to the mobility assessed.

Conclusions: The results of this study, in addition to confirming the negative effect of diabetes on AJM of young T1D patients, suggest that during these evaluations the sport-related effect should be considered because it can induce significant changes of AJM.

KEYWORDS
ankle range of motion, limited joint mobility, sport-related effect, type 1 diabetes

1 | INTRODUCTION

Type 1 diabetes (T1D) is one of the most common endocrine and metabolic conditions among children.† The incidence and prevalence of this disease is different from one world region to another; however, epidemiological studies showed that in recent years, the annual incidence of T1D has increased by 2% to 4% along with diabetes affecting children under 15 amounting about half a million.1–3 Despite recent advances in patient care beginning at the pediatric age, diabetic patients may develop some complications during their lifetime.1,4 One of these complications is limited joint mobility (LJM) that has been defined as the reduction of joint range of motion (ROM), usually associated with stiffness, which can affect the joints of the whole body in patients with diabetes at different ages.5–9

Even if the etiopathogenesis has not been fully explained, however, it is known that several factors can concur in defining it. It has been reported that in patients with diabetes the reduced glycemic control maintained over time is the most important cause of LJM.10 The main biochemical abnormality in joint tissue induced by diabetes is the excess of non-enzymatic glycosylation of collagen that produces advanced glycation end products (AGEs). AGEs increase the collagen cross-links altering the mechanical properties of fibers,
reducing elasticity and tensile strength and thus inducing mechanical stiffness.6–9,11

As a result, LJM is a complication that begins developing at disease onset, can affect young patients, and its prevalence is higher in subjects with long-term disease.9,12,13

In addition to known factors such as the metabolic control maintained and diabetes duration, others unknown can also contribute to an increased stiffness of skin, joint capsule, ligaments, and tendons and then to the development of LJM.9,14

It has been reported that in adults, the abnormal use of joints, as in the case of an altered gait biomechanics or the lack of movement, can play a role in the development of LJM.15–19

On the contrary, it has been shown that just a few weeks of exercise training program can improve joint mobility in patients with diabetes.20–23 Even in young subjects it has been suggested that lifestyle and sports practiced can modify their LJM.9,24,25

All this suggests that the evaluation of the sport-related effect on young subjects’ joint mobility could allow a better understanding of the causes and of the ensuing LJM.

Regarding joints to evaluate, it is well known that LJM is a widespread complication affecting joints of the whole body. The distal joints of upper limbs generally, and finger joints specifically, can be particularly affected and have been thoroughly studied.5–12 However, lower limbs also can be affected by diabetes. The fact that the foot and ankle joints continuously bear weight could magnify the typical stiffening effects of diabetes.6,9,26

In particular, ankle ROM can be significantly affected by diabetes. Studying ankle ROM in young T1D patients can be important because its deficit can affect the quality of gait and posture, in addition to the motor and postural development of young patients.16,27–29

The aims of this study were to verify the presence of ankle LJM in both plantar and dorsiflexion in young T1D patients and determine the possible role of sport practiced on AJM deficits.

2 | PATIENTS AND METHODS

Patients attending the Meyer Children Hospital of Florence, Italy, were consecutively recruited for evaluation of AJM in plantar and dorsal flexion. A total of 82 patients with T1D were evaluated and compared with 226 healthy controls. Both young groups (patients and controls) ranged in age from 8.8 to 18.0 years. Data were collected on age, sex, body mass index (BMI), type of diabetes, diabetes duration, lower limb-dominance, and sport practiced. BMI was expressed as body weight in kilograms divided by height in meters squared (kg/m²). The detailed clinical characteristics of study participants are shown in Table 1. Exclusion criteria were presence of current foot and ankle problems at baseline as well as orthopedic and/or surgical complications. The physical examination included foot inspection and presence of neuropathy. Hemoglobin A1c was measured at baseline by high-performance liquid chromatography (HPLC) method. While in both groups, there was a number of subjects who had practiced soccer, volleyball, basketball, and dance for at least 1 year continuously before the AJM assessment, in the patients’ group, some subjects were sedentary or practiced swimming, tennis, and other sports, such as athletics, horse riding, and martial arts. If subjects were practicing more sports at the same time, the subject was assigned to the sport group which had the most weekly sessions and, if the training sessions were equal, subject was assigned to the one practiced longer. But if that was not the case, the subject was assigned to the group “other sports.”

3 | DETERMINATION OF JOINT MOBILITY

AJM was evaluated using an inclinometer (Fabrication Enterprises Inc, White Plains, NY)30–32 with the patient lying supine with the feet over the edge of the hospital bed, The knee, corresponding to the evaluated ankle, was extended and put over a rigid support 5-cm high. The maximum range of dorsal and plantar flexion was determined after drawing with the demographic pen the fifth metatarsal bone and positioning the inclinometer along the diaphysis of the bone, with one extremity put on the distal condyle. The subtalar joint was in a neutral position while the ankle joint was in the resting position that it naturally takes on the sagittal plane.

All measurements were performed by the same observer, recording the mean of 3 consecutive readings. All participants, parents, or care givers of the young patients were informed on the purpose of the study and its experimental procedures before obtaining their written informed consent and the enrollment in the study. The protocol and the consent forms were approved by the Pediatrics Ethics Committee of Meyer Children’s Hospital in Florence (protocol numbers: 161/2016 on September 29, 2016). The study was performed according to the principles expressed in the Declaration of Helsinki.

4 | STATISTICAL ANALYSIS

Data were reported as means ± SD or percentage, as appropriate. ROM values were expressed in degree and reported as means ± SD. Comparisons among groups were analyzed by ANOVA, using the Bonferroni correction for multiple comparisons. Comparisons between frequencies were performed using the χ² method.

Multiple regression analysis was performed using the presence of diabetes as the dependent variable and all other variables as confounding factors (metabolic control, duration of disease, sex, age, BMI) for univariate analysis. A 2-tailed P value of <.05 was regarded as statistically significant. All calculations were performed using the SPSS system for Windows Version 24.0 (SPSS Inc., Chicago, Illinois).

5 | RESULTS

As shown in Table 1, patients and controls were well matched for age, sex, and BMI; Total AJM was significantly lower in young patients with T1D compared to controls (P < .017). In particular, plantar flexion resulted to be the most reduced in patients (P < .002).

We performed a multivariate analysis with AJM as the dependent variable. After this analysis, age, sex, duration of disease,
hemoglobin 1Ac, and BMI did not show correlation with the mobility assessed. From this analysis, only diabetes remained significantly associated with AJM reduction.

The analysis of the effect of different sports practiced on AJM showed that it was significantly reduced in soccer players of control group ($P < .001$) while this difference was no more evident in patients with T1D (Tables 2 and 3).

However, among patients, the group of soccer players showed lower mobility than patients practicing other sports, while there was no significant difference in mobility after excluding those who practiced soccer (Table 2).

When the patients’ group is compared to controls, excluding soccer players, the significance of the difference between the 2 groups is marked (Table 2; $P < .001$).

Subdividing controls and patients with T1D by sex, excluding once again soccer players, the control group males showed a notable reduction of plantar flexion ($P < .006$) and of the total AJM ($P < .014$; Table 5), while in the patients’ group there were no differences between genders.

Mobility between right and left ankle was not significantly different in those with diabetes or in controls, independently by the type of sport practiced.

6 | DISCUSSION

In T1DM adult patients, especially if they have peripheral neuropathy, LJM is considered a dangerous complication because it becomes a major ulcerative risk factor. In young patients, LJM is not associated with the risk of developing foot ulcers and it cannot be evaluated as a dangerous complication in the category of nephropathy or neuropathy. However, the study of LJM in young subjects with T1DM, in addition to being investigated for its correlation with other severe chronic complications induced by diabetes (i.e., retinopathy or nephropathy), should be considered also for its possible negative effects on the body and motor development. In this sense, it is known that LJM is both the cause and the effect of abnormal postures and deformities of the hand and foot.

This study investigated how diabetes affects ankle plantar and dorsal flexion. In addition, we studied how practicing different sports could affect AJM of young patients with T1D.

The results of this study on 2 large groups of young subjects with and without T1D show that in young patients the AJM is significantly reduced compared to healthy controls (Table 1).

In particular, plantar flexion was significantly reduced in patients.

These results confirm that diabetes can induce alterations of connective and muscle tissues in the lower limb and foot. Among these, the effects of diabetes on the Achilles tendon and plantar fascia are particularly marked and they can induce an even stiffer feet posture in an even more plantar flexion. It is known that these alterations over time lead to gait abnormalities and the development of deformities.

The control group was composed by subjects practicing 4 different sports when AJM evaluation was carried out, while the T1D patients group, according to the recruitment system adopted, practiced more sports in addition to being also composed by a group of sedentary subjects (Tables 2 and 3). Control subjects who practiced soccer showed a significant AJM reduction in each of the movements evaluated and a lower AJM than patients. This negative effect of soccer is less evident in patients probably because diabetes in itself reduces AJM by making it similar to the value recorded in soccer players.

The negative effect of soccer on ankle mobility resulted to be worse than that induced by diabetes, and it aligns the groups of patients to the same level of mean mobility (Tables 2 and 3).

Due to the significant negative effect of soccer on AJM, the data collected were processed without considering soccer players, both in patients and in controls.
|                                  | Soccer       | Basketball  | Dance       | Other sports | No sports | P value   |
|----------------------------------|--------------|-------------|-------------|--------------|-----------|-----------|
| No.                              | 14           | 7           | 7           | 40           | 11        |           |
| Gender (M/F)*                    | 13/1         | 6/1         | 0/7         | 22/18        | 5/6       | <.002     |
| Age (y)                          | 12.8 ± 2.6 [9.2-17.5] | 12.7 ± 2.5 [9.8-17.7] | 12.7 ± 2.6 [9.2-16.9] | 13.1 ± 2.5 [9.2-18] | 12.8 ± 3.2 [9.3-18] | NS        |
| BMI (kg/m²)                      | 20.3 ± 3.9 [14.3-28.5] | 16.6 ± 2.1 [14.4-20.1] | 20.5 ± 2.1 [17.5-23.6] | 19.8 ± 3.8 [14-27.6] | 20.5 ± 3.3 [15.5-27.2] | NS        |
| Diabetes duration (y)            | 4.3 ± 1.9 [1.3-7.1] | 7.9 ± 4.0 [2.1-14.8] | 4.8 ± 3.1 [1-8.7] | 5.8 ± 3.6 [0.2-15.2] | 6.0 ± 2.8 [1.5-11.8] | NS        |
| HbA1c (%)                        | 7.3 ± 0.7 [6.3-8.8] | 7.5 ± 0.6 [6.6-8.3] | 7.0 ± 0.4 [6.5-7.7] | 7.7 ± 1.2 [5.6-11.7] | 7.5 ± 1.0 [6.3-8.8] | NS        |
| Total right AJM (°)              | 61.2 ± 7.4 [48-71.4] | 64.6 ± 9.8 [45-75] | 63.0 ± 17.0 [29-81.3] | 64.6 ± 7.8 [41.3-82.3] | 65.0 ± 10.3 [53.3-84.7] | NS        |
| Total left AJM (°)               | 58.9 ± 9.9 [353-77.7] | 62.6 ± 4.8 [56.7-70] | 61.3 ± 16.9 [27.4-82] | 62.3 ± 8.9 [3.3-81.7] | 64.4 ± 10.2 [41.4-76] | NS        |
| ΔRight/left (°)                  | 6.0 ± 4.2 [0.6-12.7] | 6.0 ± 3.8 [2-11.7] | 3.1 ± 4.2 [0.7-12.3] | 4.0 ± 4.4 [0.1-17] | 5.0 ± 5.2 [0.4-15.4] | NS        |
| Plantar flexion (°)              | 26.2 ± 6.0 [14-35.4] | 30.8 ± 8.6 [17.7-44] | 28.6 ± 9.9 [10-41.3] | 28.6 ± 6.4 [14.3-39.3] | 29.0 ± 4.5 [19.7-38] | NS        |
| Dorsal flexion (°)               | 93.9 ± 13.2 [69.3-121.3] | 96.5 ± 6.7 [84-104] | 95.8 ± 25.7 [46.4-122] | 98.3 ± 13.0 [58-130] | 100.4 ± 16.0 [75-120.7] | NS        |
| Total AJM (°)                    | 120.1 ± 15.9 [83.3-147.7] | 127.3 ± 13.6 [101.7-145] | 124.4 ± 33.5 [56.4-163.3] | 126.9 ± 15.9 [76.7-164] | 129.5 ± 19.0 [94.7-158.7] | NS        |
| Time of practice (yrs)           | 4.7 ± 2.2 [2-9] | 4.0 ± 2.8 [1-9] | 4.3 ± 2.0 [1-7] | 3.1 ± 2.1 [1-9] | -         | NS        |

Abbreviations: AJM, ankle joint mobility; ANOVA, Analysis of variance; BMI, body mass index; NS, Non-significant. One-way ANOVA (P value) test. Values are means ± standard deviation [range]. AJM expressed as means ± SD degrees (°). a vs b: P < .05.

*a By χ² method.
TABLE 3  Main characteristics and joint mobility of controls subdivided by sport practiced

| Control group | Soccer | Volleyball | Basketball | Dance | All groups P value | All less soccer group P value |
|---------------|--------|------------|------------|-------|-------------------|-------------------------------|
| No.           | 93     | 91         | 25         | 17    |                   |                               |
| Gender (M/F)  | 83/10  | 34/57      | 23/2       | 6/11  |                   |                               |
| Age (y)       | 13.0 ± 2.2 [9.16.8]ab1 | 12.4 ± 1.7 [8.7-16.2]b1, a2 | 10.8 ± 1.0 [8.9-12.2]a1 | 12.7 ± 1.0 [8.7-17.1]b1, a2 |                   |                               |
| BMI (kg/m²)   | 19.2 ± 2.5 [14.6-23.9] | 18.8 ± 2.6 [14-26.3]b | 20.4 ± 4.3 [16-31.2]b | 20.3 ± 4.5 [14.3-26.4] |                   |                               |
| Total right AJM (°) | 59.6 ± 10.7 [12-81.3]b | 70.9 ± 8.7 [44-92.7]b | 69.9 ± 10.5 [38-89.3]b | 72.7 ± 9.9 [57.6-86]b |                   |                               |
| Total left AJM (°) | 59.8 ± 11.6 [14.7-75.6]b | 70.4 ± 9.0 [49-92.9]b, a1 | 70.1 ± 13.3 [36.6-95.7]b | 75.6 ± 12 ± [59.3-91.9]b |                   |                               |
| ΔRight/left (°) | 5.4 ± 4.6 [0-18.6] | 4.7 ± 4.4 [0-24.6] | 4.9 ± 3.6 [0-16] | 5.4 ± 4.2 [0-27] |                   |                               |
| Plantar flexion (°) | 28.0 ± 7.6 [5.7-52]b | 34.3 ± 6.6 [21-49.4]b | 32.1 ± 9.6 [10-6-49.7]b | 36.3 ± 8.9 [22.9-42]b |                   |                               |
| Dorsal flexion (°) | 91.4 ± 17.5 [24-129.3]b | 107.1 ± 13.9 [74.6-149.7]b | 108.0 ± 17.5 [64-135.3]b | 112.0 ± 16.9 [83.9-130.6]b |                   |                               |
| Total AJM (°) | 119.4 ± 21.1 [29.7-156.6]b | 141.3 ± 16.6 [96.7-183]b | 140.1 ± 23.1 [74.6-185]b | 148.3 ± 21.6 [118.5-170.7]b |                   |                               |
| ΔPlantar flexion (°) | 5.8 ± 2.8 [1-8] | 4.4 ± 2.6 [1-10] | 2.8 ± 1.6 [1-7] | 1.6 ± 0.8 [1-3] |                   |                               |

Abbreviations: AJM, ankle joint mobility; ANOVA, Analysis of variance; BMI, body mass index; NS, Non-significant. One-way ANOVA (P value) test. Values are means ± standard deviation [range]. AJM expressed as mean ± SD degrees (°). a vs b: P < 0.05. *By χ² test. a vs. b, a1 vs. b1, a2 vs. b2: P < 0.05.
exerted in addition to speed and amplitude of movement in different sports could induce excessive stress and overuse on periarticular structures of young patients.25,26,45,50 Moreover, in sports such as soccer LJM may worsen due to the continuous trauma to which joints such as the ankle can undergo.25,51,52

As a whole, the results show that diabetes significantly reduces AJM in young T1D subjects. Moreover, this study allowed us to determine that even the sport practiced by young patients can contribute to the development and the amount of LJM. In particular, the sport practiced can significantly modify such parameters and hinder the interpretation and use of the data collected by AJM measurement.

However, the measurement of AJM, both in dorsiflexion and plantar flexion, as evaluated in this study, can provide important information on joint conditions disease-induced and therefore on the risk of developing joints, gait, and postural alterations.

Although LJM should be studied in detail, and sports practice should be always promoted in childhood, even in young patients with T1D, it may be useful to adopt appropriate strategies to prevent the development of LJM and the stiffness of periarticular tissues generally. This could be achieved by appropriate exercise training protocols and daily lifestyle interventions as well as maintaining a good metabolic control.

**Conflict of interest**

The authors have no conflicts of interest regarding the content of this article.
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