Original Article

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Effects of gender and age on the range of motion of foot joints in Japanese diabetic patients

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Abstract

Although patients with diabetes often are well known to have limited mobility in their ankle joints, limited information is available regarding how this effect is distributed by gender or age. This study was performed to address these questions. The subjects were divided into four groups, i.e., 28 male diabetic older (MDO) patients (age range, 50 - 69 years), 14 male diabetic young (MDY) patients (age range, 30 - 49 years), 10 female diabetic older (FDO) patients (age range, 50 - 69 years), and 10 healthy male control subjects (age range, 50 - 69 years). Control age and gender matched (CAG) means that the control subjects matched with MDO patients in gender and age. The parameters examined were passive range of motion of plantar flexion and dorsiflexion of the ankle joint, flexion and extension of the first metatarsophalangeal joint, and pronation as well as supination of the subtalar joint. Each range of motion was compared across all four groups. The ankle ranges of motion for the MDO, MDY, FDO, and CAG groups were 55.4° ± 8.4°, 56.8° ± 6.9° , 60.7° ± 9.5° , and 69.1° ± 9.2° , respectively. The MDO and MDY groups had significantly decreased capability in this regard compared with the CAG group. In contrast, the first metatarsophalangeal ranges of motion for the MDO, MDY, FDO, and CAG groups were 82.9° ± 9.6° , 86.7° ± 13.7° , 90.2° ± 11.6°, and 96.3° ± 8.9°, respectively. The MDO group had significantly lower values than the CAG group, but there was no significant difference in the subtalar range of motion between these two groups. This study suggested that limited ankle joint mobility may occur in female diabetic patients independent of age.

KEY WORDS

Diabetes mellitus, Limited joint mobility, Foot joints, Gender, Aging

Introduction

Having a normal range of motion (ROM) of the foot joints is one of the physical functions necessary for performing a forward movement of the smooth center of gravity during walking. Once the ROM of ankle joints is restricted, it causes an increase in the plantar pressure during the stance phase [1, 2)]. It is well known that patients with diabetic mellitus (DM) frequently develop limited joint mobility (LJM) of the foot joints [1-6)]. For those diabetic patients who are prone to foot ulcers due to poor peripheral circulation dynamics and impaired sensation[3-5)], LJM of the ankle increases the risk of foot ulcer formation via an increase in plantar pressure[7-9)]. Therefore, it is clearly important to prevent this issue from developing if patients are to maintain a high quality of life and remain active in their daily living. At this point it appears that ROM issues with diabetic patients have not been examined in detail regarding gender and age.

In previous studies it has been shown that females

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have higher muscle flexibility and ROM than males[10]. From these facts, it is clear that females with DM can be expected to have a smaller LJM than diabetic males of the same age. It is also clear that if the gender is the same, the ankle ROM becomes increasingly restricted with age[11]. Earlier studies have shown that LJM of the hand can develop in childhood and also in young-onset insulin-dependent DM patients[12, 13]. In other words, there is a possibility that LJM is similarly generated even in young diabetic patients. There have been reports suggesting the influence of gender differences and age on LJM in diabetic patients, but details have not been clarified. It would be valuable to rigorously determine the effects of gender and age to better anticipate, prevent, and treat the risk of LJM in diabetic patients. In this study we therefore aimed to definitively understand the relationship between ankle ROM, gender, and age in diabetic patients. The hypothesis is that LJM at the ankle of females with DM is suppressed compared to that in males of the same age, and that in young male diabetic patients the foot ROM is restricted as much as for those middle-aged.

Methods

1. Subjects

Our subjects consisted of 38 older DM patients (age range, 50-69 years), 14 younger male DM patients (age range, 30-49 years), and 10 male healthy control subjects (age range, 50-69 years) were also enrolled. These diabetic patients admitted to the Japanese Red Cross Kanazawa Hospital for glycemic control and diabetes education. These subjects were divided into four groups as follows: male diabetic older patients group (MDO), younger male diabetic patients group (MDY), female older diabetic patients group (FDO), and a control age- and gender-matched (CAG) group. CAG means that the control subjects matched with MDO patients in gender and age. All subjects were able to walk without assistance. No subjects had a history of diabetic foot ulcers or arteriosclerosis obliterans. The exclusion criteria for the present study were any severe orthopedic or central nervous system diseases affecting the gait pattern.

All examinations were performed in accordance with the Declaration of Helsinki, and all patients provided informed consent for participation in the present study, which was approved by the Japanese Red Cross Kanazawa Hospital ethics committee.

2. Measurements

The measured parameters included passive ROM of the plantar flexion and dorsiflexion of the ankle joint, flexion and extension of the first metatarsophalangeal joint, and pronation and supination of the subtalar joint. We measured the LJM using the right foot, and all ROM assessments were executed using well-established methods[14, 15]. All ROMs were measured by two physical therapists who were not members of the research group. The examiners and participants were blinded to the purpose of this study. Measurements of the ankle and first metatarsophalangeal joints were performed with patients in the supine position, with a roll placed under the knee to position it in a slight flexion. The subtalar joint was maintained in an anatomical position, and the stationary arm was the longitudinal axis of the fibula, while the movable arm was the sole of the heel. The ankle and toes were maintained in the neutral position. The axis was placed over the dorsum of the first metatarsophalangeal joint of the toe being measured, and, in this case, the stationary arm was the longitudinal axis of the metatarsal, while the movable arm was the longitudinal axis of the proximal phalanx.

Measurements of the subtalar joint were also performed with patients in the prone position, with the foot protruding from the bed. The ankle and first metatarsophalangeal joints were maintained in an anatomical position. The stationary arm, in this case, was the center line on the back of the lower leg, and the movable arm was the longitudinal axis of the calcaneus. All measurements were performed using a double-armed digital goniometer (GM-180; nihon-ikakikaiseisakusyo, Osaka, Japan) calibrated in 1-degree increments. The maximum ROM of each joint was measured three times and the average of these three values was calculated.

We collected key data items on the diabetes status of each subject (i.e., duration, status of diabetic polyneuropathy, and hemoglobin A1c levels at admission). Diabetic polyneuropathy was defined as an abnormality in the nerve condition velocity, or an attenuation of the protective sensation, as determined by the Semmes-Weinstein 4.56 monofilament test.

3. Statistics

Data considered to be parametric in nature were examined using a one-way analysis of variance. Non-parametric data regarding the subjects, such as age, hemoglobin A1c levels, and duration of diabetes, were examined using the Kruskal-Wallis test, with the Bonferroni test used for post hoc analysis. The status of diabetic polyneuropathy was compared across the three diabetic groups (MDO, MDY, and FDO) with the chi-squared test. Each ROM was compared across all four groups (MDO, MDY, FDO, and CAG) with a one-way analysis of variance. The Bonferroni test was used for the post hoc analyses. The significance level was set at $p < 0.05$. Statistical analyses were performed using SPSS ver.11.0 for Windows (SPSS, Inc., Chicago, IL, USA).

Results

The characteristics of our subjects are shown in Table 1. The each ROMs in CAG were almost similar to the reference values[14, 15].There were no statistical differences across the groups regarding the diabetes status. The passive range of motion of ankle joint (ANK) measurements for the MDO, MDY, FDO, and CAG were 55.4°± 8.4°, 56.8°± 6.9° , 60.7°± 9.5°, and 69.1° ± 9.2 ° , respectively, and we noted that these values were significantly lower in the MDO and MDY than in the CAG (Fig. 1). The (passive range of motion of metatarsophalangeal joint) MTP values for the MDO, MDY, FDO, and CAG were 82.9°± 9.6° , 86.7°± 13.7°, 90.2 °± 11.6 °, and 96.3 °± 8.9 °, respectively. Here it was clear that the MDO had significantly lower values compared with the CAG group (Figure. 1). There was no significant difference across the other groups. There was also no significant difference between the groups in the passive ROM of the subtalar joints.

Table 1. Subjects characteristics and range of motion

	MDO	MDY	FDO	CAG	p-value
Subjects	28	14	10	10	
Age (years)	59.8 ± 5.9	42.1 ± 5.8†‡*	59.2 ± 5.1	59.2 ± 5.1	<0.01
Body weight (kg)	74.1 ± 11.6‡	81.3 ± 14.7‡	56.7 ± 11.5	67.8 ± 12.2	<0.01
Body mass index (kg/m^2)	25.2 ± 3.6	27.3 ± 4.3	23.0 ± 3.8	23.4 ± 4.1	<0.05
Hemoglobin A1c levels (%)	9.2 ± 1.3	10.8 ± 2.3	9.6 ± 1.9		0.097
Time since diabetes diagnosis (years)	8.5 ± 7.5	4.3 ± 6.7	5.8 ± 7.6		0.132
Diabetic polyneuropathy (%)	8(28.6)	2(14.3)	1(10)		0.356
ANK	55.4 ± 8.4*	56.8 ± 6.9*	60.7 ± 9.5	69.1 ± 9.2	<0.01
MTP	82.9 ± 9.6*	86.7 ± 13.7	90.2 ± 11.6	96.3 ± 8.9	<0.05
ST	26.0 ± 7.9	26.5 ± 5.3	29.0 ± 5.3	28.0 ± 5.3	0.614

† : p < 0.01 vs MDO, ‡ : p < 0.01 vs FDO, *: p < 0.01 vs CAG
Data are *n* or means ± SD.
ANK, passive range of motion of ankle joint; MTP, passive range of motion of metatarsophalangeal joint; ST, passive range of motion of the subtalar joint.
MDO: older and male group with DM, MDY: younger and male group with DM, FDO: older and female group with DM, CAG: age- and sex-matched and not diabetic

Discussion

An important result of this study is that in the ANK tests in both the MDY and the MDO were about equally restricted compared with that in the CAG. Previous reports have shown that in healthy people,

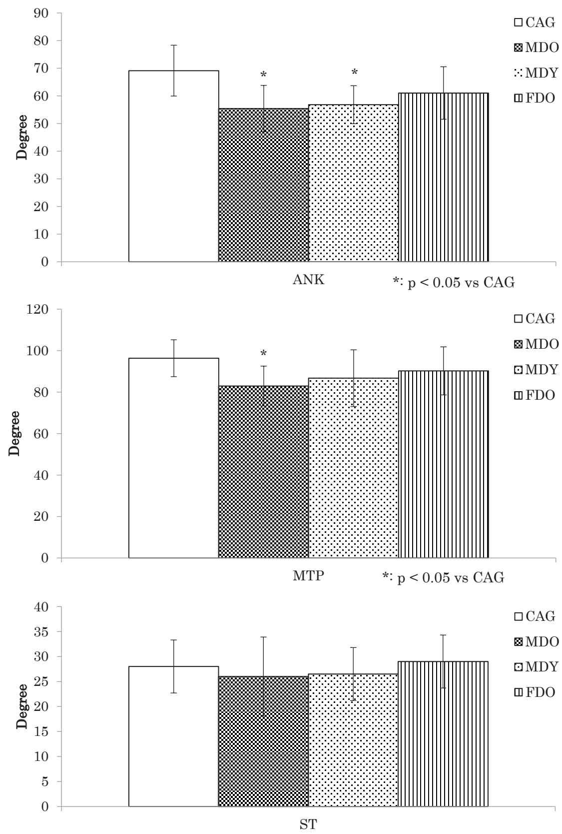

Figure 1. Range of motion of each joint
ANK, passive range of motion of ankle joint; MTP, passive range of motion of metatarsophalangeal joint; ST, passive range of motion of the subtalar joint.
MDO: older and male group with DM, MDY: younger and male group with DM, FDO: older and female group with DM, CAG: age- and sex-matched and not diabetic

the ankle ROM is greater in younger people[11] because ROM presumably becomes restricted with age due to the degeneration of collagen cross-linked structures and a general decrease in the amount of physical activity[16]. On the other hand, it has been reported that LJM does occur in young diabetic patients[12, 13]. Even in these cases, LJM may be caused by increased mechanical rigidity resulting from an increase in collagen cross-linking due to glycation stress and fibrosis of the connective tissue resulting from peripheral blood circulation ischemia[17]. Indeed, this would suggest that the ankle LJM of diabetic patients may be independent of age.

The second important result here is that the outcome for the FDO did not differ significantly from that of either the MDO or the CAG with regard to ANK. Earlier studies have reported that the muscle flexibility of males is low in healthy people[10], and the ankle ROM of males is less than that of females[11]. In this context, it has been suggested that females, with generally smaller muscle sizes compared with males, have less stretched connective tissue, and therefore passive joint resistance torque may be smaller. Referring to these previous studies, differences between genders may be observed by increasing the number of female subjects.

Unlike the data regarding ANK, LJM could not be found at MTP in the MDY. Furthermore, in the data regarding subtalar joints, LJM could be found neither in the MDY nor the MDO. This result shows that LJM appears in the ankle joint of the foot in male diabetic patients, compared to the first metatarsophalangeal and subtalar joints. Therefore, in young male diabetic patients, it is clinically important to evaluate the ankle ROM at an early stage and find the degree of LJM.

One of the limitations of this investigation is that we did not perform a multivariate analysis. Since this work was based on a single facility and the number of subjects was small, it was not possible to sufficiently account for possible confounding factors. In particular, the inability to create a younger female diabetic patients group was a major issue in this study. Another limitation is that the subjects were all Japanese. Hemmerich et al.[18] reports that a non-Western floor sitting culture requires a relatively large ROM for the hip, knee, and ankle joints. Since, in this regard, the Japanese culture is quite unique, the implications of our results here might not be entirely transferable to a broader population.

Given these various limitations, further study involving a broader range of populations would be required to check whether these results are generalizable. It would be particularly interesting to study the difference in responsiveness to treatment of LJM in the context of a rigorous longitudinal study.

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日本人糖尿病患者の足部関節可動域における性別と年齢の影響

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要　旨

【はじめに】足関節の関節可動域制限は糖尿病の患者に発生する頻度が高いことが明らかにされているが，性差や年齢が与える影響は明らかにされていない。本研究の目的は，糖尿病患者における足関節を含む足部関節可動域と性差，年齢の関係を検証することとした。
【方法】対象は糖尿病教育・血糖コントロール目的に入院した糖尿病患者のうち 50 から 69 歳の男性患者 28 名（糖尿病群）を対象とした。比較対象群として年齢，性別をマッチングさせた健常人 10 名 (コントロール群)，年齢のみをマッチングさせた女性患者 10 名（女性糖尿病群），性別のみをマッチングさせた 30 から 49 歳までの男性患者 14 名（壮年男性糖尿病群）を加えた。測定は右下肢の他動関節可動域を足関節底屈 - 背屈方向，第一中足趾節間関節屈曲 - 伸展方向，距骨下関節回内 - 回外方向で計測し， 4 群間で比較した。
【結果】足関節可動域は 55.4 ± 8.4°（糖尿病群），56.8 ± 6.9°（壮年男性糖尿病群），60.7 ± 9.5°（女性糖尿病群），69.1 ± 9.2° (コントロール群) であり，コントロール群と比較して糖尿病群，壮年男性糖尿病群は有意に低値であった。第一中足趾節間関節可動域は 82.9 ± 9.6°（糖尿病群），86.7 ± 13.7°（壮年男性糖尿病群），90.2 ± 11.6°（女性糖尿病群），96.3 ± 8.9° (コントロール群) であり，コントロール群と比較して糖尿病群は有意に低値であった。
【結論】男性糖尿病患者の足関節可動域は，加齢要因とは独立して可動域制限が進展している可能性がある。