J. Phys. Ther. Sci. 31: 540–544, 2019

The Journal of Physical Therapy Science

Original Article

Relationship between range of motion of foot joints and amount of physical activity in middle-aged male diabetic patients

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Abstract. [Purpose] This study aimed to verify the relationship between foot range of motion and the amount of physical activity in diabetic patients. [Participants and Methods] There were twenty-eight male patients with diabetes (age ranged from 50 to 69 years old) and 10 healthy, non-diabetic male individuals within the same age range in the diabetes group and control group, respectively. The passive ranges of motion of the following joints were measured in the right foot of each participant: the ankle joint, the first metatarsophalangeal joint, and the subtalar joint. The amount of daily physical activity was estimated using the short Japanese version of the International Physical Activity Questionnaire. [Results] The mean range of motion of the ankle joints in the diabetic and control groups was 55.4 ± 8.4° and 69.1 ± 9.2°, respectively, whereas the mean range of motion of the first metatarsophalangeal joints in the diabetic and control groups was 82.9 ± 9.6° and 96.3 ± 8.9°, respectively. The diabetic group showed a significantly higher restriction in joint range of motion than did the control group. The amount of physical activity was a contributing factor toward the ankle range of motion according to multiple regression analysis. [Conclusion] We determined that the range of motion in the ankle joints of diabetic patients was affected by their level of physical activity.

Key words: Range of motion, Physical activity, Diabetes mellitus

(This article was submitted Feb. 14, 2019, and was accepted Apr. 3, 2019)

INTRODUCTION

The range of motion (ROM) of the ankle joint is important for the smooth forward movement of the center of gravity during walking. Restriction of ankle joint ROM causes increased plantar pressure during walking[1, 2]. Limited joint mobility (LJM) of the ankle frequently occurs not only in patients who have experienced foot injuries, such as trauma of the ankle joint, but also in those with diabetes mellitus (DM)[1–6]. For diabetic patients who are prone to foot ulcers triggered by poor peripheral circulation dynamics and impaired sensation[3–5], LJM in the foot increases the plantar pressure and consequently the risk of foot ulceration[3, 4, 7–9]. Therefore, it is important to prevent LJM in the foot to maintain the activities of daily living and the quality of life. One of the known factors of LJM is the duration of DM in diabetic patients[10]. In addition, diabetic polyneuropathy tends to strongly restrict ROM[1]. Although the relationship is still unclear, the amount of physical activity (PA) may also be related to foot ROM[6]. Thus, studies of foot ROM are carried out by researchers in the field of DM in addition to researchers on orthopedic diseases, such as ankle sprains, Achilles tendonitis and plantar fasciitis. However, there are few studies on the relation between foot ROM and PA. PA is an important factor in exercise therapy to diabetic patients. It has been reported that the amount of PA increases as a result of lifestyle guidance[11]. The amount of PA is related to glucose

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Table 1. Characteristics of participants

Characteristic	Diabetes (n=28)	Control (n=10)	p-value
Age (yrs)	59.8 ± 5.9	59.2 ± 5.1	0.795
Height (cm)	171.4 ± 6.5	170.1 ± 4.9	0.550
Body weight (kg)	74.1 ± 11.6	67.8 ± 12.2	0.151
Body mass index (kg/m^2)	25.2 ± 3.6	23.4 ± 4.1	0.199
Diabetes duration (yrs)	8.8 ± 7.6		
Hemoglobin A_{1c} level (%)	9.21 ± 1.29		
Diabetic polyneuropathy	9		
Amount of PA per day (kcal)	275.9 ± 420.8	89.4 ± 73.8	0.328
Range of motion			
ANK (°)	55.4 ± 8.4	69.1 ± 9.2	0.000*
MTP (°)	82.9 ± 9.6	96.3 ± 8.9	0.000*
ST (°)	26.0 ± 7.9	28.0 ± 5.3	0.470

Diabetic polyneuropathy was defined as an abnormality in the nerve condition velocity or attenuation of the protective sensation determined by the Semmes-Weinstein 4.56 monofilament test.
PA: physical activity; ANK: passive range of motion of ankle joint; MTP: passive range of motion of metatarsophalangeal joint; ST: passive range of motion of subtalar joint.
*p<0.01.

and lipid metabolism[12] and affects the incidence of cardiac disease, cerebrovascular disease and cancer[13]. Furthermore, PA is related to the autonomy in activities of daily living in elderly people[14]. Increasing the amount of PA not only improves glucose metabolism but it is also an important factor related to a healthy life. Since the amount of PA investigated by the IPAQ is related to the number of steps[15], a large amount of PA may affect foot ROM due to a larger amount of mechanical stimulus to the ankle joint. We hypothesized that foot ROM and the amount of PA are related and that foot ROM increases with the amount of PA. The aim of this study was to verify the relationship between foot ROM and the amount of PA in diabetic patients.

PARTICIPANTS AND METHODS

The participants were 28 male diabetic patients (DM group) aged between 50 and 69 years who were admitted to the Japanese Red Cross Kanazawa Hospital for glycemic control and diabetes education. The control group consisted of 10 healthy, age-matched male controls without a history of chronic medical illness (the control group). All participants were able to walk without any assistive device. None of the participants had a history of diabetic foot ulcers. The exclusion criteria were severe orthopedic or central nervous system disease affecting gait pattern. The participants' characteristics are shown in Table 1. Information on diabetes status (duration of diabetes, status of diabetic polyneuropathy and hemoglobin A_{1c} level at admission) was collected. Diabetic polyneuropathy was defined as an abnormality in the nerve condition velocity or attenuation of the protective sensation determined by the Semmes-Weinstein 4.56 monofilament test. Examinations were performed according to the Declaration of Helsinki. All patients provided written informed consent for participation in the present study. This study was approved by the Kanazawa University Ethics Committee (769-1).

Joint mobility was measured at the right foot. The passive ranges of motion (ROM) of the following joints were measured: plantar flexion and dorsiflexion of the ankle joint (ANK), flexion and extension of the first metatarsophalangeal joint (MTP) and pronation and supination of the subtalar joint (ST). All ROMs were measured using previous methods[16, 17]. Measurements of the ankle and first metatarsophalangeal joints were performed with the participants in the supine position, with a roll placed under the knee to keep the knee in a slight flexed position. The subtalar joint was maintained in a neutral position. The stationary arm was aligned with the longitudinal axis of the fibula, and the movable arm was aligned parallel to the fifth metatarsal for ANK measurement. During the ROM measurement for MTP, the stationary arm was placed on the longitudinal axis of the metatarsal, and the movable arm was the longitudinal axis of the proximal phalanx. The ankle was maintained in the neutral position. Measurements of ST were performed with the participants in the prone position, with the foot over the edge of the plinth. The ankle and first metatarsophalangeal joints were maintained in an anatomical position. The stationary arm was aligned to the midline on the back of the lower leg, and the movable arm was aligned to the longitudinal axis of the calcaneus. All measurements were performed by a physiotherapist who was not a primary investigator of this study using a double-armed digital goniometer (GM-180, Nippon Medical & Chemical Instruments Co., Osaka, Japan) calibrated in 1-degree increments. The maximum ROM of each joint was represented by the average of three measurements.

The amount of PA per day was estimated using the short version of the International Physical Activity Questionnaire (IPAQ), a self-administered questionnaire[18]. The Japanese version of IPAQ had already been guaranteed for reliability and validity in diabetic patients[19]. This questionnaire comprised of items required to investigate the amount of energy required for physical activity of varying intensities. It was possible to estimate energy expenditure during 1 week of PA. In this study, the energy expenditure in 1 week was divided into seven equal parts, representing the amount of PA per day.

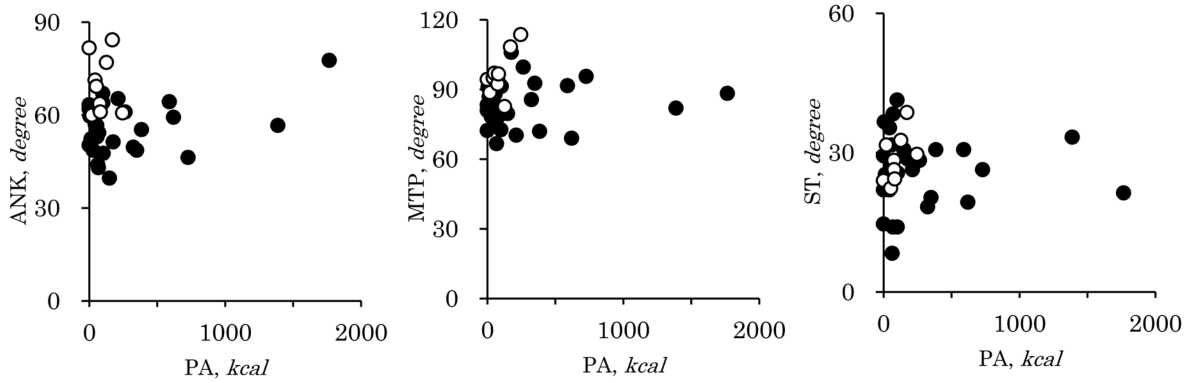

Fig. 1. The scatter diagram between PA and range of motion.
PA: physical activity; ANK: passive range of motion of ankle joint; MTP: passive range of motion of metatarsophalangeal joint; ST: passive range of motion of subtalar joint.
Symbols are: (●) are diabetes group; (○) are control group.

Table 2. Ankle joint of motion result of multiple regression analysis in diabetic patients

	β-Regression coefficient	p-value
Amount of physical activity	0.392	0.039*
Age	−0.120	0.537
Hemoglobin A_{1c} levels	0.064	0.731
Diabetes duration	−0.278	0.130
Diabetic polyneuropathy	0.204	0.272

R=0.392, R^2=0.154, adjusted R^2=0.121, *p<0.05.

Table 3. First metatarsophalangeal joint of motion result of multiple regression analysis in diabetic patients

	β-Regression coefficient	p-value
Diabetes duration	0.496	0.007*
Amount of physical activity	−0.169	0.332
Age	0.256	0.147
Hemoglobin A_{1c} levels	0.132	0.449
Diabetic polyneuropathy	0.095	0.590

R=0.496, R^2=0.246, adjusted R^2=0.217, *p<0.01.

The non-paired t-test was used to test group differences for parametric variables. The Mann-Whitney test was used to test in-between group differences for PA. Age, PA, hemoglobin A_{1c} level, duration of diabetes and diabetic polyneuropathy were entered into a stepwise linear regression to identify factors associated with ANK and MTP. P-values <0.05 were considered to indicate statistical significance. Statistical analyses were performed with SPSS for Windows (SPSS, Chicago, IL, USA).

RESULTS

The scatter diagrams between PA and ROM were shown in Fig. 1. The ANK values for the DM and control groups were 55.4 ± 8.4° and 69.1 ± 9.2°, respectively. The DM group showed significantly more restriction than the control group. The MTP values for the DM and control groups were 82.9 ± 9.6° and 96.3 ± 8.9°, respectively; the DM group also showed significantly more restriction than the control group. There was no significant difference between the groups in ST. The amount of PA for the DM and control groups was 275.9 ± 420.8 and 89.4 ± 73.8 kcal, respectively; there was no significant difference between the groups (Table 1). After multiple regression analysis using ANK as the dependent variable and PA, age, hemoglobin A_{1c}, duration of diabetes and diabetic polyneuropathy as independent variables, only PA was selected as a factor affecting ANK (Table 2). In the multiple regression analysis conducted using MTP as a dependent variable and PA, age, hemoglobin A1c, duration of diabetes and diabetic polyneuropathy as independent variables, only the duration of diabetes was selected as a factor affecting MTP (Table 3).

DISCUSSION

The important result of this study was that ANK and MTP were decreased in the DM group as in the previous study[1–6], and that PA was selected as a factor influencing ANK rather than variables related to glycation stress, such as hemoglobin A1c level, duration of diabetes and diabetic polyneuropathy. As a mechanism, advanced glycation end products reduce the sliding of collagen fibers, leading to loss of viscoelasticity of the entire soft tissue[20]. Abate et al.[6] suggested that LJM in DM patients may be one of several factors in low PA. In other words, low PA may accelerate ankle LJM by glycation in diabetic patients. Intervention by mechanical stimuli, such as manual therapy, has been reported to improve ROM of diabetic patients[5]. Francia et al. recommended the exercise of the joints through the full ROM as an approach to LJM in a review of diabetic foot and exercise therapy[21]. Therefore, according to the results of improvement of lower limb flexibility along PA improvement[22], increased PA may influence the ankle ROM by promoting the use of ankle joints and increase the amount of mechanical stimulus to constituents of ankle joints. Lifestyle guidance and exercise instruction to increase the amount of PA for prevention of LJM can be considered important as well.

A limitation of this study is that it was conducted only on men between 50 and 69 years of age. It is not known whether women would show similar results; women have higher muscle flexibility than men[23] and higher ANK mobility[24]. ROM decreases with age[24, 25]; older patients experience greater joint restriction, whereas younger patients have greater joint mobility. Although MTP was positively correlated with PA in the control group, it was not correlated with PA in the DM group. MTP of diabetic patients may have been influenced by a specific walking pattern such as low stride length[26]. However, it was impossible to clarify this point with this research design. Another limitation of the study is that it was conducted at a single facility on a small number of participants. In near future, increasing the number of participants may contribute to determine the amount of PA needed to maintain ANK. It will be desirable to investigate detailed PA and the plantar pressure variation during walking in the diabetic patients.

In conclusion, ANK and MTP ROMs were significantly decreased in the DM group. ANK was explained by PA. The increased PA may influence the ankle ROM by promoting the use of ankle joints and mechanical stimulus to constituents of ankle joints. Lifestyle guidance and exercise instruction to increase the amount of PA are important for the prevention of LJM in diabetic patients.

Conflict of interest

None.

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