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Original Article

Factors affecting the range of motion of the ankle and first metatarsophalangeal joints in patients undergoing hemodialysis who walk daily

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Abstract. [Purpose] Increased plantar pressure during walking is a risk factor for foot ulcers because of reduced range of motion at the ankle and first metatarsophalangeal joints. However, the range of motion in patients undergoing hemodialysis has not yet been determined. A cross-sectional study was performed to investigate the factors affecting the range of motion of the ankle and first metatarsophalangeal joints in patients undergoing hemodialysis who walk daily. [Subjects and Methods] Seventy feet of 35 patients receiving hemodialysis therapy were examined. Measurements included the passive range of motion of plantar flexion and dorsiflexion of the ankle joint, and flexion and extension of the first metatarsophalangeal joint. [Results] Hemodialysis duration was not associated with ankle and first metatarsophalangeal joint range of motion in patients undergoing hemodialysis. Diabetes duration was significantly associated with limited ankle joint mobility. Finally, blood hemoglobin levels, body mass index, and age were associated with first metatarsophalangeal joint range of motion. [Conclusion] The present study identified age, diabetes, and decreased physical activity, but not hemodialysis duration, to be risk factors for limited joint mobility of the ankle and first metatarsophalangeal joints in patients undergoing hemodialysis.

Key words: Hemodialysis, Range of motion

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INTRODUCTION

Joint range of motion (ROM) is an important physical function of daily living. In particular, normal ROM of the ankle and first metatarsophalangeal joints is important for smooth movement of the center of gravity in the anterior direction in the terminal stance during gait. Decreased ROM of the ankle and first metatarsophalangeal joints results in limited joint mobility (LJM) of the foot joints, causing gait disturbance and increased plantar pressure during walking. LJM of the ankle and first metatarsophalangeal joints in patients with diabetes was associated with elevated maximum peak plantar pressure during gait[1)]. Furthermore, high plantar pressure is a risk factor for diabetic foot ulcers[2)]. An association between LJM of the ankle and first metatarsophalangeal joints and risk of diabetic foot ulcers has been reported by a number of studies[3–8)].

However, only a few studies have evaluated the relationship between LJM of foot joints in dialysis patients[9)]. Elevated serum phosphorous levels, elevated calcium and phosphorous product values, and hyperparathyroidism are reportedly associated with vascular calcification in patients undergoing hemodialysis[10)]. Furthermore, peripheral arterial disease is common among patients undergoing hemodialysis. Therefore, patients undergoing hemodialysis are at an increased risk of ischemic foot ulcers. Moreover, diabetic mellitus is a major risk factor for foot ulcers. In particular, sensory loss because of diabetic peripheral neuropathy is strongly correlated with an increased risk of neuropathic foot ulceration[11, 12)]. Thus, patients undergoing hemodialysis have an increased risk of neuropathic foot ulcers. Nevertheless, foot joint ROM in patients undergoing

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hemodialysis is unclear. Joint stiffness because of amyloidosis has been reported in patients receiving long-term dialysis[9]. In addition, articular hyper mobility has been reported in this patient population[13]. However, neither of these studies with conflicting results examined foot joints or evaluated ROM.

The importance of ROM in preventing foot ulceration in patients undergoing hemodialysis has yet to be completely elucidated. Therefore, it was hypothesised that hemodialysis therapy was a risk factor for LJM of the foot. To test this hypothesis, ankle and first metatarsophalangeal joint ROM in patients undergoing hemodialysis were evaluated to assess the correlation between hemodialysis therapy and LJM.

SUBJECTS AND METHODS

Seventy feet of 35 patients who received hemodialysis therapy at our hospital (Hemodialysis Center of Japanese Red Cross Kanazawa Hospital) were examined. Examinations were performed according to the Declaration of Helsinki. All patients were able to walk without an assistive device. Patient characteristics are shown in Table 1. On preliminary examination, the ROM of both the foot joints was asymmetrical. Therefore, the joints of both the feet were measured. Hemodialysis duration ranged from 7 to 246 months, including periods of peritoneal dialysis in two patients. The exclusion criteria for the present study were severe orthopedic and central or peripheral nervous system disease affecting gait pattern. All patients provided informed consent for participation in the present study.

The parameters measured were passive ROM of flexion and extension of the first metatarsophalangeal joint and plantar flexion and dorsiflexion of the ankle joint. ROM was measured according to previously described methods[14]. All the measurements were performed with patients in the supine position, with a roll placed under the knee to position the knee in slight flexion. The subtalar joint was maintained in an anatomical position. The stationary arm was the longitudinal axis of the fibula, and 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. The stationary arm was the longitudinal axis of the metatarsal, and the movable arm was the longitudinal axis of the proximal phalanx. All ROMs were measured with a double-armed digital goniometer (GM-180, nihon-ikakikaiseisakusho, JPN) calibrated in 1-degree increments. The maximum range of dorsal flexion to plantar flexion was recorded. The mean of three readings was calculated and reported as the final measured value. All measurements were performed by the same investigator (K.W.). To prevent measurement bias, another investigator recorded all measurements (M.S.). Clinical data were extracted from medical notes. Data included the following variables: hemodialysis duration, diabetes duration, body mass index (BMI), and serum albumin (ALB), hemoglobin (Hb), hematocrit (Ht), and serum parathyroid hormone-intact (PTH-int) levels.

Correlational analyses were performed using Pearson correlation coefficients to determine associations between each ROM and age, hemodialysis duration, diabetes duration, BMI, and ALB, Hb, Ht, and PTH-int levels. Pearson correlation coefficients between ROM and diabetes duration were calculated for the data of patients with diabetes only. Age, hemodialysis duration, diabetes duration, BMI, and ALB, Hb, Ht, and PTH-int levels were entered into a stepwise linear regression to identify factors associated with foot joint ROM, with multi co-linearity eliminated. P values <0.05 were considered to indicate statistical significance. Statistical analyses were performed with SPSS for Windows (SPSS, Inc., Chicago, IL, USA).

RESULTS

ROM values for the first metatarsophalangeal joint and ankle joint were 80.3° ± 16.8° and 64.9° ± 13.6°, respectively.

A positive correlation was observed between ROM of the first metatarsophalangeal joint and hemodialysis duration ($r=0.33$, $p=0.005$), and Hb ($r=0.40$, $p=0.001$), Ht ($r=0.38$, $p=0.001$) and ALB levels ($r=0.26$, $p=0.03$). A negative correlation was observed between ROM of the first metatarsophalangeal joint and age ($r=-0.40$, $p=0.001$; Table 2). A positive correlation was observed between ROM of the ankle joint and hemodialysis duration ($r=0.33$, $p=0.005$). A negative correlation was observed between ROM of the ankle joint and age ($r=-0.39$, $p=0.001$; Table 2).

ROM of the first metatarsophalangeal joint was positively correlated with Hb and negatively correlated with age and BMI (Table 3). ROM of the ankle joint was negatively correlated with diabetes duration (Table 4).

DISCUSSION

To the best of our knowledge, this is the first study to determine the factors affecting ROM of the ankle joint and the first metatarsophalangeal joint in patients undergoing hemodialysis who walk daily. The present study had three major findings. First, hemodialysis duration was not involved in the ankle joint and metatarsophalangeal joint ROM in patients undergoing hemodialysis. Second, diabetes duration was a significant risk factor for LJM of the ankle. Finally, Hb levels, BMI, and age were significant risk factors for reduced ROM of the first metatarsophalangeal joint in multiple regression analyses.

Receiving long-term dialysis were prone to tendinous and ligamentous hyperlaxity and articular hyper mobility because of secondary hyperparathyroidism[13]. Although in the present study, it was hypothesised that LJM correlates with hemodialysis duration, the results of the present study are consistent with the proposal made previous study[13]. An anatomical study suggested an interaction between the geometry of the ligaments and the shapes of the articular surfaces in guiding and

Table 1. Patient clinical and biochemical characteristics

Clinical and biochemical characteristics	n or mean (SD)
Patients	35
Age (years)	63.0 (11.52)
Gender (male/ female)	27/8
Hemodialysis duration (months)	79.9 (59.79)
Primary disease for which hemodialysis was performed	
Diabetic nephropathy	17
Nephritis	12
IgA nephropathy	14
Nephrosclerosis	1
Polycystic kidney	1
Body mass index (kg/m^2)	20.8 (2.50)
Serum albumin (g/dl)	3.7 (0.41)
Hemoglobin (g/dl)	10.5 (1.41)
Hematocrit (%)	32.9 (4.39)
Parathyroid hormone-intact (pg/ml)	193.4 (185.91)
Patients with diabetes mellitus	18
Diabetes duration (months)	272.7 (102.22)

Nephritis includes chronic nephritis, interstitial nephritis and glomerulonephritis.

Table 2. Pearson correlation coefficients between range of motion of foot joints and variables

Variables	First metatarso-phalangeal joint	Ankle joint
Age	−0.40 ††	−0.39 ††
Body mass index	−0.14	−0.13
Hemodialysis duration	0.33 ††	0.33 ††
Serum albumin	0.26 †	0.11
Hemoglobin	0.40 ††	0.08
Hematocrit	0.38 ††	0.07
Parathyroid hormone-intact	0.08	0.17
Diabetes duration*	0.07	−0.19

*Feet of patients with diabetes mellitus (n=36). †p<0.05; ††p<0.01

Table 3. Factors affecting range of motion of the first metatarsophalangeal joint from linear regression analysis

	Unstandardized Coefficients	Standardized Coefficients	95% confidence interval	VIF
(Constant)	119.59 †		68.02 to 171.15	
Hemoglobin	3.77 †	0.31	1.27 to 6.27	1.07
Age	−0.60 †	−0.41	−0.92 to −0.28	1.18
Body mass index	−1.98 †	−0.29	−3.41 to −0.55	1.11

R=0.58; R^2=0.33; adjusted R^2=0.30; †p<0.01

Table 4. Factors affecting range of motion of the ankle joint from linear regression analysis

	Unstandardized Coefficients	Standardized Coefficients	95% confidence interval
(Constant)	71.99 †		68.40 to 75.59
Diabetes duration	−0.059 †	−0.58	−0.068 to −0.034

R=0.58; R^2=0.34; adjusted R^2=0.33; †p<0.01

stabilizing passive ankle dorsi-plantar flexion[15]. Releasing the first plantar aponeurosis bundle increased ROM of the first metatarsophalangeal joint[16]. Therefore, in this study, it was propose that the positive correlation between ROM of both the joints and hemodialysis duration is predominantly because of the joint structure being enhanced by tendons and ligaments, such as at the first metatarsophalangeal or ankle joint. However, previous study described joint stiffness in patients receiving long-term dialysis[9]. Thus, the role of tendinous and ligamentous hyperlaxity in LJM in patients undergoing hemodialysis is unclear. Hemodialysis duration was not found to be associated with ROM of the first metatarsophalangeal joint or ankle joint in the present study, even after adjustment for age, BMI and diabetes duration. Therefore, hemodialysis duration may not be associated with foot joint ROM.

The second major finding of the present study was that diabetes duration was associated with LJM of the ankle. Regarding the natural history of LJM, diabetes duration is the most important determinant of the risk of LJM[17]. The results of the present study support the conclusions of this review that showed that increased diabetes duration is associated with reductions in ROM of the ankle joint. The accumulation of advanced glycation end products (AGEs) in tissues with low turnover, such as tendons, results in the formation of covalent cross-links within collagen fibers, thus, altering their structure and functionality[18]. The formation of AGEs reduces collagen fiber sliding and results in compensatory increases in collagen fiber stretching resulting in loss of viscous elastic properties[19]. Thus, in the present study, it was proposed that increased glycation stress results in LJM of the ankle in diabetes patients undergoing hemodialysis in a similar manner to that reported in diabetes patients without hemodialysis. This finding highlights the importance of diabetic foot care in patients undergoing hemodialysis.

Another important finding of the present study was that Hb, BMI and age were all found to be associated with ROM of the first metatarsophalangeal joint using multiple regression analyses. Hb is a determinant of physical activity[20, 21]. In addition, previous studies have indicated low physical activity as a risk factor for LJM[22, 23]. In the present study, Hb was found to be positively correlated with ROM of the first metatarsophalangeal joint. Reduced physical activity because of anemia may contribute to decreased ROM. A strong negative correlation was reported between BMI and the amount of physical activity[24, 25]. Moreover, a negative correlation was found between obesity and the amount of physical activity[26]. In the present study, BMI was found to be negatively correlated with ROM of the first metatarsophalangeal joint. This finding may be the cause of the correlation between BMI and the amount of physical activity. BMI is an indicator of the nutritional status in addition to body composition, such as muscle mass adiposity. In this study, ALB was used as an indicator of nutrition status. No correlation was observed between ALB and ROM of the first metatarsophalangeal joint, even after adjustment for BMI. The influence of Hb and BMI on ROM of the first metatarsophalangeal joint indicates that decreased physical activity is associated with reduced ROM of the first metatarsophalangeal joint. In a previous study comparing healthy young individuals and older individuals, ROM of the first metatarsophalangeal joint was found to be reduced in older individuals[27]. The results of the present study demonstrate the association between age and reduced ROM of the first metatarsophalangeal joint, in agreement with previous reports[27]. Age-related changes in ROM are influenced by a reduced length of muscles or connective tissues around the joints because of low compliance of joint structures[28]. Anatomically, the biarticular muscles participating in the movement of the first metatarsophalangeal joint, such as the flexor hallucis longus and extensor hallucis longus, are tendinous components of the muscle-tendon unit. Reduced flexor hallucis longus and extensor hallucis longus length may be involved in age-related reduction of ROM of the first metatarsophalangeal joint.

In conclusion, hemodialysis duration did not correlate with ROM of the first metatarsophalangeal and ankle joints, and it does not affect ROM. The findings of the present study indicate that age, diabetes and decreased physical activity, but not hemodialysis therapy, are associated with limited joint mobility of the foot joints of patients undergoing hemodialysis. A limitation of our study was the insufficient evaluation of physical activity even though we predicted that physical activity would not be associated with foot joint ROM. To establish effective methods for preventing foot ulcers, further studies are required to clarify the association between ROM of foot joints and gait pattern accompanied by increased plantar pressure.

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