INTRODUCTION

1.1 | Patients with diabetes mellitus and their social background

An excessive intake of energy and a reduction of physical activity are considered as risk factors of diabetes mellitus (DM). The number of DM patients is increasing worldwide and is expected to increase from 1 in 11 adults to 1 in 10 adults by 2040.\(^1\) In DM patients with long-standing hyperglycemia, complications—such as retinosis, nephrosis, and diabetic polyneuropathy (DP)—can arise. In DP, impaired sensation and motor abilities can affect balance or gait ability\(^2\) and can lead to muscle atrophy and loss of motor function. Therefore, a reduction in motor function influences the reduction in active mass.

1.2 | Relationship between locomotive syndrome and DM

In 2007, the Japanese Orthopedic Association (JOA) proposed the concept of “locomotive syndrome,”\(^6\) which is characterized by impaired gait ability because of movement disorders or lifestyle. Moreover, locomotive syndrome was reported to be related to female sex with old age and obesity,\(^7\) and the risk for gonitis becomes high with an increasing number of comorbid conditions, such as impaired glucose tolerance, dyslipidemia, and hypertension, all of which are components of metabolic syndrome.\(^8\)

DM, which is a condition with impaired glucose tolerance, may have an influence on motor function. In Japan, our previous report on DM patients with symptoms of DP showed low values on the Two-Step Test, an index of gait ability in locomotive syndrome.\(^9\) Indeed,
DM is related to locomotive syndrome, and the presence of DP can likely affect the Two-Step value. Therefore, the Two-Step value can be useful in DM patients. The Two-Step Test can easily measure gait ability without the need for special tools. Therefore, this test was used for evaluating the gait ability of local residents. The present study focused on DM patients who did not have DP and discussed the effect of DM on the Two-Step value (i.e., gait ability).

2 | METHODS

2.1 | Selection criteria

This cross-sectional study compared the Two-Step values between DM patients (32 male, 28 female; mean age 62.2 years) and regional residents without DM (25 male, 18 female; mean age 61.8 years). This study was targeted at middle aged and young-elderly individuals (45-74 years old), in whom the risk of diabetic disease increases. The exclusion criteria were: the presence of DP, which can affect the motor function of DM patients; dialysis treatment; or visual impairment. The glycated hemoglobin was based on the international National Glycohemoglobin Standardization Program. The presence of DP was evaluated on the basis of the following diagnostic criteria: (a) presence of subjective symptoms, such as numbness; (b) decreased or absent vibration sense on both medial malleoli; and (c) both Achilles tendon reflexes were decreased or absent. DM patients who had at least two of these criteria were excluded.

2.2 | JOA Two-Step Test

We carried out the Two-Step Test in the hospital. Subjects were instructed to take two steps with as long a stride as possible, and then to bring their feet together and stop. If the subject lost balance, the test was invalid. We measured the length of the two steps from the starting line to the tips of the subject’s toes where they stood. The Two-Step value was calculated on the basis of the recommendations of the JOA, as follows:

\[
\text{Two-Step value} = \text{maximum two-step length (cm)} \div \text{height (cm)}.
\]

2.3 | Statistical analyses

The matched baseline characteristics and the Two-Step value were compared between the DM patients and the regional residents using the unpaired t test, with \( \chi^2 \) verification for the rate of the sex. Moreover, in order to take into consideration the impact of sex difference, we performed the same statistical analysis for each sex. We computed the Spearman’s correlation coefficient of the Two-Step value and basic information. All significance levels were set to 5%. We used SPSS 21.0J (IBM, Tokyo, Japan).

2.4 | Ethical considerations

The research on the DM patients was approved by the Chiba-chuuou Medical Center Ethics Committee (Chiba, Chiba, Japan; approval number H27-Ken 1). The research on the regional residents was approved by the Niigata Rehabilitation University Ethics Committee (Murakami, Niigata, Japan; approval number 112). Informed consent was obtained from all subjects.

3 | RESULTS

The average age of this study population was 60 years. The overall study indication was that height was significantly higher in the regional residents than in the DM patients. Contrarily, body mass index (BMI) was significantly higher in the DM patients than in the regional residents. In the male subgroup, height was significantly higher in the regional residents than in the DM patients. In the female subgroup, BMI was significantly higher in the DM patients than in the regional residents (Tables 1-3). Correlation was observed in the Two-Step value of female DM patients among BMI values (Table 4). The Two-Step value was significantly lower in the DM patients than in the regional residents in the female subgroup; in the male subgroup, this difference was not observed (Figure 1-3).

4 | DISCUSSION

4.1 | Patient characteristics

The results of this study suggest that gait ability can decline in female DM patients.

The mean BMI of the DM patients was ≥25 kg/m² (pre-obese). The major cause of DM was excessive energy intake. In many cases,

| TABLE 1 | Comparison of the baseline characteristics according to the presence of DM in the overall study participants |
|----------|-------------------------------------------------|-----------------|-------------------|
|          | DM patients without DP | Regional residents without DM | P value |
| Number of cases (n) | 60 | 43 | - |
| Male/female (n) | 32/28 | 25/18 | 0.628 |
| Age (years) | 62.2 ± 8.1 | 61.8 ± 7.2 | 0.818 |
| Height (cm) | 159.5 ± 8.9 | 163.7 ± 10.2 | <0.05 |
| Weight (kg) | 66.5 ± 15.1 | 63.3 ± 12.0 | 0.257 |
| BMI (kg/m²) | 26.1 ± 5.1 | 23.5 ± 2.9 | <0.05 |
| HbA1c (%) | 8.5 ± 2.2 | - | - |
| DM disease duration (years) | 9.1 ± 8.9 | - | - |
| Two-Step value | 1.41 ± 0.19 | 1.47 ± 0.11 | 0.067 |

Values are presented as mean ± SD, unless otherwise specified. Height was significantly higher in the regional residents than in the DM patients. BMI was significantly higher in the DM patients than in the regional residents. BMI, body mass index; DM, diabetes mellitus; DP, diabetic polyneuropathy; HbA1c, glycated hemoglobin.

| \( \chi^2 \)-test | \( t \)-test | \( \chi^2 \)-test | \( t \)-test |
|-------------------|-------------|----------------|-------------|
| 0.001 | 0.05 | 0.01 | 0.05 |

Unpaired t test, \( \chi^2 \) verification (P < 0.05).
TABLE 2 Comparison of the baseline characteristics and the Two-Step values according to the presence of DM in the male subgroup

|                          | DM patients without DP | Regional residents without DM | P value |
|--------------------------|------------------------|-------------------------------|---------|
| Number of cases (n)      | 32                     | 25                            | -       |
| Age (years)              | 60.6 ± 8.7             | 62.1 ± 7.5                    | 0.489   |
| Height (cm)a             | 165.5 ± 6.4            | 170.0 ± 8.1                   | <0.05   |
| Weight (kg)              | 70.1 ± 13.8            | 68.8 ± 11.9                   | 0.705   |
| BMI (kg/m²)              | 25.6 ± 4.5             | 23.7 ± 3.0                    | 0.080   |
| HbA1c (%)                | 8.8 ± 2.2              | -                             | -       |
| DM disease duration (years) | 9.1 ± 8.3              | -                             | -       |
| Two-Step value           | 1.48 ± 0.17            | 1.48 ± 0.11                   | 0.938   |

Values are presented as mean ± SD, unless otherwise specified. Height was significantly higher in the residual regions than in the DM patients in the male subgroup.

BMI, body mass index; DM, diabetes mellitus; DP, diabetic polyneuropathy; HbA1c, glycated hemoglobin.

TABLE 3 Comparison of the baseline characteristics and the Two-Step values according to the presence of DM in the female subgroup

|                          | DM patients without DP | Regional residents without DM | P value |
|--------------------------|------------------------|-------------------------------|---------|
| Number of cases (n)      | 28                     | 18                            | -       |
| Age (years)              | 63.9 ± 7.2             | 61.3 ± 7.0                    | 0.234   |
| Height (cm)              | 152.7 ± 6.0            | 154.9 ± 4.9                   | 0.185   |
| Weight (kg)              | 62.4 ± 15.7            | 55.8 ± 7.2                    | 0.060   |
| BMI (kg/m²)a             | 26.6 ± 5.8             | 23.2 ± 2.9                    | <0.05   |
| HbA1c (%)                | 8.3 ± 2.1              | -                             | -       |
| DM disease duration (years) | 9.2 ± 9.6              | -                             | -       |
| Two-Step valuea          | 1.34 ± 0.18            | 1.46 ± 0.12                   | <0.05   |

Values are presented as mean ± SD, unless otherwise specified. BMI was significantly higher in the DM patients than in the regional residents. The Two-Step value was significantly lower in the DM patients than in the regional residents in the female subgroup.

BMI, body mass index; DM, diabetes mellitus; DP, diabetic polyneuropathy; HbA1c, glycated hemoglobin.

*Unpaired t test, \( \chi^2 \) verification \((P < 0.05)\).

DM patients in the early stage of disease were overweight due to unhealthy dietary habits. Moreover, insulin resistance is one of the important features of sarcopenic obesity. Insulin resistance increases when obesity is accumulated intramuscularly. Furthermore, insulin resistance can lead to muscle weakness. Because the burden placed on a perarticulation increases the degree of visceral adiposity, BMI and walking velocity have been reported to have an inverse correlation with Two-Step value in female DM patients among body mass index values. DM, diabetes mellitus; DP, diabetic polyneuropathy; F, female; M, male. *Spearman’s correlation coefficient \((P < 0.05)\).

|                          | Age      | Height   | Weight   | BMI       |
|--------------------------|----------|----------|----------|-----------|
| All subjects             | -0.286*  | 0.216*   | -0.117   | -0.300*   |
| Regional residents without DM |         |          |          |           |
| M and F                  | -0.253   | 0.127    | 0.110    | 0.040     |
| M                        | -0.323   | 0.130    | 0.028    | -0.054    |
| F                        | -0.178   | -0.044   | 0.142    | 0.147     |
| DM patients without DP   |          |          |          |           |
| M and F                  | -0.306*  | 0.229    | -0.171   | -0.339*   |
| M                        | -0.297   | -0.020   | -0.086   | -0.090    |
| F                        | -0.192   | -0.138   | -0.513*  | -0.532*   |

Correlation was observed in Two-Step value of female DM patients among body mass index values.

DM, diabetes mellitus; DP, diabetic polyneuropathy; F, female; M, male. *Spearman’s correlation coefficient \((P < 0.05)\).

**FIGURE 1** The result of the Two-Step value in the overall study participants. The unpaired t test \((P < 0.05)\) revealed that the Two-Step value was not significantly different between the diabetes mellitus (DM) patients and the regional residents in the overall study participants.

**FIGURE 2** The result of the Two-Step value in the male subgroup. The unpaired t test \((P < 0.05)\) revealed that the Two-Step value was not significantly different between the diabetes mellitus (DM) patients and the regional residents in the male subgroup.
relationship.\textsuperscript{14} Visceral adiposity itself is a factor that can cause locomotive syndrome, especially affecting motor function.

DM patients with long-standing hyperglycemia can develop DP, which can cause muscle atrophy, impair gait ability, and ultimately decrease the BMI. However, because DM patients with DP were excluded in this study, the results were probably strongly affected by visceral adiposity.

4.2 Two-Step value was low for female DM patients

Our results showed that the Two-Step value was lower in female DM patients than in female regional residents of the same age. With aging, the amount of muscles decreases;\textsuperscript{15,16} in females, there is an additional tendency for reduction in bone mineral density.\textsuperscript{17} Moreover, in elderly females, visceral adiposity and locomotive syndrome are related.\textsuperscript{7}

In this study, the BMIs of female DM patients were significantly higher than in the female regional residents. The degree of visceral adiposity was higher in the female DM patients than in the female regional residents. Further, a correlation was observed in the Two-Step value of female DM patients among BMI. Similarly to elderly females, muscle strength declines easily with visceral adiposity, and in many cases, existing DM patients who show the symptoms of DP tend to be stout. Sarcopenia visceral adiposity, a condition with decreased muscle quantity, has been shown to have a stronger relationship with walking velocity or gait ability compared with the usual sarcopenia.\textsuperscript{18} The Two-Step Test for locomotive syndrome is an index of gait ability and is compounded by muscle strength, balance, and the glenoid range of motion. DM restricts the range of motion in the foot\textsuperscript{19} and reduces the amount and strength of lower limb muscles.\textsuperscript{13,20,21} This can explain the low Two-Step value in the elderly female DM patients in this study.

This study presents a new observation: The gait ability in female DM patients can be impaired, even before the development of DP. The numbers of DM patients and reserve DM patients are increasing rapidly. The Two-Step Test is a simple method and is useful in evaluating the gait ability in DM patients. The female Two-Step value was suggested to be influenced by DM.

This study had a limitation: The study population comprised elderly individuals; therefore, the effect was of both DM as well as aging. In the future, the impact of DM on the Two-Step value should be confirmed by large-scale studies that account for age and factors other than BMI.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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REFERENCES

1. International Diabetes Federation. IDF Diabetes Atlas 2015. https://www.idf.org/diabetesatlas. Accessed February 8, 2018.
2. Lim KB, Kim DJ, Noh JH, Yoo J, Moon JW. Comparison of balance ability between patients with type 2 diabetes and with and without peripheral neuropathy. PM R. 2014;6:209-214.
3. Hewston P, Deshpande N. Falls and balance impairments in older adults with type 2 diabetes: Thinking beyond diabetic peripheral neuropathy. Can J Diabetes. 2016;40:6-9.
4. Mueller MJ, Minor SD, Sahrmann SA, Schaal JA, Strube MJ. Differences in the gait characteristics of patients with diabetes and peripheral neuropathy compared with age-matched controls. Phys Ther. 1994;74:299-308.
5. de Mettelinge TR, Delbaere K, Calderson P, Gysel T, Van Den Noortgate N, Cambier D. The impact of peripheral neuropathy and cognitive decrements on gait in older adults with type 2 diabetes mellitus. Arch Phys Med Rehabil. 2013;94:1074-1079.
6. Yoshimura N, Muraki S, Oka H, et al. Association between new indices in the locomotive syndrome risk test and decline in mobility: Third survey of the ROAD Study. J Orthop Sci. 2015;20:896-905.
7. Muramoto A, Imagama S, Ito Z, et al. Waist circumference is associated with locomotive syndrome in elderly females. J Orthop Sci. 2014;19:612-619.
8. Yoshimura N, Muraki S, Oka H, et al. Accumulation of metabolic risk factors such as overweight, hypertension, dyslipidaemia, and impaired glucose tolerance raises the risk of occurrence and progression of knee osteoarthritis: A 3-year follow-up of the ROAD Study. Osteoarthritis Cartilage. 2012;20:1217-1226.
9. Ninomiya H, Kazuki K, Kubo A. Effect of diabetic polyneuropathy on the Two-Step test result [in Japanese]. Rigakuryoho Kagaku. 2016;31:77-79.
10. Japanese Orthopaedic Association. Locomotive syndrome pamphlet 2015. https://locomo-joa.jp/en/index.pdf. Accessed July 13, 2018.
11. Yasuda H, Sanada M, Kitada K, et al. Rationale and usefulness of newly devised abbreviated diagnostic criteria and
staging for diabetic polyneuropathy. Diabetes Res Clin Pract. 2007;77:5178-5183.
12. Park SW, Goodpaster BH, Strotmeyer ES, et al. Accelerated loss of skeletal muscle strength in older adults with type 2 diabetes: The Health, Aging, and Body Composition Study. Diabetes Care. 2007;30:1507-1512.
13. Nomura T, Ikeda Y, Nakao S, et al. Muscle strength is a marker of insulin resistance in patients with type 2 diabetes: A pilot study. Endocr. 2007;54:791-796.
14. Latorre Román PA, García-Pinillos F, Huertas Herrador JA, Cozar Barba M, Muñoz Jiménez M. Relationship between sex, body composition, gait speed and body satisfaction in elderly people. Nutr Hosp. 2014;30:851-857.
15. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol. 2000;89:81-88.
16. Gallagher D, Visser M, De Meersman RE, et al. Appendicular skeletal muscle mass: Effects of age, gender, and ethnicity. J Appl Physiol. 1997;83:229-239.
17. Akessen K. New approaches to the pharmacological treatment of osteoporosis. Bull World Health Organ. 2003;81:657-664.
18. Kohara K. Sarcopenic obesity in aging population: Current status and future direction for research. Endocrine. 2014;45:15-25.
19. McPoil TG, Yamada W, Smith W, Cornwall M. The distribution of plantar pressures in American Indians with diabetes mellitus. J Am Podiatr Med Assoc. 2001;91:280-287.
20. Almurdhi MM, Reeves ND, Bowling FL, Boulton AJ, Jeziorska M, Malik RA. Reduced lower-limb muscle strength and volume in patients with type 2 diabetes in relation to neuropathy, intramuscular fat, and vitamin D levels. Diabetes Care. 2016;39:441-447.
21. Asada F, Nomura T, Tagami M, Kubota M, Ohashi M, Nomura M. Lower-limb muscle strength according to bodyweight and muscle mass among middle age patients with type 2 diabetes without diabetic neuropathy. J Phys Ther Sci. 2017;29:1181-1185.

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