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SHORT REPORT

Regular exercise behavior is related to lower extremity muscle strength in patients with type 2 diabetes: Data from the Multicenter Survey of the Isometric Lower Extremity Strength in Type 2 Diabetes study

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ABSTRACT
Owing to several contributing factors, continuation of exercise therapy is difficult for patients with type 2 diabetes. One potential factor that has not been well examined is the influence of muscle strength on regular exercise behavior. We examined the relationship between regular exercise behavior and knee extension force (KEF) in 1,442 patients with type 2 diabetes. In sex-specific univariate analysis, KEF was significantly higher in patients who regularly exercised than in patients who did not regularly exercise. However, age, but not exercise behavior, was significantly different between KEF quartiles. Accordingly, KEF and age might strongly influence exercise behavior. In the multivariate analyses using age and other parameters as covariates, KEF was a significant explanatory variable of regular exercise in both men and women, suggesting that muscle strength could influence regular exercise behavior.

INTRODUCTION
In patients with type 2 diabetes, exercise improves cardiopulmonary function, glycemic control and lipid metabolism; lowers blood pressure; and increases insulin sensitivity[1]. However, as clearly shown in the interventional Diabetes Prevention Program study, it is difficult for patients to achieve and maintain regular exercise behavior[2]: half of the participants failed to continue exercise for 150 min a week. In cross-sectional surveys of Japanese patients with diabetes, the adherence rate for regular exercise therapy was approximately 50%[3,4]. Factors related to regular exercise include the availability of free time, adequate understanding regarding exercise therapy and psychological factors[3].

Maintenance of muscle strength is important for maintaining the ability to carry out activities of daily living[5], thus there has been a focus on individuals with low levels of muscle strength. However, the relationship between muscle strength and the ability to maintain regular exercise behavior has not been examined. Such information might be useful for exercise guidance. The present study examined the influence of lower extremity muscle strength on regular exercise.

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METHODS
Data collection
Participants included 1,442 patients with type 2 diabetes without severe complications in the Multicenter Survey of the Isometric Lower Extremity Strength in Type 2 Diabetes (MUSCLE-std) Study[6]. Regular exercise behavior was defined as two sessions of exercise per week with a duration of at least 30 min. Participants who continued regular exercise behavior for at least 6 months (maintenance stage or later) were defined as engaging in regular exercise[7]. Lower extremity muscle strength was measured using maximum isometric knee extension force (KEF). The non-dominant leg (the pivot leg, i.e., the leg with which an individual would not kick a ball) was designated as the leg from which the measurements were to be carried out. The length of the lower leg (moment arm) was

measured from the knee joint space to the center of the sensor pad of the muscle strength-measuring instrument (μTas MT-1 or μTas F-1; Anima Inc., Tokyo, Japan). The absolute value for isometric KEF (N) multiplied by the moment arm (m) was used to calculate the KEF (Nm). Furthermore, relative KEF (Nm/kg) was calculated by dividing KEF (Nm) by bodyweight (kg), and was subsequently used in the analyses. Diabetes status was determined using diabetes duration and glycated hemoglobin (HbA1c) levels. Diabetic complications included in the analyses were the presence of diabetic neuropathy[8], diabetic retinopathy and diabetic nephropathy[9].

Statistical analysis

For analysis, regular exercise behavior as the variable was defined as 1 (action stage or earlier [<6 months]) or 2 (maintenance stage or later [≥6 months]). Initially, variables from groups with or without regular exercise behavior were compared using the *t*-test and χ^2-test. Next, parameters were compared according to KEF quartiles by sex using the *t*-test and χ^2-test for qualitative variables, and the Kruskal–Wallis test and Tukey's multiple test for quantitative variables. Furthermore, using logistic regression analysis, the relationship of KEF in combination with regular exercise was analyzed by sex in three models. The response variable was regular exercise behavior, defined as 1 (absence) or 2 (presence). Continuous explanatory variables included KEF, age, body mass index, diabetes duration and HbA1c; categorical variables included diabetic polyneuropathy, defined as 1 (absence) or 2 (presence); diabetic retinopathy, defined as 1 (absence) or 2 (simple or more severe retinopathy); and diabetic nephropathy, defined as 1 (stage <3) or 2 (stage ≥3). $P < 0.05$ was considered significant. In addition, medications used to treat diabetes mellitus are shown for reference, but were not used in the statistical analysis.

RESULTS

Of the 1,442 participants, there were 893 men and 549 women. Age was 60.9 ± 12.1 years (mean ± standard deviation; range 30–87 years); body mass index 25.0 ± 4.5 kg/m^2; diabetes duration 9.0 ± 8.6 years; and HbA1c 9.3 ± 2.3%. There were 544 patients with diabetic polyneuropathy (37.7%), 138 patients with diabetic retinopathy (simple or more severe retinopathy; 9.6%), 374 patients with diabetic nephropathy (stage ≥3; 25.9%), 634 patients receiving insulin therapy (44.0%), 1,060 patients taking oral antidiabetic drugs (73.5%), and 34 taking glucagon-like peptide-1 receptor agonists (2.4%). Participants who engaged in regular exercise comprised 27.4% of men and 26.0% of women. Age and KEF were significantly higher in patients who regularly exercised than in patients who did not regularly exercise in both men and women (Table 1). Quartiles (Q) of KEF (Nm/kg; mean ± standard deviation) were as follows: men, Q_1, 1.16 ± 0.22; Q_2, 1.62 ± 0.10, Q_3, 1.96 ± 0.09; and Q_4, 2.49 ± 0.29; women, Q_1, 0.75 ± 0.15; Q_2, 1.09 ± 0.07; Q_3, 1.34 ± 0.07; and Q_4, 1.84 ± 0.29. In both men and women,

Table 1 | Clinical characteristics by the presence or absence of regular exercise behavior

	Men			Women		
	Presence of regular exercise behavior *n* = 245	Absence of regular exercise behavior *n* = 648	*P*-value	Presence of regular exercise behavior *n* = 143	Absence of regular exercise behavior *n* = 406	*P*-value
Knee extension force (Nm/kg)	1.87 ± 0.51	1.79 ± 0.52	<0.05	1.38 ± 0.42	1.21 ± 0.42	<0.001
Age (years)	65.0 ± 10.5	57.8 ± 12.6	<0.001	66.4 ± 9.6	61.6 ± 11.7	<0.001
Body mass index (kg/m^2)	24.0 ± 3.1	25.3 ± 4.6	<0.001	23.8 ± 3.8	25.5 ± 5.1	<0.001
Diabetes duration (years)	11.0 ± 9.1	8.2 ± 8.3	<0.001	9.3 ± 7.2	9.1 ± 9.0	NS
HbA1c (%)	8.5 ± 2.1	9.7 ± 2.3	<0.001	8.4 ± 2.0	9.4 ± 2.2	<0.001
Presence of diabetic neuropathy	88 (35.9)	246 (38.1)	NS	37 (25.8)	173 (42.6)	<0.001
Presence of diabetic retinopathy	54 (22.0)	159 (24.6)	NS	41 (28.6)	120 (29.5)	NS
Presence of diabetic nephropathy	19 (7.7)	71 (11.0)	NS	6 (4.1)	42 (10.3)	<0.05

Data are mean ± standard deviation or *n* (%). HbA1c, glycated hemoglobin. NS, not significant.

Table 2 | Clinical characteristic by knee extension force in quartiles

Parameters	Q_1 (Lowest)	Q_2	Q_3	Q_4 (Highest)	*P*-value
Men	*n* = 223	*n* = 224	*n* = 223	*n* = 223	
Regular exercise	50 (22.4)	63 (28.1)	61 (27.4)	71 (31.8)	NS
Age (years)	65.3 ± 12.2†	60.7 ± 12.1‡	57.2 ± 12.1§	55.8 ± 11.2§	<0.001
BMI (kg/m^2)	25.0 ± 4.8	25.0 ± 4.5	25.1 ± 4.3	24.8 ± 3.6	NS
Diabetes duration (years)	10.9 ± 9.5†	9.5 ± 8.7†‡	8.3 ± 8.5‡§	7.1 ± 7.3§	<0.001
HbA1c (%)	9.2 ± 2.1	9.5 ± 2.5	9.5 ± 2.5	9.3 ± 2.4	NS
Presence of diabetic neuropathy	121 (54.3)†	91 (40.6)‡	71 (31.8)‡§	51 (22.9)§	<0.001
Presence of diabetic retinopathy	71 (31.8)†	51 (22.8)†‡	50 (22.4)†‡	41 (18.4)‡	<0.01
Presence of diabetic nephropathy	31 (13.9)†	30 (13.4)†‡	14 (6.3)‡	15 (6.7)†‡	<0.01
Women	*n* = 137	*n* = 138	*n* = 137	*n* = 137	
Regular exercise	23 (16.8)†	28 (20.3)†‡	45 (32.8)‡	47 (34.3)‡	<0.001
Age (years)	65.8 ± 11.6†	64.0 ± 10.8†	63.2 ± 10.7†	58.5 ± 11.1‡	<0.001
BMI (kg/m^2)	26.0 ± 5.5†	25.9 ± 4.8†‡	24.4 ± 4.4‡§	23.9 ± 4.3§	<0.001
Diabetes duration (years)	11.5 ± 9.8†	9.9 ± 8.3†	8.3 ± 8.4‡	7.0 ± 7.1‡	<0.001
HbA1c (%)	9.0 ± 2.0	9.4 ± 2.3	9.3 ± 2.3	8.9 ± 2.1	NS
Presence of diabetic neuropathy	68 (49.6)†	60 (43.5)†	52 (38.0)†	30 (21.9)‡	<0.001
Presence of diabetic retinopathy	61 (44.5)†	41 (29.7)†‡	28 (20.4)‡	31 (22.6)‡	<0.001
Presence of diabetic nephropathy	19 (13.9)	11 (8.0)	9 (6.6)	9 (6.6)	NS

Data are mean ± standard deviation or *n* (%). *P*-values were derived from Kruskal–Wallis tests or χ^2-tests. Results from *Z*-test or Tukey's multiple test values showing †, ‡ or § are not different when the same symbol is present, and are significantly different when a different symbol is present. BMI, body mass index; HbA1c, glycated hemoglobin. NS, not significant; Q, quartile.

Table 3 | Influence of knee extension force in combination with other parameters on regular exercise behavior as the response variable in logistic regression analysis

	Men			Women		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Model 1						
Knee extension force	2.108	1.537–2.891	<0.001	3.633	2.177–6.062	<0.001
Age	1.063	1.046–1.080	<0.001	1.057	1.033–1.081	<0.001
Body mass index	0.981	0.940–1.024	NS	0.982	0.934–1.032	NS
Model 2						
Knee extension force	2.008	1.457–2.767	<0.001	3.068	1.814–5.189	<0.001
Age	1.049	1.031–1.067	<0.001	1.047	1.022–1.072	<0.001
Body mass index	0.978	0.936–1.022	NS	0.968	0.920–1.018	NS
Diabetes duration	1.016	0.998–1.035	NS	0.988	0.963–1.013	NS
HbA1c	0.864	0.800–0.933	<0.001	0.821	0.740–0.912	<0.001
Model 3						
Knee extension force	1.898	1.368–2.632	<0.001	2.882	1.683–4.933	<0.001
Age	1.050	1.031–1.068	<0.001	1.053	1.027–1.079	<0.001
Body mass index	0.978	0.936–1.022	NS	0.981	0.930–1.033	NS
Diabetes duration	1.024	1.005–1.045	<0.05	0.998	0.971–1.026	NS
HbA1c	0.866	0.801–0.936	<0.001	0.835	0.751–0.928	<0.001
Diabetic neuropathy	0.813	0.567–1.166	NS	0.485	0.297–0.791	<0.01
Diabetic retinopathy	0.738	0.494–1.103	NS	1.398	0.846–2.308	NS
Diabetic nephropathy	0.660	0.368–1.183	NS	0.391	0.151–1.010	NS

CI, confidence interval; HbA1c, glycated hemoglobin; NS, not significant; OR, odds ratio.

age was significantly different between KEF quartiles (Table 2). However, exercise behavior was not clearly different between KEF quartiles in men. Table 3 shows the relationship between regular exercise behavior and KEF in logistic regression analysis. In both men and women, KEF was a significant explanatory variable for regular exercise in all models.

DISCUSSION

Just over one-quarter of participants exercised regularly, and age was significantly higher in patients who regularly exercised than age in patients who did not regularly exercise; these results are similar to those of the Japanese population in general[10]. However, the current percentage of patients who regularly exercised was low in comparison with previously reported values in Japanese patients with type 2 diabetes[4], but definitions of regular exercise were different from the present study. In sex-specific univariate analysis, KEF was significantly higher in patients who regularly exercised than in patients who did not regularly exercise. Furthermore, we analyzed the relationship between regular exercise behavior and KEF with consideration of diabetes status and diabetic complications as covariates. In several models of the multivariate analyses, including age and other parameters as covariates, KEF was a significant explanatory variable for regular exercise in both men and women. This indicates that a higher level of lower extremity muscle strength might be important for regular exercise. In contrast, exercise behavior was not clearly different between KEF quartiles. Muscle strength and age have a strong negative correlation[11]. Accordingly, age might have strongly influenced the results of the analysis, showing that exercise behavior was not significantly different between KEF quartiles. Owing to the nature of the cross-sectional design of the present study, this does not establish a causative relationship between KEF and regular exercise behavior. Indeed, in our previous report of data from the MUSCLE-std study, in both men and women aged 50–69 and 70–87 years, regular exercise behavior was a significant explanatory variable for KEF[12]. Additionally, continuation of regular exercise is necessary to maintain muscle strength[13]. Thus, there appears to be an interactive relationship between maintenance of muscle strength and regular exercise. Finally, HbA1c was significantly higher in patients who regularly exercised than that in patients who did not regularly exercise. This result provides evidence regarding the effectiveness of exercise therapy for patients with type 2 diabetes.

The present report had several limitations. First, details of regular exercise behavior, such as intensity, frequency and type, were not identified and might have independent relationships with KEF. Second, we did not investigate psychological factors of participants; this might be important, as self-efficacy is related to stages of behavior change, such as maintenance of regular exercise[14]. Accordingly, further prospective studies are required to clarify the contribution of lower extremity muscle strength to regular exercise behavior in patients with diabetes.

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DISCLOSURE

The authors declare no conflict of interest.

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