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Original Article

Effective training of squat exercise -- HiSquat trial for patients with diabetes --

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Abstract

***Background*:** Recent clinical problems in primary care medicine include metabolic syndrome (Met-S) as well as other problems, such as diabetes mellitus, locomotive syndrome (Loc-S) and flailty in middle-age to older people. Regarding exercise therapy for patients with Met-S and Loc-S, aerobic exercise and also resistance (anaerobic) exercise have been considered as necessary. Thus, simple and effective resistance exercise methods should be clarified.

***Subjects and Methods*:** The subjects were 61 patients (male 36, female 25) with diabetes mellitus (66.9 ± 13.5 years old, mean ± SD). Subjects were instructed to perform a continuous squat exercises 5 minutes in morning and evening every day for 6 months, using the small exercise equipment 'HiSquat". The movements included 1) walking or jogging, 2) inner thigh exercise, 3) outer thigh exercise, 4) straight thigh exercise. Parameters were height, body weight, body mass index (BMI), abdominal circumference, thigh circumference and blood HbA1c value. The treatment of the subjects were not changed during the 6 months. HbA1c value was compared between 0 and 6 months.

***Results*:** The fundamental data before the study were as follows: height 159.4 ± 8.4 cm, body weight 62.5 ± 13.8 kg, BMI 24.5 ± 4.7 kg/m^2, abdominal circumference 86.8 ± 10.7 cm, thigh circumference 42.9 ± 6.4 cm, HbA1c 6.8 ± 0.9%. HbA1c value at 6 months was 6.4 ± 1.0%, with a statistically significant decrease of 0.4%. As for the correlation analyses, a positive significant correlation was observed between BMI and the thigh/height ratio, and a negative significant correlation was observed between age and thigh/waist ratio.

***Conclusion*:** In this study, the HbA1c value was significantly decreased, which suggests the exercise effect of HiSquat. Our study provides fundamental data for the value of waist/thigh circumference in the exercise therapy, and also the efficacy of HiSquat; consequently it suggests the efficacy of HiSquat use for Met-S, Loc-S and flailty, which are increasing concerns in anti-aging medicine of Japan.

***KEY WORDS*:** HiSquat, squatting, diabetes mellitus, HbA1c, exercise therapy

Introduction

Recent clinical problems in anti-aging medicine include metabolic syndrome (Met-S) as well as other problems, such as diabetes mellitus (DM), locomotive syndrome (Loc-S) in middle-age people and frailty in older people. For patients with Met-S and Loc-S, exercise therapy, such as aerobic exercise, and also resistance (anaerobic) exercise therapy have been considered necessary. Thus, a simple and effective resistance exercise is awaited.

The relationship between sedentary condition and chronic disease has been a controversy for years. Several guidelines for physical activity have been reported [1-5]. Systematic review and meta-analyses of these guidelines were studied, and they demonstrated that too much sitting poses a risk for chronic disease and premature death, and controlling of time spent in leisure exercise or moderate to vigorous physical activity would promote the health [6,7].

Recent investigation of systematic reviews and meta-analyses revealed that people with a prolonged sedentary time have a higher risk for all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, and cancer incidence [8]. In particular, the hazard

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ratio for type 2 diabetes incidence was extremely high, at 1.910. Thus, sedentary life seems to have a great influence on the development of metabolic syndrome and arteriosclerotic diseases.

On the other hand, regarding the necessity of exercise for the shortage of physical activity and sports has been emphasized. Exercise is classified into aerobic and anaerobic (resistance) exercise. Resistance exercises (muscle-strengthening activities) should be done involving major muscle groups on two or more days according to the guideline of WHO and other countries [1,2]. Resistance exercise (muscle training, weight training) has effects on muscle hypertrophy, muscle power and muscle endurance [9]. Furthermore, it has positive effects on the aging decrease of muscle volume, decrease of bone mineral density, decrease of muscle metabolism and increase of body fatty tissue [10], leading to a better performance of physical activity in daily life [9]. According to the meta-analysis results of the resistance exercise for aged people, muscle power would be recovered by approximately 20-30% [11].

Recently, the management for Met-S, Loc-S and frailty has been a focus and an educational movement has started in the Japanese Orthopaedic Association and in other medical societies [12,13]. In the guideline of locomotive syndrome, a squatting exercise has been recommended, because squatting is a simple use of one's body weight without special equipment, and it is expected to be effective for daily QOL and ADL [14,15].

In these clinical fields, we have investigated several published studies concerning anti-aging medicine, diabetes and diet and exercise therapy [16-18]. Here, we have evaluated the effect of squatting exercise in the clinical setting. We used a new squat equipment 'HiSquat' and applied it for patients with diabetes mellitus, and analyzed the effect of 6 months of exercise [19,20].

Subjects and Methods

Subjects

The subjects of this study consisted of 61 patients (males: 36, females: 25) with diabetes mellitus (66.9 ± 13.5 years old, mean ± SD), who were outpatients of a primary care clinic in Tokushima, and who were enrolled in our research program for 6 months. DM therapy included diet and exercise without medication in 7 patients, oral anti-diabetic drugs in 46 patients and insulin therapy in 8 patients. The following oral anti-diabetic drugs were used: insulin stimulators, 9 patients; glucose absorption blocking, 17 patients; insulin resistance modulators, 28 patients; incretin-related drugs, 39 patients and SGLT2 blockers 2 patients. We excluded the subjects who were not allowed to perform exercise therapy due to retinopathy or nephropathy.

Method

The subjects have continued squat exercise 5 minutes in morning and evening every day for 6 months. They used the small sport equipment 'HiSquat (trademark registration number 3179684) (*Fig. 1*) [19,20]. The depth of squat was from quarter to half. One leg was extended to the back and then the opposite leg was extended to the back, in turn. The exercise included the following movements: 1) walking or jogging on the HiSquat for 2 minutes with the hip level as usual, while grasping the back of a chair nearby with hands, 2) inner thigh exercise: the position of bilateral knees was close and squat movement was performed 10 round times for about 1 minute, 3) outer thigh exercise: the same as 2), and 4) straight thigh exercise: the same as 2), in total about 5 minutes from 1) to 4). The details of the squat exercise have been shown in a textbook and on the homepage [19,20]. Regarding the clinical management of each subject, their diet and pharmacological treatment were not changed, as a general rule, during the 6 months period of the study.

Parameters

The parameters of the subjects included stature, body weight, BMI, abdominal circumference (horizontal level at the navel), thigh circumference (10 cm upper level from the upper ridge of the patellar), and blood HbA1c value. We compared the HbA1c levels before and after the project. The data before was the value of 0 month, and the data after was the average the data at 6 and 7 months. From these data, including thigh circumference/height ratio and thigh/waist circumference ratio, we analyzed the correlation among various factors.

Ethical Considerations

The present study was conducted in compliance with the ethical principles of the Declaration of Helsinki and Japan's Act on the Protection of Personal Information, and with

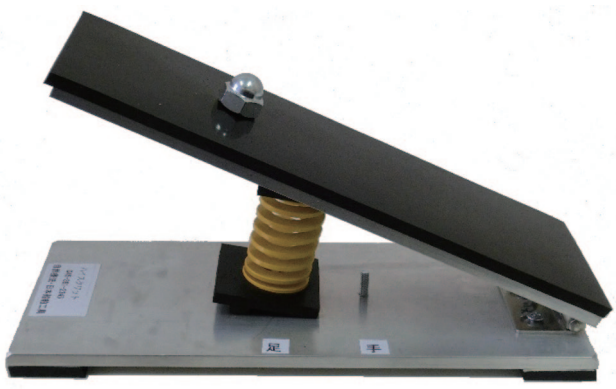

Fig. 1. **HiSquat (the exercise equipment for squat movement)**

reference to the Ministerial Ordinance on Good Clinical Practice (GCP) for Drug (Ordinance of Ministry of Health and Welfare No. 28 of March 27, 1997). No ethics committee meeting was held. We obtained informed consent from the subjects concerning this questionnaire.

Results

1) Data of subjects:

The fundamental data at start of the study revealed that body mass index (BMI) was 24.5 ± 4.7 kg/m^2, and HbA1c (before) was 6.8 ±0.9% (mean±SD) (***Table 1***). BMI distribution of 61 subjects before the project is shown in ***Fig. 2***, and the median value was 23.5 kg/m^2 and 23/61 (37.8%) showed BMI more than 25 kg/m^2.

2) Changes in value of HbA1c:

The value of HbA1c was 6.4 ± 1.0% (mean ± SD) at 6 months. The decreased level of HbA1c for 6 months was 0.4%, which was statistically significant (***Fig. 3***). The decreased level of HbA1c for 61 subjects is shown in ***Fig. 4***, and 32/61 (52.4 %) showed decrease more than 0.3%.

3) Correlations among obtained data:

Several meaningful correlations among these data are shown in ***Fig. 5***. Significant positive correlations were seen between waist and thigh circumference (a), body mass index and thigh/height ratio (b,c), and a significant negative correlation was seen in age and thigh/waist ratio (e). In contrast, there was no significant correlation between BMI and thigh/waist ratio (d), or among HbA1c values (before or after study, changed) and other factors (f).

Table 1. fundamental data

	mean ± SD
height	159.4 ± 8.4 cm
body weight	62.5 ± 13.8 kg
body mass index (BMI)	24.5 ± 4.7 kg/m^2
abdominal circumference	86.8 ± 10.7 cm
thigh circumference	42.9 ± 6.4 cm
HbA1c (before)	6.8 ± 0.9 %
HbA1c (6 months)	6.4 ± 1.0 %

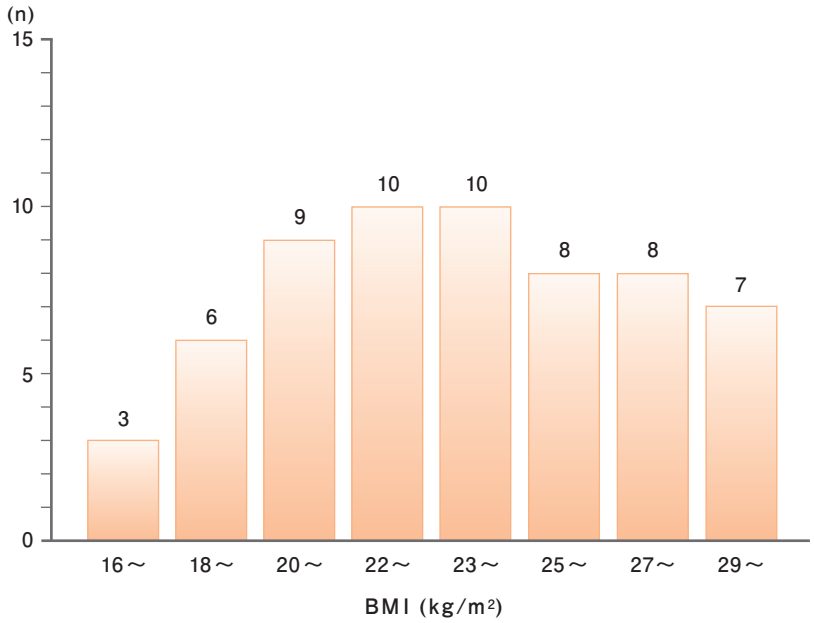

Fig. 2. **Body Mass Index (BMI) distribution of 61 subjects.**

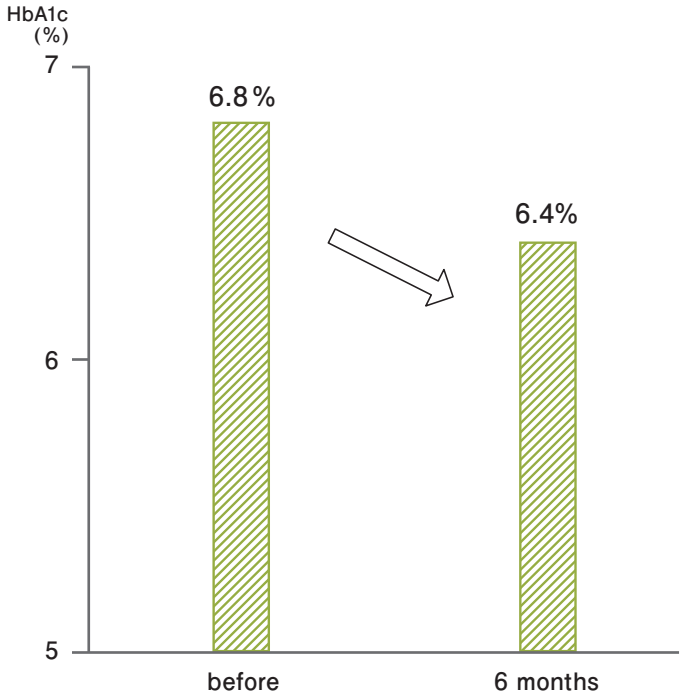

Fig. 3. **The changes of HbA1c value in 61 patients with diabetes mellitus**
There was a significant difference between the two (P<0.05, paired-t test).

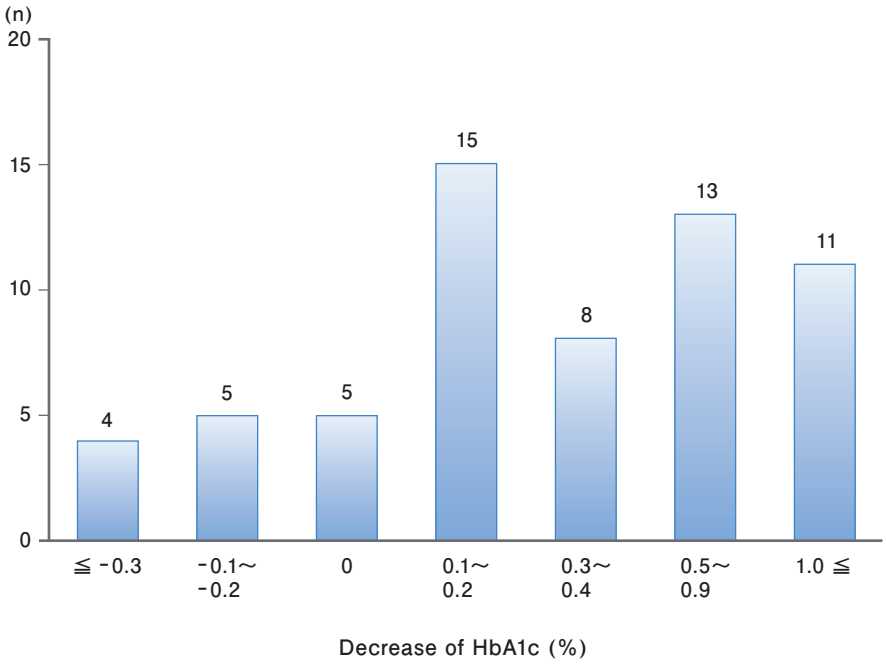

Fig. 4. **The distribution of the decrease of HbA1c value in the patients with diabetes mellitus**

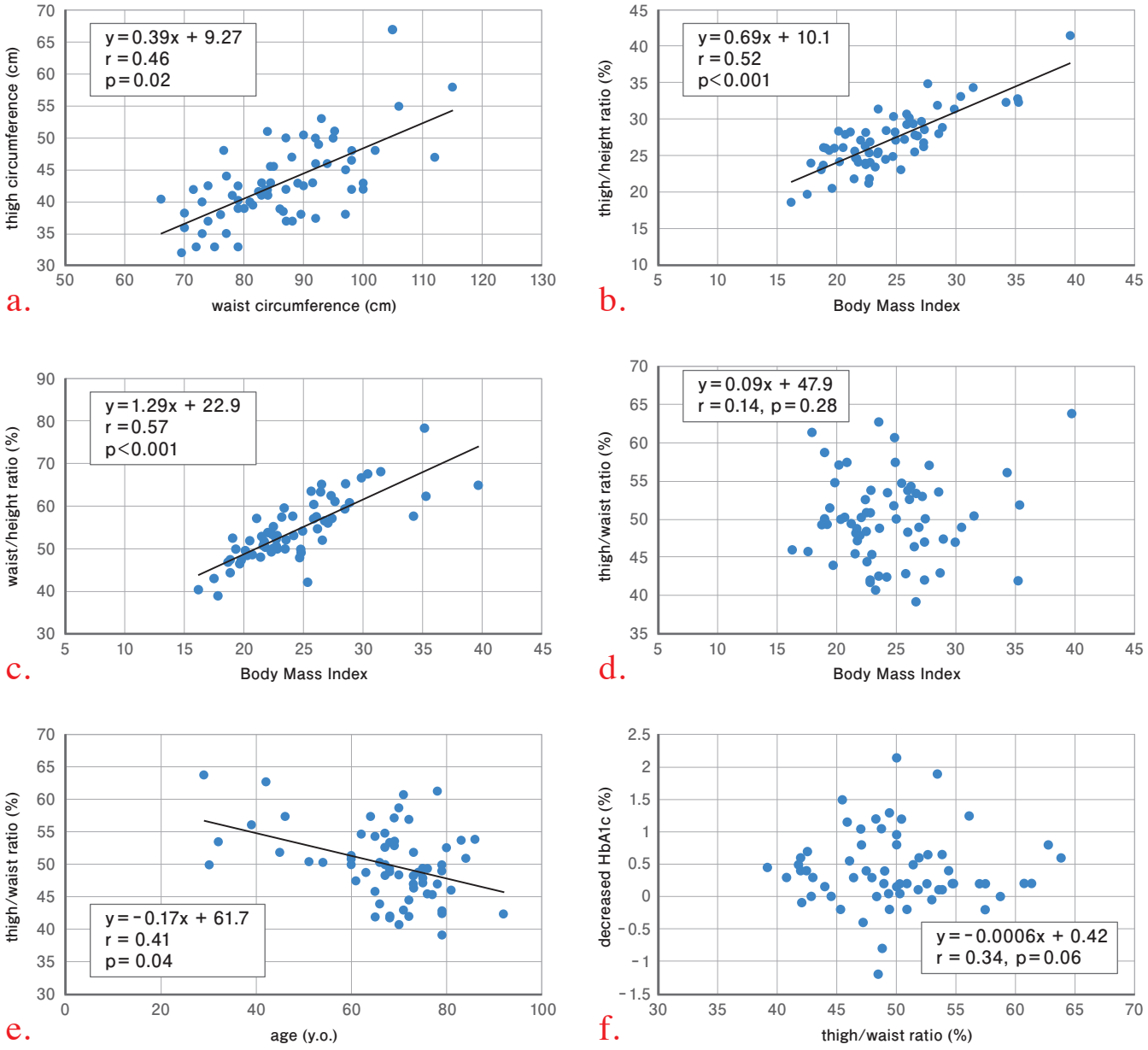

Fig. 5. **Correlation among body mass index (BMI), waist circumference, thigh circumference, thigh/waist circumference ratio, thigh/height ratio and age.**

a. Correlation between thigh and waist circumference (significant correlation, $p<0.05$)
b. Correlation between BMI and thigh/height ratio (significant correlation, $p<0.001$)
c. Correlation between BMI and waist/height ratio (significant correlation, $p<0.001$)
d. Correlation between BMI and thigh/waist ratio (no significant correlation)
e. Correlation between age and thigh/waist ratio (significant correlation, $p<0.05$)
f. Correlation between thigh/waist ratio and decreased HbA1c (no significant correlation)

Discussion

Physical activity and diabetes

As for the relationship between sedentary condition and chronic diseases, systematic reviews and meta-analyses were investigated in 48 reports [6], 18 reports [7], and 47 reports [8]. Biswas et al. showed the disease and hazard ratio (HR): cardiovascular disease mortality (1.179), cardiovascular disease incidence (1.143), cancer mortality (1.173), cancer incidence (1.130), and type 2 diabetes incidence (1.910) [8].

The relationship between physical activity and type 2 diabetes, as investigated in 45,668 cases for 11 years [21], reported an incidence rate ratio of 1.86 (95% CI: 1.54, 2.24) for 5 hours relative to <1 hour of television per day. Intervention studies of interrupting sitting time with short bouts of light- or moderate-intensity walking showed lowered postprandial glucose and insulin levels [22]. Considering these reports, Lynch and Owen [23] stated in an editorial that further studies should consider the effects within population subgroups.

Several guidelines on physical activity for health have recently been shown [1,3-5]. WHO reported the Global Recommendations on Physical Activity for Health in 2010 [1]. In the 18 to 64 years old group and also in the older than 65 years old group, the recommended levels of physical activity for health included the following: 1) 75-150 min/week of moderate to vigorous intensity aerobic physical activity, and also 2) muscle-strengthening activities involving major muscle groups on two or more days a week.

Furthermore, the demerit of daily sedentary behavior such as sitting or lying down has been emphasized. Australian Bureau of Statistics (ABS) 2013 showed "Make your Move -- Sit less -- Be active for life!" on the front cover of the guideline [3]. Recently, Mayor reported that prolonged sitting time would lead to great risk, regardless of exercise habit [24].

In Japan, the impact of daily total physical activity level on premature deaths has been investigated in a large-scale population-based cohort study in Japan (JPHC study) with 83,034 Japanese citizen ages 45-74 years. Compared with subjects in the lowest quartile, increased daily total physical activity was associated with a significantly decreased risk of all-cause mortality in both sexes (hazard ratios for the second, third, and highest quartiles were: men, 0.79, 0.82, 0.73 and women, 0.75, 0.64, 0.61, respectively) [25]. As for the cancer risk of the subjects performing leisure-time sports or physical exercise >1 day /week in the JPHC study, the hazard ratio (HR) in each quartile was 0.80, 0.81, 0.61, respectively [26]. Thus, daily physical activity with sports or exercise showed a merit of health and wellness in the investigation for Japanese such as in the JPHC study.

Data analysis

We compared the current study with previous reports concerning physical activity, metabolic syndrome and diabetes. Based on the stature of 61 subjects (***Table 1***) and BMI distribution (***Fig. 2***), the obesity ratio was 23/61 (37.7%), which seems to be the average frequency in typical primary care out-patient setting. According to 0.4% decrease of HbA1c (***Fig. 3***) and the distribution of decreased HbA1c (***Fig. 4***), we analyzed the factors influencing the value of HbA1c.

As a result, it was not BMI, but the HbA1c level at 0 months that seemed to influence the decrease degree of HbA1c. We classified the 61 cases into the following two groups based on the HbA1c value at the start of our project: group A (less than 6.55%, n=30), and group B (more than 6.6%, n=31). The decrease of HbA1c value was 0.11 ± 0.35% and median 0.175% in group A, and 0.69 ± 1.08% and median 0.65% in group B. Taking all 61 cases together, the decrease of HbA1c was 0.41 ± 0.86% and median 0.30%.

Consequently, the effect of HiSquat seemed to be small in group A, and greater in group B. In other words, poorly controlled patients with diabetes mellitus would seem to have a greater effect by performing squatting, and are recommended to try exercise therapy on HiSquat equipment.

Correlation analyses yielded the following speculation (***Fig. 5***): 1) BMI, waist and thigh circumferences have a mutual correlation, and several factors would be clinically and statistically useful factors in future studies, such as thigh/waist ratio, thigh/height ratio, waist/height ratio (***Fig. 5a,b,c***). 2) The thigh/height ratio would have less error and would be statistically a more useful factor than the thigh/waist ratio (***Fig. 5c,d***). 3) The thigh/waist ratio would be a useful factor, indicating the aging decrease of muscle volume (***Fig. 5e***). 4) There was no significant correlation between HbA1c (pre-, post- or changed values) and other factors (***Fig. 5f***), suggesting that exercise therapy for 6 months would not be sufficient for a remarkable reduction of weight, or decreased HbA1c, as compared to diet therapy for months with a marked weight loss.

As to BMI and thigh circumference, we would be careful for evaluating the following viewpoints; 1) BMI is calculated by the values of height and body weight without the ratio of muscle and fat, resulting in limitation to some extent for evaluation of BMI, 2) the evaluation of thigh circumference after starting squat exercise would include variable condition, such as thinner changes by decrease of subcutaneous fat in early stages, and stable – thicker changes by increase of muscle volume in later stages, 3) from our current research, the measurement of waist and thigh circumference would be useful for evaluating the effect of exercise, with some attention for influencing variables of BMI and thigh circumference.

Effect of squat

From the point of anti-aging and protective medicine, the neurosurgeon, Brett Osborn [27] stated that there are five exercises to protect against 'Disease of Aging', including: 1) squatting, 2) overhead press, 3) deadlift, 4) bench press, 5) pull-up / chin-up. Squatting is a full-body exercise: it is the basic movement around which all training should be centered. He cited a large, long-term study of 8762 men aged 20-80 [28], in which after 18.9 years of follow-up, the men still living were those with the most muscular strength.

Hagen, an educator of fitness exercise, summarized "stronger for long–a functional training elixir", and presented six primal movement patterns with variations/progression [29]. Those are 1 squat, 2 lunge, 3 pull/dead lift/row, 4 push/plank/hover, 5 twist (torso rotation), 6 gait (walk/run), in which the squat is the most fundamental and valuable. Two types of squatting activities in 24 healthy older adults (70-85 years) were tried [30]. One is a typical self-selected depth (normal squat; SQ) and another is a squat onto a chair (chair squat; CSQ, 43.8cm), and descending and ascending phase joint kinematics and kinetics were investigated. CSQ generated greater hip flexion angles, whereas SQ generated greater knee and ankle flexion angles, suggesting possible application of either SQ or CSQ for each elder in the future.

The dose-response relationship of training intensity to training effect was investigated by searching in PubMed for publications of five years [31]. Thirty-three studies from more than 1500 papers were used for the recommendation of strength training in the elderly (>60 years of age), and presented the following results: 1) For increasing muscle mass, recommended training dosage would be 8–12 repetitions per muscle group in 70–85% of the one-repetition-maximum, 3 sets; 2–3 training units per week; at least 8–12 weeks, 2) For training of intramuscular coordination, recommended training dosage would be up to 8 repetitions per muscle group with intensities of more than 80% of the one-repetition-maximum; 3–5 sets; 3 training units per week; several weeks [31]. As stated above, when the middle-aged to elderly aged person tries to exercise for the purpose of anti-aging or exercise therapy, squatting as well as other resistance training and stretching would be recommended for promoting physical health [32].

The exercise equipment 'HiSquat' can be used in different ways according to the different types of subjects. First, when athletes exercise for heavy muscle training with a low hip level, the way of squatting would be full-bottom, full or parallel.

Second, when middle-aged or elderly people use HiSquat for slight to moderate resistance training with a shallow hip level, the way of squatting would be half or quarter. In this case, the squatting movements are continued with position support by grasping the back of a chair or a table. This complemental movement with a chair would be useful for continuing daily exercise therapy, because a series of exercise movements such as warm up, stretch, muscle training can be performed [32]. We can stretch the neck, shoulders, upper back, quadriceps and hamstring/calf, and also strengthen the 5-minute walk, squat, toe stand, knee curl, and knee extension. Therefore, the combination of HiSquat and a chair would be useful for the daily continuation of stretch and muscle training with each different program.

Recently, the development of an air-squat training support system using Microsoft Kinect has been reported [33]. The exercise method is that subjects assume the half-squatting position and sustain the position for one second, which would be effective and can be evaluated for the amount of exercise effect by computer analysis. Such a trial will facilitate development of a new era in the combined field of information, communication and technology (ICT), medicine and fitness.

The combined activity of sitting, walking and stepping are reportedly favorable for diabetic patients. The difference in the effects among sitting, standing and stepping was investigated and is clarified as follows [34]: 1) sitting-to-standing reallocations 2 hours/day showed significant 2% lower fasting plasma glucose, 11% lower triglycerides, 6% lower total/HDL-cholesterol ratio, 2) sitting-to-stepping similarly showed significant 11% lower BMI, 7.5 cm lower waist circumference, 11% lower 2-h plasma glucose, 14% lower triglycerides, and 0.10 mmol/L higher HDL-cholesterol per 2 h/day, and 3) standing-to-stepping similarly showed significant 10% lower BMI, and 11% lower 2-h plasma glucose.

Thus, a daily stepping habit would be beneficial for the glucose profile, and we suggest that HiSquat exercise would be clinically useful due to moderately strong stimuli to large muscles including quadriceps and hamstrings.

In our investigation and speculation, we could estimate the limitation of this study as follows: 1) The research design is short of control group, which enables only comparison between pre- and post- investigation, 2) There are possibly other confounding factors that made the subjects lead regular and healthy life in the current intervention, 3) If the intervention should be discontinued, their lifestyle would be possibly returned back to the original settings, 4) we could not clarified that only squatting might have decreased the value of HbA1c, in this current research design.

Significance of diabetes prevention

American College of Sports Medicine (ACSM) has reported "ACSM's Guidelines for Exercise Testing and Prescription, 9th ed" [35,36], which shows the pre-exercise checklist for subjects with high risks. The risks are classified into 5 categories: 1) diagnosed CVD (cardiovascular disease), 2) possible CVD. 3) DM and at least one additional item (from among10 items), 4) end-stage CKD, and 5) COPD. Category (3) items consist of age, DM, hypertension, hypercholesterolemia and smoking, indicating that DM is an important risk factor.

On the other hand, prevention of DM is also important in anti-aging medicine. In the centenarian study of Keio University, the past history included hypertension in the largest portion, and then followed by cataract, bone fracture and CVD in 302 centenarians living in Tokyo [37]. Severe obesity and severely thin were a few among them. Of course, the centenarians suffered from a variety of diseases, however, the fewest had DM in their past history. Their DM prevalence was only 6% which is markedly lower than the average value (about 20%) in those aged 70s and 80s. These findings indicate that it is very meaningful to prevent DM or control it strictly in order to achieve healthy longevity which is the purpose of the anti-aging medicine.

As to preventing glycative degeneration changes in anti-aging medicine, exercise therapy in older age people could be carried out with easy accessibility, low cost, short training time and feeling for efficacy. From this point, HiSquat would be an effective useful tool for exercise therapy. Many aged people tend to have a difficulty to go outside or to use various equipment due to the aging process. Furthermore, some aged would lose motivation or activation from incompletion of his activity, or by comparison of his performance with others.

On the contrary, the aged people would gain a successful positive emotion from the preparation of attending some opportunities, the refreshing experience on attendance and the network with new friends. In the context of primary care, we should take these merits and weak points into consideration, and then correspond in accordance with each person.

Conclusions

Here, we studied the effect of exercise therapy in the patients with diabetes mellitus using the exercise equipment (HiSquat). As a result, HbA1c value was significantly decreased 0.4% in 61 subjects. Our results would provide fundamental data of exercise therapy for diabetes, and can serve as a reference for the applicable exercise for each subject and patient in anti-aging medicine.

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Statement of conflict of interest

Non contributory.

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