Muscle strength at young age is not associated with future development of type 2 diabetes in Japanese male athletes

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Abstract Muscle strengthening activity and high muscle strength were reported to protect against the development of type 2 diabetes in middle age. On the other hand, the reported prevalence of type 2 diabetes is higher in former top-level power sports athletes compared to healthy non-athlete men. High muscle strength may be a risk factor for type 2 diabetes. However, it is not clear whether high muscle strength can predict the future development of type 2 diabetes. This study examined the relationship between muscle strength at a young age and the future development of type 2 diabetes in former Japanese college athletes by a historical cohort study. Subjects were male alumni who graduated from the Physical Education School of Juntendo University. Hand-grip strength at college age (1971-1991) and type 2 diabetes history, as determined by follow-up questionnaires (2007-2009, and 2011), were collected. Relationships between hand-grip strength and new cases of type 2 diabetes were analyzed by Cox proportional hazards models and adjusted for relative risks. Data of hand-grip strength and medical history of 617 subjects were collected. The median follow-up period was 27 years, and 29 men developed type 2 diabetes. There was no relationship between incidence of type 2 diabetes and muscle strength level after adjustment for potential risk factors. The adjusted hazard ratios (HRs) and 95% confidence intervals of the low, medium, and high muscle strength categories were 1.00 (reference), 1.12 (0.46-2.70) and 0.70 (0.25-1.92), respectively. We concluded that muscle strength at a young age does not predict the future development of type 2 diabetes in Japanese male athletes.

Keywords: hand-grip strength, young age, diabetes, former college athletes

Introduction

In Western Pacific countries, including Japan, 138 million people over the age of 20 years have type 2 diabetes mellitus (T2DM), and it is predicted that this figure will rise to 202 million by 203512. Although the prevalence of overweight and obesity in Asian countries is low compared to Europe and the United States, the prevalence of T2DM has increased over the last 15 years3,4. These data suggest that other risk factors, independent of obesity, might influence the development of T2DM in Asian countries.

It has been reported that peripheral muscle strength is one of the risk factors for T2DM. A negative association was observed between hand-grip strength and development of T2DM5. Strengthening of muscle activity was associated with lower risk of T2DM5. It has also been reported that the decrement of muscle strength with aging, such as sarcopenia, is a risk factor for the development of T2DM7, and that increasing muscle strength is associated with better insulin sensitivity8. Considered together, the above results suggest a close relationship between muscle strength and T2DM.

However, several studies have suggested that athletes engaged in vigorous muscle strength training, could be at high risk for the development of T2DM. For example, the prevalence of T2DM among top-level power sports athletes, such as weightlifters, boxers, and track and field throwers, is equal or greater than that among healthy non-athlete men3,10. Thus, too much muscle strength, as seen in power athletes, may be one of the risk factors of T2DM. However, these reports are all cross-sectional studies, and it is still unclear whether high muscle
strength in athletes can predict the future development of T2DM.

The Physical Education School of Juntendo University Alumni Cohort Study included subjects engaged in college sports clubs such as track and field, gymnastics, soccer, and judo, and who participated in training for competitions in their respective sport. Most of the study subjects were competitive athletes at least while attending college. The main theme of the present study was the relationship between physical performance during college attendance and future disease development. The study subjects also participated in a previous study published by our group, which found that high-level cardiorespiratory fitness at a young age could predict T2DM later in life. The present study is an extension of the above study and was designed to determine the relationship between muscle strength and future development of T2DM.

Materials and Methods

Subjects. Subjects included male alumni of the Physical Education School of Juntendo University. Initial acceptance to the college was by an entrance examination for motor skills and other tests. Students in this study came from all over Japan and most became members of one or more of the college sports clubs, such as track and field, gymnastics, soccer, or judo, in which they trained and participated in competitions in their respective sport.

Muscle strength test. Most alumni underwent an athletic test that included testing of muscle strength once a year; these data were collected from 1971 onwards. Muscle strength was measured by a hand-grip dynamometer; providing a simple and direct isometric method for assessment of strength of hand and forearm skeletal muscles. This study used the data from each subject’s last athletic test. Data of body height and weight were also collected and used to calculate the body mass index (BMI, kg/m²).

Prevalence of diabetes mellitus. A total of 3,918 alumni, who graduated between 1956 and 1991, underwent a follow-up health examination and responded to a self-administered questionnaire in 2007-2009, and 2011. Those who had died or were without a record of an address were excluded. Female alumni were not included because the given university only started admitting women after 1991. The questionnaire included questions about medical background and diagnosis of T2DM by a physician after graduating from the university, along with age at diagnosis. Participants were also asked about smoking, from which we estimated their smoking habits during the time in university. In this study, we used the data of alumni who graduated between 1971 and 1991, because handgrip strength data was not available between 1956 and 1970.

Informed consent. Along with the questionnaire in 2011, prospective participants were also sent a letter of informed consent approving the collection and use of their athletic test data for research purposes. The signed responses and answered questionnaires were regarded as giving consent. Privacy precautions were maintained through Juntendo University, and all data were anonymized before analysis. The study protocol was reviewed and approved by the Juntendo University Ethics Committee in 2007 (No.19-131).

Statistical analysis. Thirty-nine percent of subjects, or 1,385 male alumni returned the follow-up questionnaire. The number of male alumni who graduated in 1956-1991 was 3,918. However, 382 alumni had already died or had an unknown address. We, therefore, sent the self-administered questionnaire to 3,536 alumni; and 1,385 alumni (39%) filled out and returned it. Thus, 35% of the alumni (1,385/3,918) of all students who graduated in 1956-1991 were covered by this questionnaire. Among 2,525 male alumni who graduated in 1971-1991, 33.0% or 832 of them returned the alumni follow-up questionnaire; and hand grip strength data were available in 617 (74.2%) of them. Therefore, we analyzed these 617 male alumni who graduated between 1971 and 1991, responded to the follow-up questionnaire, and whose hand-grip strength data were available at the time (Fig. 1). For each subject, the duration of follow-up was counted from the year of graduation (1971-1991) until the time of the follow-up questionnaire responses in 2007-2009, and 2011, or the time of diagnosis of T2DM. The muscle strength level was categorized into tertiles (low, medium, or high) based on the hand-grip strength at the time in college. The association between muscle strength and incidence of T2DM was assessed by Cox proportional hazards models. Data were adjusted for age (continuous variable, 1-year-old ticks), year of graduation (continuous variable, 1-year increments), BMI (continuous variable, 1 kg/m² increments), smoking (category, yes or no), and college sports club participation (category, yes or no). Factors included in the multivariate model were selected according to the known risk factors for T2DM which have been reported previously. The year of graduation and college sports club participation were used as surrogate variables of economic status and physical activity, respectively. Multivariable-adjusted hazards ratio and 95 percent confidence interval (95% CI) for T2DM were obtained using the low muscle strength group as the reference category. All statistical analyses were conducted using SPSS 23.0 for Windows (SPSS Inc., Chicago, IL).

Results

The characteristics of the study subjects are shown in Table 1. The median BMI of the study subjects during their time in college was within the normal range, while 35 subjects were defined as overweight (BMI ≥ 25 to < 30 kg/m²) and only 5 as obese (BMI ≥ 30 kg/m²). Ninety-
nine percent of the subjects registered in a college sports club. Characteristics of T2DM and non-T2DM were similar.

Table 2 shows the physical characteristics of the subjects while at college stratified by the muscle strength level. Men of the highest muscle strength group had the highest body height, weight, and BMI levels.

The follow-up period was 27 years (interquartile range: 23-31 years), which included 16,857 person-years of observation. The median age at the time of the follow-up questionnaire was 50 years (interquartile range: 47-54 years), and 29 men had developed T2DM during this period. No one self-declared to be diagnosed with diabetes during their college years.

To examine the relationship between muscle strength level and development of T2DM, we evaluated the incidence rate and hazard ratios in the low, medium and high muscle strength groups. The incidence and hazard ratio of T2DM was similar among the groups (Table 3). The trend of the hazard ratios was also similar after adjustment for
### Table 2. Characteristics of male subjects by muscle strength level

| Muscle strength | Low   | Medium | High  |
|-----------------|-------|--------|-------|
| n               | 241   | 201    | 175   |
| Hand-grip strength (kg) | 45 (43-47) | 51 (50-52) | 57 (55-60) |
| Age (years)     | 23 (23-23) | 23 (23-23) | 23 (22-23) |
| Year of graduation | 1982 | 1982 | (1978-1985) | (1979-1986) | 1982 (1979-1986) |
| Body height (cm) | 170.1 | 172.6 | 175.0 |
| (165.8-174.3) | (168.8-177.2) | (171.7-179.5) |
| Body weight (kg) | 62.4 (59.0-65.6) | 65.7 (61.8-70.4) | 70.4 (65.6-75.0) |
| BMI (kg/m²)      | 21.6 (20.6-22.5) | 22.1 (21.2-22.8) | 22.8 (21.7-24.3) |
| Smoker (%)       | 113 (46.9) | 105 (52.2) | 78 (44.6) |
| College sports club participation (%) | 238 (98.8) | 198 (98.5) | 173 (98.9) |

Data are median (IQR: interquartile range) or number of patients (%)

### Table 3. Adjusted hazard ratio for diabetes according to muscle strength level

| Muscle strength level, tertiles | Low   | Medium | High  | p for Trend |
|--------------------------------|-------|--------|-------|-------------|
| Number of subjects             | 241   | 201    | 175   |             |
| Person-years of follow-up      | 6628  | 5500   | 4729  |             |
| Diagnosed type 2 diabetes      | 10    | 10     | 9     |             |
| Rate per 10,000 person-years   | 15.1  | 18.2   | 19.0  |             |
| Age adjusted hazard ratio (95% CI) | 1.00 (reference) | 1.28 (0.53-3.09) | 1.29 (0.52-3.18) | 0.57 |
| Age and BMI adjusted hazard ratio (95% CI) | 1.00 (reference) | 1.13 (0.47-2.73) | 0.72 (0.26-1.95) | 0.86 |
| Multivariable adjusted hazard ratio* (95% CI) | 1.00 (reference) | 1.12 (0.46-2.70) | 0.70 (0.25-1.92) | 0.85 |

*Cox proportional hazards models adjusted for age (continuous variable, 1-year-old ticks), year of graduation (continuous variable, 1 year increments), BMI (continuous variable, 1 kg/m² increments), smoking (category, yes or no), and college sports club participation (category, yes or no).
several parameters (Table 3). In addition, the cumulative incidence rates of T2DM were comparable among the groups (Fig. 2). These data suggest that there is no association between muscle strength at a young age and the development of T2DM in physically-active Japanese men.

For sub-analysis, we investigated the relationship between potential risk factors of T2DM and T2DM incidence. Only BMI was significantly associated with T2DM, while other potential risk factors were not (Table 4).

**Table 4. Potential risk factors for diabetes**

|                      | Crude hazard ratio (95% CI) | Multivariable adjusted hazard ratio (95% CI) |
|----------------------|-----------------------------|---------------------------------------------|
| Age (years)          | 0.51* (0.26-0.97)           | 0.56 (0.29-1.07)                           |
| Year of graduation   | 0.61 (0.29-1.29)            | 1.07 (0.95-1.20)                           |
| BMI (kg/m²)          | 1.30* (1.13-1.50)           | 1.31* (1.12-1.53)                          |
| Smoker (yes/no)      | 1.10 (0.99-1.23)            | 0.65 (0.30-1.41)                           |
| college sports club  | 0.40 (0.05-3.00)            | 0.48 (0.06-4.09)                           |

# Model included hand-grip strength (continuous variable: 1 kg increments), age (continuous variable, 1 year old ticks), year of graduation (continuous variable, 1 year increments), BMI (continuous variable, 1 kg/m² increments), smoking (category, yes or no), and college sports club participation (category, yes or no)

*p < 0.05

**Discussion**

We investigated the relationship between the level of muscle strength using hand-grip strength and future development of T2DM among Japanese male athletes. After adjustment for potential confounding factors, the results showed no significant difference in the incidence of T2DM among men with various levels of muscle strength. These data suggest that muscle strength at a younger age does not influence future development of T2DM in Japanese male athletes.

The relationship between muscle strength and development of T2DM is equivocal and may be influenced by the characteristics of the study subjects. For example, low muscle strength is considered a risk factor for T2DM in the general population, while a high prevalence of T2DM is observed in power sports athletes. In our study cohort, 99% of the subjects were athletes in competitive college sports as students. However, we could not count the precise number of power sports athletes in this cohort because power sports are defined not only by the specific sport, but also by the player position in a given sport (e.g., in rugby football, not backs, but the forward position). In our preliminary analysis, the percentage of subjects who participated in power sports, including rugby, football, judo and field throwers, was relatively higher in the high strength group (17%) compared to the other two groups (6%, each). However, even in the muscle grip strength group, the percentage of power sports athletes was only 17%, suggesting most of the subjects in the group participated in other types of athletics, such as endurance sports, soccer, basketball, track and field, short distance running, and gymnastics. These data suggest that not only muscle
strength, but also subject characteristics may influence the results.

In analysis of potential risk factors, high BMI was significantly associated with T2DM. Consistently, high BMI and weight gain were reported as risk factors of T2DM\(^{13,17,20}\). For example, an increase of 1kg/m\(^2\) BMI in young age was associated with 1.2 times risk of T2DM later in life in European individuals\(^{19}\). These data suggested that a small increase in BMI at a young age might be a risk of future T2DM not only in European individuals, but also in Japanese male athletes.

Although muscle strength at a young age did not predict future development of T2DM in Japanese male athletes, it remains unknown whether the relationship is similar to the general population. Most previous studies have shown an association between muscle strength in middle age men (mean age 51.9) and the development of T2DM\(^5\). Thus, it is also possible that muscle strength in middle age men is a good marker for the prediction of T2DM, but not at a young age. Nonetheless, our data showed that Japanese male athletes with high cardiorespiratory fitness during their college years are at low risk for future T2DM\(^1\), similar to the general population\(^2\).

Our study has several limitations that need to be discussed. First, the subjects are not representative of all Japanese athletes. However, our student cohort came from all over Japan and were selected for admission by an entrance examination for motor skills. Second, we could not deny the possibility of selection bias because our study included alumni who had responded to a follow-up questionnaire. Therefore, these individuals might be more health conscious than those who did not respond. In addition, we could obtain 74.2% hang-grip strength data in participants who returned the questionnaire; which also might bias the results. At least, subject characteristics in the present study, including body height, body weight, and hand-grip strength, were similar to mean values of those in Juntendo University students from 1980 to 1991\(^{21}\). Third, female alumni were excluded because none were registered at the college in 1971. Fourth, recall bias was possible because the questionnaire was cross-sectional and subjects needed to recall their medical background. However, at least, the accuracy of the examination by mail was tested in a previous study, and was considered to be a sufficient method for an epidemiological study\(^{22}\). Finally, we did not directly diagnose diabetes by an oral glucose tolerance test or medical check-up data, and diabetic subjects who died before this study were not counted.

In conclusion, our data demonstrated that BMI, but not muscle strength at young age, is a good predictor of future development of T2DM in Japanese male athletes.

Conflict of Interests

The authors declare no competing financial or non-financial interests.

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