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Secular trends in the grip strength and body mass index of sport university students between 1973 and 2016: J-Fit+ study

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ABSTRACT

Background/Objective: Sport university students are a unique population because they usually have a strong sport background since early childhood. In this study, we aimed to examine secular trends in grip strength of male, first-year sport university students in comparison with the general population between 1973 and 2016.

Methods: Existing data on the grip strength of 6,308 sport university students aged 18 years were examined. The data were obtained from the Juntendo Fitness Plus Study, a study of the Department of Physical Education/Health and Sports Science of Juntendo University. For reference, age- and sex-matched data (18 years old, male) on the grip strength were obtained from a national database.

Results: Compared with the general population, the sport university students had greater body mass index and stronger grip strength at all times.

Conclusions: The grip strength of sport university students significantly declined between the 1980s and 1990s, and it has plateaued since 2000, albeit at low levels. Compared with the peak performance of sport university students in 1984, the grip strength of students in 2016 was significantly lower by 8.1 kg. The downward trends were also confirmed in the general population during the same periods. In conclusion, the grip strength of sport university students has significantly declined over the last few decades.

Introduction

Physical fitness is a powerful marker of current health and a predictor of future health.[1] It includes cardiorespiratory fitness and muscular fitness. Previous studies suggested that cardiorespiratory fitness is strongly associated with cardiovascular and all-cause mortality.[2,3] Recently, increasing evidence has suggested that reduced muscle fitness, as measured by grip strength, is also associated with an increased risk of all-cause, cardiovascular, and premature death.[4–6] Grip strength measurement is appealing as a simple, quick, and inexpensive means of stratifying an individual's risk of cardiovascular death. Therefore, measurement of grip strength is potentially useful for monitoring an individual's health status.

Examination of temporal changes in grip strength of young people is limited because the vast majority of previous studies examined secular changes in cardiorespiratory fitness.[7] To the best of our knowledge, secular changes in the grip strength of a young population have been examined in only two previous studies.[8,9] For example, Tremblay et al. examined temporal changes in grip strength in a representative sample of Canadian children and adolescents aged 6–19 years; they compared the grip strength between youth in 1981 and those in 2007–2009. In their study, they showed that youth in 2007–2009 had significantly lower grip strength than those in 1981 and concluded that grip strength significantly declined during this period.[8] Although this study provided important implications, they involved only two time points, which may reflect only a perturbation caused by assessment year rather than an "overall" trend. To date, no study has examined the overall trend by conducting yearly assessment in grip strength

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consistently for a long period of time.

University years are a critical period for health as students increasingly make independent choice about their lifestyle and health practices.[10] Meanwhile, unhealthy behavior, such as having unbalanced diet and/or reductions in physical activity, can occur due to increases in academic stress and experiences of freedom from parental restriction.[10] The prevalence of physical inactivity seems to rapidly increase during the university years.[11,12] In particular, dramatic changes in lifestyle often occur at the first year of university, and consequently the risk of unfavorable weight gain could increase during the same period.[13,14] Furthermore, an international comparison study revealed that the prevalence of physical inactivity is higher among university students from Asia Pacific than from Europe and the USA[15], which calls for considerable attention among that population. Japanese people aged 18–24 years were reported to have the lowest exercise participation rate compared with those from other age groups.[16] An explanation for the reduction in exercise participation might be attributed to the changes in educational system including participation in a sport club activity throughout junior, high school, and university.[16] National representative data showed that 81.2% and 64.9% of the Japanese students in junior high school and high school, respectively, belonged to at least one sport club activity, whereas only 39.8% of the students in university did.[17] These findings suggest that the sharp decline in sport club participation occurred between high school and university years. Late adolescence and early adulthood appear to be significant periods of transition as muscular strength during this period seems to be associated with the current and future cardiometabolic health.[18–20]

The Juntendo Fitness Plus Study (J-Fit$^+$ Study) is a study of the Department of Physical Education/Health and Sports Science of Juntendo University. It included subjects engaged in college sports clubs such as track and field, gymnastics, soccer, and judo, and those who participated in training for competitions in their respective sport.[21,22] Most of the study subjects were competitive athletes at least while attending college.[21,22] Sport university students are a unique population because they usually have a strong sport background since early childhood and are more likely to continue to engage in a sport club activity during their university years. Previous studies showed that sport club participation rate is higher in sport university students than in the general population (98.7% vs. 39.8%).[17,21,22] In addition, sport university students are required to take the curricula of physical activity and sports sciences, which promote an active and healthy lifestyle in addition to having practical lessons in which students learn and partake in physical activity during the university years. Therefore, revealing the differences in grip strength performance between sport university students and the general population might suggest the importance of physical activity and sport experience from early childhood to university years. Furthermore, how the grip strength of sport university students had changed over the past few decades in comparison with the general population is unknown. Therefore, the present study aimed to examine secular trends in grip strength among the first-year sport university students in comparison with the general Japanese population. The study also aimed to investigate the secular trend in body mass index (BMI) among the sport university students as grip strength is known to be significantly influenced by BMI.[23]

Methods

Study participants

In Juntendo University, anthropometric and physical fitness tests including grip strength had been conducted as part of the university curriculum, and the test results are available since 1973. The students in the university were selected for admission based on entrance examination of physical fitness tests, including grip strength and motor skill tests. To examine the secular changes in grip strength and BMI among the first-year sport university students, we used the data of those outcomes between 1973 and 2016 from the J-Fit$^+$ Study. Although we did not determine the ethnic background of the students, almost all students were Japanese. For example, students entering the Department of Physical Education/Health and Sports Science of Juntendo University were all local students, and no international students enrolled in the department in 2018. Inclusion criteria were male, 18 years of age, and availability of valid data on the main exposures (grip strength, height, and body weight). Biological age has been reported to be significantly associated with physical fitness.[24] Therefore, the present study used only data of 18-year old students to exclude the potential age influence as the majority of the first-year students aged 18 years. In addition, the present study used only the data of male students. This is because the majority of the students from the J-Fit$^+$ Study were male as the departments of the university used to be exclusively for male students until 1991, and fewer samples of female students were available to examine the secular changes in grip strength. Data on 7,883 sport university students were collected. Of these students, 1,257 (15.9%) were excluded because they were aged 19 years or older. In addition, 318 students (4.0%) did not comply with valid data on anthropometry and/or grip strength. The final sample for this study comprised 6,308 sport university students (80.0%). Privacy precautions were maintained through Juntendo University, and all data were anonymized before analysis. All study participants provided informed consent, and the study design was approved by the institutional ethics committee (Approval number: 29–171).

Assessment of grip strength and anthropometry

Forearm grip strength was measured using a hand dynamometer (Takei Scientific Instruments Co., Ltd) according to a standardized study protocol that had been used in the national fitness survey.[25] The inter-trial reliability was reported for the hand dynamometer.[26] The grip bar was adjusted so that the second joint of the fingers were bent to grip the handle of the dynamometer. The participant stood upright, with the arm vertical and the dynamometer close to the body. The participants were then asked to squeeze the handgrip dynamometer as hard as possible. The test was completed twice each in the left and right arms, and the best records of the left and right arms were averaged. Since grip strength is highly associated with body size, calculating “relative grip strength” was recommended to adjust the influence of the body size.[27] Therefore, relative grip strength, which was defined as absolute grip strength divided by BMI, was computed.[27]

Anthropometric characteristics were measured with subjects barefoot and in their underwear. Body weight was measured to the nearest 0.1 kg with a digital scale (YAGAMI Inc.), and standing height was measured to the nearest millimeter using a stadiometer (YAGAMI Inc.). We calculated BMI as weight (kg) divided by squared height (m).

Grip strength and anthropometric characteristics were measured by a research expert with specialization in sport and exercise science from Juntendo University. In addition, third- and fourth-year university students who underwent several training sessions to measure the outcomes under the supervision of a research expert from Juntendo University were recruited as examiners. Although the fitness test was constantly conducted every

year since 1973, the test was not conducted in some years due to policy changes for the physical fitness test (data were not available in 1983 (for grip strength), 1995 (for anthropometry), and 1996 (for grip strength and anthropometry)).

National data

In Japan, annual surveillance of physical fitness has been performed by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) since 1964 when the 18th Summer Olympic Games was held in Tokyo. This annual surveillance is performed to evaluate physical fitness and exercise, as well as life and eating habits across the life course, from Japanese children to the elderly.[28] The details of the surveillance were described elsewhere.[29,30] The results of the surveillance had been statistically processed annually by the MEXT, and published as the "Annual Report on the Survey of Physical Fitness and Athletic Ability" every year.[28] In the present study, we used the national representative data on grip strength and anthropometry (i.e., height and weight) of 18-year-old Japanese male population to set age- and sex-matched references.[28] In the annual surveillance, data of 18-year-old Japanese male were collected from national university (first year) and national college students (fourth year). Several colleges and universities according to regions (i.e., Hokkaido, Tohoku, Kanto, Chubu, Kansai, Shikoku, Kyusyu) were randomly selected, and students attending the selected college and university were recruited as participants.[28] Sample sizes for 18-year-old Japanese males differed each year due to population availability (from 1,000 to 2,000). Sport-related departments were excluded in the annual surveillance. Although the mean and standard deviation of grip strength, height, and weight were available, BMI was not reported in the annual surveillance. Therefore, we calculated BMI as weight (kg) divided by squared height (m) using the reported mean of height and weight in the annual surveillance. The data between the J-Fit$^+$ Study and the national surveillance were comparable as both surveys used the same measurement protocols.[25]

Statistical analysis

Temporal changes were examined in sport university students and the general population. As the purpose of the study was to examine the "overall trends" in grip strength and BMI, we used a 5-year simple moving average to demonstrate the secular changes in those outcomes (for the crude data in each assessment year, see Appendices A-E).

A formula of a 5-year simple moving average is shown below:

$$\text{5-year simple moving average}_{\,i} = (x_{i-2}+x_{i-1}+x_i + x_{i+1}+x_{i+2})/5$$

As data were not available in some years (1983 [for grip strength], 1995 [for anthropometry], and 1996 [for grip strength and anthropometry]), some data were ascertained using a 3- to 4-year simple moving average (e.g., grip strength in 1981–1985 was calculated with a 4-year simple moving average). Percent changes (%) in grip strength and BMI were calculated, with data being standardized to the year 1973 = 0%; positive values (>0%) indicate greater grip strength and BMI in each assessment year.

Z-tests were performed to examine the difference in height, weight, and grip strength between sport university students and the general population. Linear regression models were used to examine the associations between the year of testing and the outcomes. Unstandardized coefficient (B) represents the changes in mean per year of each outcome. Positive B values indicate increases (or improvements) in means of grip strength or anthropometry, whereas negative values indicate declines in means of these outcomes. Statistical analyses were performed with SPSS for Windows (version 24.0), and a p-value < 0.05 denoted statistical significance.

Results

Overall results

The absolute data in grip strength and BMI were higher in sport university students than in the general population from 1973 to 2016. The average % difference in grip strength between the two populations was 3.9% (min: 0.4%; max: 6.7%).

The average % difference in BMI between the two populations was 3.9% (min: 2.5%; max: 5.1%). The relative grip strength from 1973 to 2016 was slightly higher in sport university students than in the general population (average % difference was 1.3% [ranging from −3.0% to 7.6%]). Data on percent changes in grip strength and BMI showed that grip strength decreased from 1973 to 2016 between the two populations. Compared with the peak performance of sport university students in 1984, the grip strength of the students in 2016 was significantly lower by 8.1 kg (−15.3% reduction). For the general population, the grip strength had been consistently declining since 1985. Compared with the peak performance of the general population in 1983, the grip strength of the population in 2016 was significantly lower by 6.0 kg (−12.7% reduction). Our regression analysis showed that the grip strength of sport university students significantly declined between the 1980s and 1990s, and it has plateaued since 2000, albeit at low levels.

Secular trends in grip strength and BMI

Secular trends in absolute grip strength and BMI of sport university students and the general population between 1973 and 2016 are shown in Fig. 1. The grip strength in both sport university students and the general population has declined over the last few decades. In particular, significant declines in grip strength occurred in the 1980s and 1990s for both populations. The grip strength in sport university students seemed stable between 1997 and 2007. However, it dropped in the late 2000s and has become stable again in recent years.

For BMI, the sport university students in the recent years were taller and heavier than the students in the past. More specifically, improvements in height and weight were observed in the 1980s, and the body size seemed to have plateaued since the 1990s. In addition, the mean BMI improved in the 1980s, and after small fluctuations in the early 1990s, it has become stable after 2000.

Secular trends in relative grip strength of sport university students and the general population between 1973 and 2016 are shown in Fig. 2. The relative grip strength from 1973 to 2016 was slightly higher in sport university students than in the general population (average % difference was 1.3% [ranging from −3.0% to 7.6%]). The relative grip strength was higher in sport university students most of the years than that in the general population, except years 1973 and 1987–1990 (Fig. 2).

Percent changes in grip strength and BMI

Temporal patterns of changes in grip strength and BMI of sport university students and their counterparts between 1973 and 2016 are shown in Fig. 3. Data are standardized to the year 1973 = 0%, with positive values (>0%) indicating greater grip strength or BMI

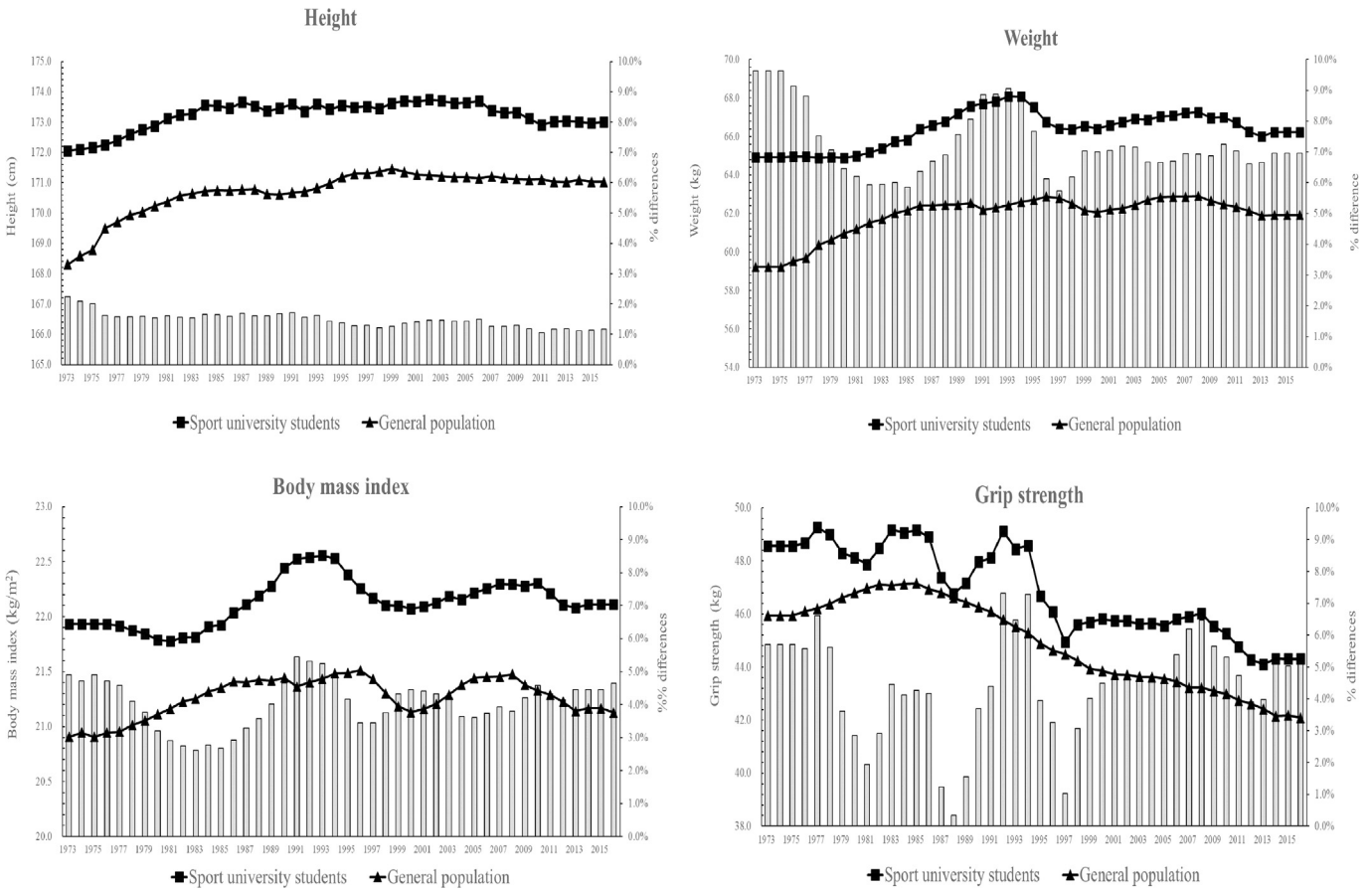

Fig. 1. Secular trends in absolute grip strength and body mass index of sport university students and the general population between 1973 and 2016. Data in the line graphs are shown using a 5-year simple moving average. Bar graphs represent the percent differences in each outcome between sport university students and the general population in each assessment year. Positive values indicate greater values of each outcome for sport university students compared with their counterparts.

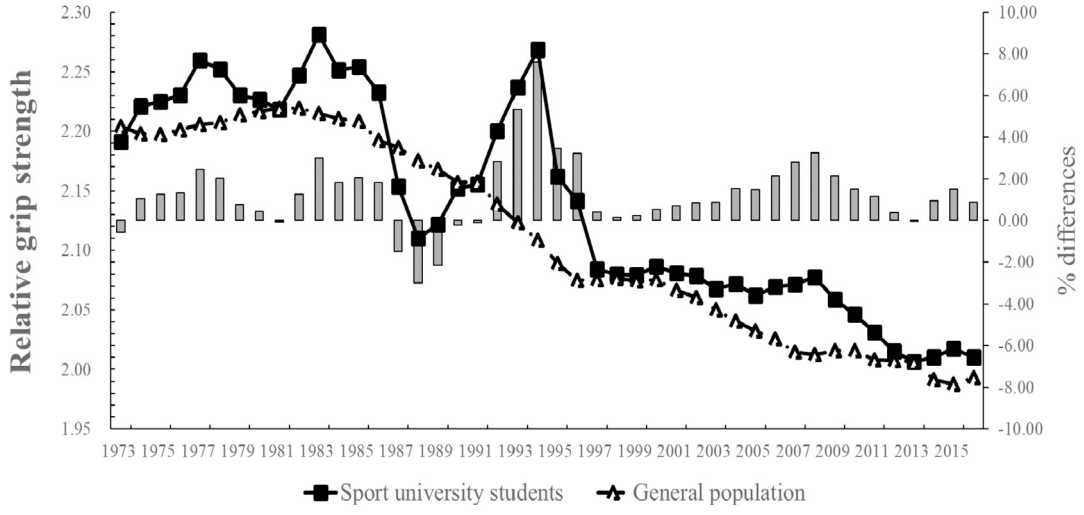

Fig. 2. Secular trends in relative grip strength of sport university students and the general population between 1973 and 2016. Data in the line graphs are shown using a 5-year simple moving average. Relative grip strength was calculated using the formula below: Relative grip strength = grip strength (kg)/body mass index (kg/m^2).

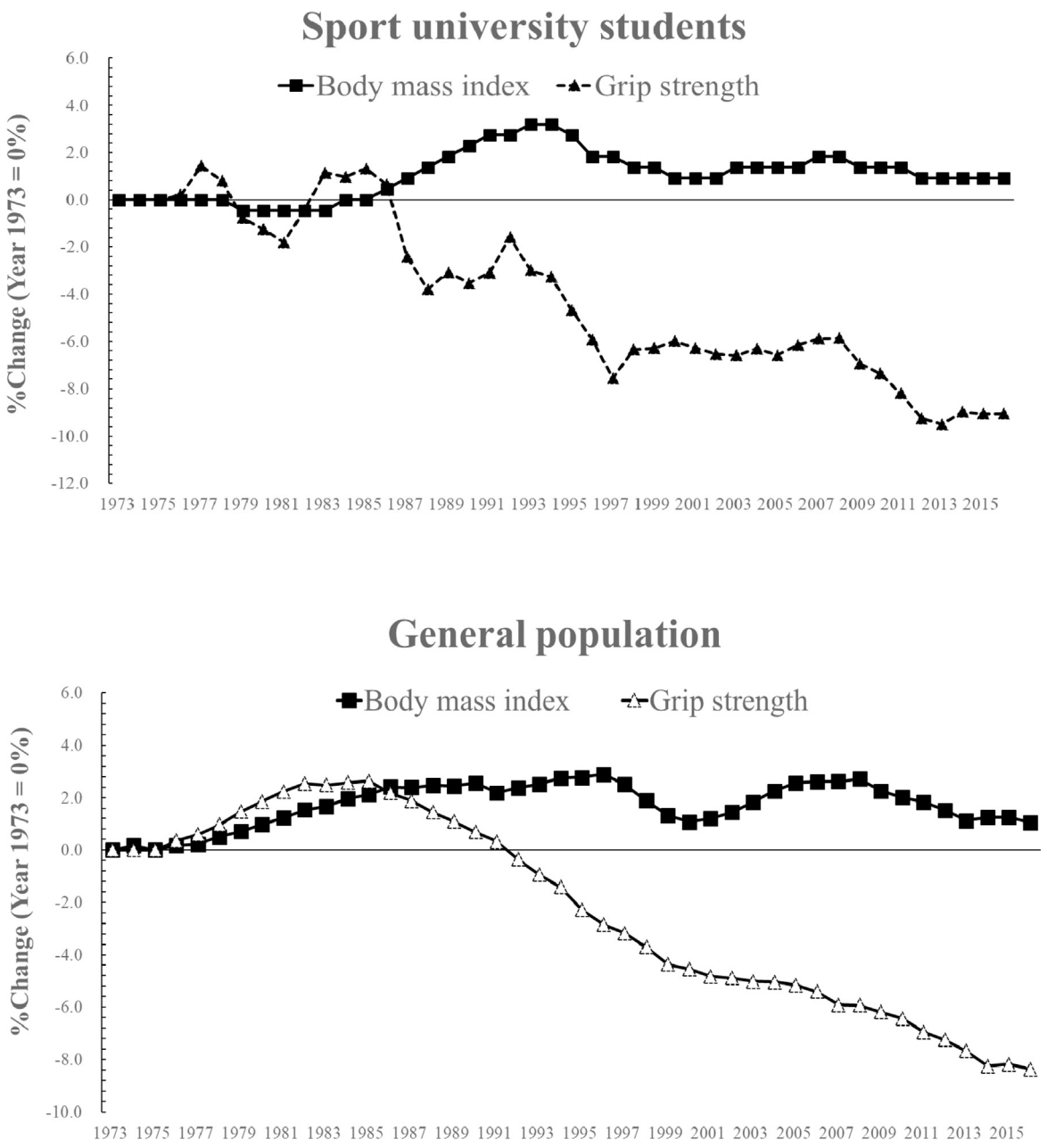

Fig. 3. Temporal patterns of changes in grip strength and body mass index of sport university students and the general population between 1973 and 2016. Data are standardized to the year 1973 = 0%, with positive values (>0%) indicating greater muscular strength or body mass index in each assessment year or vice versa.

in each assessment year. Compared with sport university students in 1973, the BMI value has been greater in the students after 1986. On the other hand, a significant decline in the grip strength of sport university students was observed since 1987. A similar trend was confirmed in the general population.

Association between the assessment year and the dependent variables

Table 1 shows the linear regression models examining the association between the assessment year and the dependent variables (grip strength and anthropometric characteristics) per decade. For grip strength, significant improvements were observed, on average by +0.35 kg/year, in the 1970s. Thereafter, significant declines occurred on average by −0.12 kg/year and −0.21 kg/year in the 1980s and 1990s, respectively. Since 2000, the grip strength has plateaued, as no significant association was found between assessment year and grip strength in the 2000s and 2010. When we pooled all data between 1973 and 2016, the grip strength declined on average by −0.12 kg/year. For BMI, significant improvements were found in height and weight, on average by +0.12 cm/year and +0.25 kg/year, in the 1980s. Consequently, BMI was also improved, on average by +0.05 kg/m^2 per year. After small fluctuations of body weight and BMI in the 1990s, they have become stable since 2000. From the pooled analysis, body size significantly improved since 1973, on average by +0.02 cm, +0.03 kg,

Table 1
Percent per year increases or decreases in grip strength and body mass index of sport university students per decade.

	Grip strength (kg)		Height (cm)		Body weight (kg)		BMI (kg/m^2)	
	B (95% CI)	p value	B (95% CI)	p value	B (95% CI)	p value	B (95% CI)	p value
1970s (n = 722)	**+0.35 (0.15 to 0.55)**	**<0.001**	+0.14 (-0.04 to 0.33)	0.133	+0.11 (-0.12 to 0.34)	0.361	0.00 (-0.06 to 0.05)	0.945
1980s (n = 1221)	**−0.12 (-0.23 to -0.02)**	**0.024**	**+0.12 (0.02 to 0.22)**	**0.022**	**+0.25 (0.12 to 0.38)**	**<0.001**	**+0.05 (0.02 to 0.09)**	**<0.001**
1990s (n = 1388)	**−0.21 (-0.31 to -0.11)**	**<0.001**	−0.02 (-0.11 to 0.08)	0.723	**−0.16 (-0.29 to -0.03)**	**0.015**	**−0.05 (-0.08 to -0.01)**	**0.007**
2000s (n = 1577)	+0.09 (-0.01 to 0.20)	0.087	0.00 (-0.10 to 0.10)	0.982	+0.13 (-0.01 to 0.26)	0.072	**0.04 (0.00 to 0.08)**	**0.047**
2010s (n = 1400)	+0.03 (-0.14 to 0.20)	0.732	−0.05 (-0.21 to 0.12)	0.581	−0.05 (-0.30 to 0.21)	0.720	0.00 (-0.07 to 0.07)	0.954
1973–2016 (n = 6308)	**−0.12 (-0.13 to -0.11)**	**<0.001**	**+0.02 (0.01 to 0.03)**	**<0.001**	**+0.03 (0.02 to 0.05)**	**<0.001**	**+0.01 (0.00 to 0.01)**	**0.003**

Linear regression models were used to examine the association between assessment year and the dependent variables (grip strength and anthropometric characteristics) per decade. Unstandardized coefficient (B) represents the changes in mean per year of each outcome. Positive B values indicate increases (or improvements) in means of grip strength or anthropometry, whereas negative values indicate declines in means of these outcomes. Significant results are presented as bold fonts.
BMI, body mass index.

and +0.01 kg/m^2 per year for height, body weight, and BMI, respectively.

Discussion

The present study provides evidence of significant declines in grip strength performance of sport university students over the last 40 years. Compared with the peak performance of the students in 1984, the grip strength of the students in 2016 was significantly lower by 8.1 kg (−15.3% reduction). In addition, our regression analyses revealed significant declines in grip strength of sport university students on average by −0.12 kg/year over the last 43 years. BMI had significantly improved, on average by +0.01 kg/m^2 per year during the same periods. Increases in BMI were reported to likely reflect increases in both fat mass and fat-free mass.[31] Therefore, increases in BMI are often associated with increases in grip strength.[32] However, our sport university students demonstrated significant declines in grip strength alongside significant improvements in BMI. These findings suggest that muscular power per unit might be significantly deteriorated.

The absolute data in grip strength and BMI were higher in sport university students than in the general population from 1973 to 2016. The average % difference in grip strength between the two populations was 3.9%. However, the difference might be influenced by the difference in BMI since BMI is known to be positively associated with grip strength.[27] Therefore, we computed relative grip strength.[27] When we compared the % differences in absolute and relative grip strength between the two populations, the extent of differences in relative grip strength was smaller than that in absolute grip strength (1.3% and 3.9%, respectively). These results might suggest that sport university students had stronger grip strength because they also had greater BMI compared with the general population. However, relative grip strength was still stronger in sport university students than in the general population. This suggests that sport university students seemed to have superior grip strength even after adjusting the influence of BMI. Sport university students are a unique population because they usually have a strong sport background since early childhood, and the majority of them continue to engage in a sport club activity during their university years.[21,22] As the levels of physical fitness may partially represent one's lifestyle behavior[1], it is plausible that sport university students have stronger relative grip strength. However, the novel finding of the study was the drastic reduction in grip strength from 1973 to 2016 even among sport university students. Compared with the peak performance of sport university students in 1984, the grip strength of the students in 2016 was significantly lower by 8.1 kg (−15.3% reduction). A similar extent of reduction was confirmed among the general population (−6.0 kg [-12.7%] reduction). The present study may demonstrate a serious public health concern since grip strength is associated with an increased risk of all-cause death, cardiovascular death, and cardiovascular disease.[4,5]

Secular trends in muscular strength

Several studies reported temporal changes in muscular strength of young people[8,33,34], but showed inconsistent results. The inconsistency might be attributed to the differences in the study participants (countries, ethnicity, age), the assessment year, methodology, and main outcomes according to each study. For example, Westerstahl et al. reported an upward trend of muscular fitness assessed by standing vertical jump in a representative sample of Swedish boys aged 16 years from 1974 to 1995.[34] On the other hand, Tremblay et al. reported a downward trend of grip strength in a representative sample of Canadian boys aged 6–19 years between 1981 and 2009.[8] Although the above-mentioned studies are of importance, they represent only two country samples and two time points (i.e., before and after assessments). Therefore, they may reflect only a local perturbation rather than an "overall" trend. In this respect, a systematic review by Tomkinson was of value because it reviewed 32 studies from 27 countries and 5 geographical regions from 1958 to 2003 to quantify the global changes in anaerobic fitness test performance of young people aged 6–19 years.[33] According to the systematic review, the power performance assessed by the single-jump test was significantly improved at +0.03% per year between 1958 and 2003.[33] However, if we focused on more detail, the power performance was improved in the 1960s and 1970s, and thereafter, the performance deteriorated in the 1980s and 1990s.[33] Interestingly, a similar trend was confirmed by our study; improvements in grip strength occurred in the 1970s, and thereafter, grip strength decreased in the 1980s and 1990s. These results may suggest that muscular fitness globally declined in the 1980s and 1990s. These reductions might have also occurred for sport university students who usually have a strong sport background since early childhood.

Strengths

This study has several strengths. First, the present study included the raw data of grip strength in more than 6,000 sport university students for over 40 years. We used consistent measurements to evaluate secular trends in grip strength of sport university students for 43 years, which allows us to examine an

"overall" trend in the grip strength of sport university students. Second, our regression analyses revealed when and how much decline occurred over the past decades, which would not be revealed in a purely descriptive study. Third, the present study included a national representative data of grip strength in the general population as reference. The reference data enabled us to determine the superiority of sport university students to the general population and the difference in temporal changes in both populations. Our findings suggest that grip strength deteriorated at the same degree for both populations, although sport university students had greater grip strength than the normal population at all times.

Limitations

This study has also limitations. First, the present study included sport university students from only one university. Therefore, the external validity of the present study is uncertain. Second, the reduction in grip strength was possibly influenced by changes in the characteristics of students attending the university. However, the influence was minimal as the university had had consistent admission policies including consistent entrance exams of physical fitness across the survey years. In addition, there seemed to be no meaningful difference in the percentage of students belonging to a sport club activity during their university years (1973 = 89.1%, 1980 = 94.7%, 1990 = 97.5%, 2000 = 89.8%, 2010 = 89.0%, 2015 = 98.6%; data are not shown). Third, clarifying the reason for the decline in grip strength over the last few decades is not possible. The decline is probably caused by trends in a network of environmental, social, behavioral, physical, psychosocial, and physiological factors. In particular, daily physical activity seems to be significantly reduced over the last few decades.[35] This reduction might have contributed to the downward trend in grip strength, although the present study contains no data on the temporal changes in the physical activity of sport university students. Further studies investigating the mechanism underlying the reduction is required.

Conclusion

The grip strength of sport university students significantly declined over the last few decades.

Conflicts of interest statement

No potential conflict of interest was reported by the authors.

Appendix A
Crude data of grip strength of sport university students and the general population

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Sport university students															
Sample size (n)	112	93	92	102	102	107	115	110	93	107	–	121	120	129	136
Mean (kg)	48.6	47.6	47.7	49.9	49.1	49.1	50.5	46.3	46.4	48.2	–	53.0	49.1	45.9	48.6
SD	6.1	5.6	6.0	6.3	6.0	5.5	6.5	5.5	5.4	5.0	–	6.2	7.1	6.7	6.0
General population															
Sample size (n)	3909	1183	218	2259	1451	1631	1528	1453	1512	1692	1896	1727	1656	1737	1898
Mean (kg)	45.9	45.8	46.5	45.6	45.9	46.7	46.3	47.4	46.8	46.8	47.6	47.1	47.2	47.0	46.9
SD	6.6	6.4	7.8	6.3	6.5	6.6	6.5	6.4	6.1	6.4	6.5	6.4	6.4	6.5	6.7
$^{**}P < 0.05$	**	**		**	**	**	**	**		**	**	**	**		**

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sport university students															
Sample size (n)	179	226	224	188	183	175	154	138	–	174	164	166	158	172	172
Mean (kg)	47.8	45.4	46.1	47.9	52.7	48.6	50.4	42.7	–	44.9	46.3	45.9	45.3	46.1	45.6
SD	5.8	5.6	7.0	6.4	10.6	5.6	7.2	6.0	–	6.8	6.4	7.0	7.6	7.0	6.2
General population															
Sample size (n)	1827	1854	1684	1876	1888	1829	1896	1980	1992	1853	1171	1036	993	1070	1032
Mean (kg)	46.5	46.4	46.2	46.2	46.0	45.7	44.8	44.9	45.1	44.0	44.4	44.1	43.6	43.6	43.6
SD	6.3	6.6	6.9	6.6	6.7	6.7	6.6	6.6	6.9	6.9	6.9	6.3	6.4	7.0	6.6
$^{**}P < 0.05$	**			**	**	**	**	**	**		**	**	**	**	**

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sport university students														
Sample size (n)	143	155	157	171	164	163	127	189	165	213	216	213	210	290
Mean (kg)	45.9	45.8	44.7	46.2	45.1	47.1	46.4	45.3	43.8	45.2	44.6	43.6	44.3	44.9
SD	7.0	7.0	7.1	6.7	6.7	7.0	6.9	6.6	6.8	19.1	7.0	6.1	6.6	6.6
General population														
Sample size (n)	990	1069	1069	1074	1046	1054	1051	1064	1019	1050	994	994	1039	1062
Mean (kg)	43.7	44.0	43.3	43.5	43.4	43.1	42.8	43.3	42.9	42.8	41.9	42.1	42.3	41.6
SD	6.8	7.1	6.6	6.7	6.7	6.5	6.4	7.1	7.0	7.0	6.5	7.0	6.5	6.5
$^{**}P < 0.05$	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Appendix B
Crude data of relative grip strength of sport university students and the general population

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Sport university students															
Sample size (n)	110	93	90	96	96	103	115	109	92	105	–	121	110	128	129
Mean	2.23	2.17	2.17	2.31	2.24	2.26	2.31	2.13	2.20	2.22	–	2.43	2.27	2.09	2.23
SD	0.26	0.22	0.26	0.29	0.28	0.24	0.26	0.26	0.28	0.21	–	0.28	0.31	0.28	0.24
General population															
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean	2.21	2.18	2.23	2.18	2.19	2.22	2.20	2.24	2.21	2.21	2.24	2.20	2.21	2.19	2.20
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sport university students															
Sample size (n)	169	217	215	181	183	165	152	–	–	173	164	166	158	172	172
Mean	2.15	2.04	2.05	2.14	2.38	2.17	2.26	–	–	2.06	2.10	2.09	2.07	2.08	2.10
SD	0.25	0.26	0.27	0.29	0.26	0.25	0.31	–	–	0.29	0.27	0.28	0.35	0.29	0.27
General population															
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean	2.16	2.17	2.16	2.16	2.14	2.16	2.08	2.08	2.08	2.04	2.09	2.08	2.09	2.07	2.05
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sport university students														
Sample size (n)	143	155	157	171	164	163	127	189	165	212	216	213	210	239
Mean	2.08	2.07	2.01	2.10	2.05	2.11	2.09	2.04	2.01	1.98	2.04	2.01	2.00	2.03
SD	0.27	0.29	0.32	0.33	0.27	0.29	0.28	0.27	0.29	0.26	0.28	0.27	0.27	0.27
General population														
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean	2.04	2.06	2.03	2.02	2.01	2.01	2.00	2.02	2.04	2.01	1.97	2.00	2.01	1.96
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Relative grip strength, which was defined as absolute grip strength divided by body mass index (BMI), was computed. The mean of BMI in the general population was calculated as weight (kg) divided by squared height (m) using the reported mean of height and weight as BMI in the general population was not reported in the annual surveillance. Therefore, the information for sample size and standard deviation of the relative grip strength in the general population was not available.

Appendix C
Crude data of height of sport university students and the general population

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Sport university students															
Sample size (n)	113	111	113	112	114	115	130	124	116	114	124	127	111	131	137
Mean (cm)	171.9	172.2	171.7	172.1	172.4	172.3	172.5	172.1	172.7	173.4	173.0	173.1	173.3	173.3	173.6
SD	6.4	5.9	6.0	5.8	6.2	5.8	5.9	6.2	6.3	6.6	5.7	5.9	6.6	6.6	6.7
General population															
Sample size (n)	3938	1137	217	2242	1422	1647	1576	1497	1533	1705	1908	1767	1697	1744	1896
Mean (cm)	168.4	168.6	166.6	168.8	169.1	169.8	169.6	170.2	169.9	170.2	170.4	170.6	170.8	170.8	170.6
SD	5.6	5.6	6.0	5.5	5.4	5.5	5.5	5.5	5.7	5.4	5.5	5.4	5.7	5.6	5.7
****P < 0.05**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sport university students															
Sample size (n)	173	222	228	188	183	170	164	–	–	175	165	170	158	172	172
Mean (cm)	174.4	173.0	172.9	174.3	173.0	173.6	173.4	–	–	173.7	173.1	173.8	173.3	173.6	173.4
SD	6.6	6.3	6.3	6.5	4.2	6.7	6.5	–	–	6.5	6.2	6.2	6.8	6.9	5.9
General population															
Sample size (n)	1844	1857	1697	1885	1994	1133	1905	2004	2053	1858	1172	1032	1017	1059	1034
Mean (cm)	170.8	170.7	170.8	171.0	170.7	170.0	170.6	171.2	171.1	171.2	170.8	171.6	171.7	171.2	171.6
SD	5.5	5.7	5.5	6.0	5.6	5.8	5.9	5.6	5.6	5.7	5.7	5.5	5.7	5.6	5.6
****P < 0.05**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sport university students														
Sample size (n)	143	156	157	171	164	164	128	189	165	213	216	214	210	290
Mean (cm)	173.9	174.3	173.2	173.9	173.2	173.5	174.3	173.5	172.3	173.1	173.7	172.9	172.6	172.9
SD	6.5	6.4	6.0	7.0	6.1	6.2	6.5	7.0	6.8	6.2	6.6	6.5	6.4	5.6
General population														
Sample size (n)	1005	1065	1073	1104	1046	1043	1050	1053	1040	1040	978	1000	1042	1034
Mean (cm)	171.2	171.1	171.2	171.1	171.4	171.1	171.1	171.0	171.4	171.1	170.9	171.0	171.1	171.0
SD	5.6	5.8	5.7	5.8	5.7	5.7	5.5	5.6	5.7	5.6	5.6	5.9	5.6	5.6
****P < 0.05**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Appendix D
Crude data of weight of sport university students and the general population

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Sport university students															
Sample size (n)	113	111	113	112	113	115	130	124	116	114	124	127	111	131	137
Mean (kg)	64.5	65.1	65.2	64.2	65.7	64.8	65.0	64.9	64.2	65.6	65.2	66.0	65.9	66.1	66.0
SD	6.9	6.3	6.5	8.0	8.0	7.3	7.8	8.3	7.3	7.9	7.1	8.5	9.0	7.2	7.8
General population															
Sample size (n)	3933	1137	216	2247	1420	1646	1573	1496	1529	1702	1903	1763	1696	1740	1898
Mean (kg)	59.0	59.7	58.0	59.6	59.8	60.5	60.5	61.4	60.9	61.4	61.7	62.2	62.2	62.6	62.2
SD	6.6	6.7	6.4	6.9	7.0	6.7	7.0	7.0	7.1	7.1	7.4	7.9	7.4	7.7	7.8
$^{**}P < 0.05$	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sport university students															
Sample size (n)	173	222	227	188	183	170	164	–	–	174	165	170	158	172	172
Mean (kg)	68.0	67.0	66.8	68.1	68.0	68.6	67.6	–	–	66.4	66.3	66.6	66.2	67.2	65.7
SD	9.4	7.8	8.1	9.4	8.1	9.3	9.5	–	–	9.2	9.2	8.3	9.4	8.9	7.8
General population															
Sample size (n)	1841	1844	1689	1879	1984	1134	1900	1987	2044	1852	1171	1032	1016	1051	1017
Mean (kg)	62.8	62.2	62.5	62.6	62.7	61.1	62.7	63.2	63.4	63.1	62.0	62.3	61.7	61.7	62.6
SD	8.1	7.9	7.7	7.9	8.2	8.5	8.4	8.2	8.4	8.4	9.2	8.1	7.4	8.1	8.1
$^{**}P < 0.05$	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sport university students														
Sample size (n)	143	156	157	171	164	164	128	189	165	213	216	214	210	291
Mean (kg)	67.2	67.4	67.1	67.0	66.4	67.5	68.1	67.3	65.5	66.8	66.3	65.4	66.3	66.6
SD	10.0	9.0	8.6	7.6	8.6	9.5	10.8	10.6	12.6	9.5	8.9	9.5	9.4	8.6
General population														
Sample size (n)	990	1051	1056	1088	1039	1027	1041	1045	1034	1029	973	980	1017	1022
Mean (kg)	62.7	62.6	62.5	63.0	63.4	62.8	62.6	62.7	61.8	62.4	62.2	61.6	61.5	61.9
SD	8.7	8.7	8.0	9.2	9.2	9.6	9.0	9.3	8.5	8.2	8.6	7.8	8.2	8.4
$^{**}P < 0.05$	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Appendix E
Crude data of body mass index of sport university students and the general population

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Sport university students															
Sample size (n)	113	111	113	112	113	115	130	124	116	114	124	127	111	131	137
Mean (kg/m2)	21.8	21.9	22.1	21.6	22.1	21.8	21.8	21.9	21.5	21.8	21.7	22.0	21.9	22.0	21.9
SD	1.6	1.4	1.6	1.9	1.9	1.9	2.0	1.9	1.9	1.8	1.7	2.2	2.1	1.7	2.0
General population															
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean (kg/m2)	20.8	21.0	20.9	20.9	20.9	21.0	21.0	21.2	21.1	21.2	21.3	21.4	21.3	21.4	21.4
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sport university students															
Sample size (n)	173	222	227	188	183	170	164	–	–	174	165	170	158	172	172
Mean (kg/m2)	22.3	22.4	22.3	22.4	22.8	22.7	22.4	–	–	22.0	22.1	22.0	22.1	22.3	21.8
SD	2.4	2.0	2.1	2.4	3.1	2.5	2.7	–	–	2.5	2.5	2.2	2.8	2.5	2.1
General population															
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean (kg/m2)	21.5	21.4	21.4	21.4	21.5	21.1	21.6	21.6	21.7	21.5	21.3	21.1	20.9	21.1	21.3
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sport university students														
Sample size (n)	143	156	157	171	164	164	128	189	165	213	216	214	210	290
Mean (kg/m2)	22.2	22.2	22.3	22.1	22.1	22.4	22.4	22.3	22.0	22.3	21.9	21.8	22.2	22.3
SD	2.7	2.4	2.6	2.1	2.4	2.5	2.8	2.7	3.4	2.6	2.3	2.6	2.5	2.6
General population														
Sample size (n)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mean (kg/m2)	21.4	21.4	21.3	21.5	21.6	21.5	21.4	21.4	21.0	21.3	21.3	21.1	21.0	21.2
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–

The mean of body mass index (BMI) in the general population was calculated as weight (kg) divided by squared height (m) using the reported mean of height and weight as BMI in the general population was not reported in the annual surveillance. Therefore, the information for sample size and standard deviation of BMI in the general population was not available.

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