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AGE-RELATED CHANGES IN MUSCLE STRENGTH OF HEALTHY JAPANESE

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ABSTRACT:

Gravity-compensated extremity joint torque values were measured in approximately 1,000 healthy Japanese to test the hypothesis that young people in Japan have less muscle strength than older people. The extremity joint torque values of the women in their 20s were significantly lower than those of the women in their 40s, 50s, and/or 60s for six extremity joint torque parameters: wrist palmer flexion, wrist dorsiflexion, elbow flexion, elbow extension, shoulder extension and hip flexion. On the other hand, according to the "physical and motor fitness survey" conducted by the Ministry of Education, Culture, Sports, Science and Technology, grip strength is decreasing in women in their 20s over time. From these findings, fifty years from now women in their 70s in Japan can be expected to have less muscle strength than women in their 70s today.

Keywords: **Muscle strength, Aging, Universal design**

1. INTRODUCTION

Japan's population stood at 127,760,000 as of Oct. 1, 2005, down by 20,000 from the year before, the first decline in 60 years. At the same time the number of people 65 years of age or over reached a record high of 25,600,000, accounting for 20.04% of Japan's total population and exceeding 20% for the first time. In time, the population decline and the increase in life expectancy together with the falling birthrate will turn the population pyramid upside down and result in a social structure in which fewer workers support a larger number of elderly retired people. Thus, it is desirable for the elderly to be able to care for themselves.

The muscle strength of the limbs makes a crucial difference in independence from a physical standpoint. While the major challenge for maintaining the independence of elderly people today is the development of user-friendly products and environments with universal design, etc., so that the elderly can live without difficulty even with little muscle strength, the independence of elderly people in the future, e.g., 50 years from now, will depend on whether young people today maintain adequate muscle strength. As reflected by recent scenes of teenagers sitting on the floor of subway cars or leaning on walls in trains and stations, young people in Japan today tend to have less physical strength than in the past.

The purpose of this study was three fold: to measure the muscle strength of the limbs of Japanese across age groups, to test the hypothesis that young people in Japan have less muscle strength than older people, and to assess age-related differences in the muscle strength of the limbs.

In this study extremity joint torque (EJT) values were measured in approximately 1,000 healthy Japanese men and women in their 20s to 70s. EJT values in the sagittal plane were obtained for 12 different EJT parameters: wrist palmar flexion (WP), wrist dorsiflexion (WD), elbow flexion (EF), elbow extension (EE), shoulder flexion (SF), shoulder extension (SE), ankle plantar flexion (AP), ankle dorsiflexion (AD), knee flexion (KF), knee extension (KE), hip flexion (HF), and hip extension (HE). EJT values were obtained as gravity-compensated extremity joint torque by isometric "make" tests with a hand-held dynamometer (HHD), and they were measured during maximal voluntary contractions in expiration (EMVC) in order to prevent strokes caused by sudden changes in blood pressure. When measuring the strength of the upper limbs, the examiner held the HHD in the hand. When measuring the strength of the lower limbs, on the other hand, the HHD was attached to the test chair to minimize possible errors caused by the

examiner's jiggle, because exertion of the lower limb muscles is greater. Also, since the issue of the representativeness of the subjects is often raised in regard to such measurements, the grip strength (GS) of each participant was measured as a baseline muscle strength value.

2. SUBJECTS AND METHODS

2. 1. SUBJECTS

The subjects of this study were approximately one thousand Japanese men and women ranging in age from the 20s to 70s and residing in cities in Japan. All of the subjects were healthy. In this study "healthy persons" means "persons without disabilities".
The age distribution of the subjects is shown in Fig. 1. Based on the assumption that older subjects have a broader data distribution, many subjects in their 60s and in their 70s were adopted.

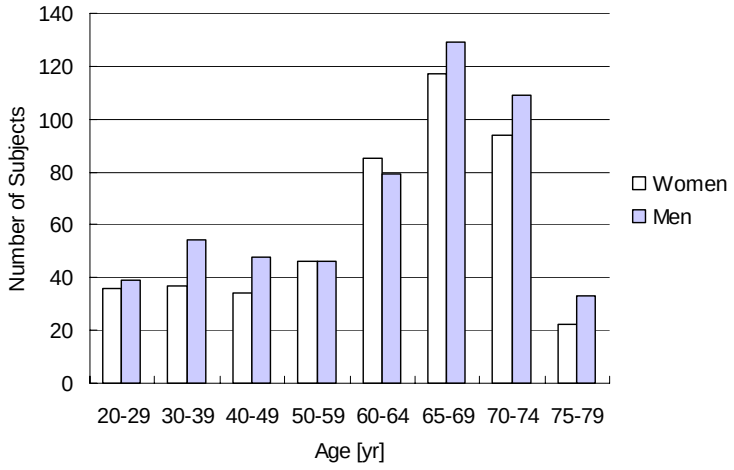

Figure 1: Age distribution among subjects

2. 2. EQUIPMENTS

Dynamometers, such as the Biodex, Cybex, or Primus, have been extensively used to make EJT measurements in rehabilitation research, but because their lack of portability, their expense, and the stress they impose on subjects as a result of restricting their limbs are obstacles to making

measurements in hundreds of subjects, including older persons, we used a strain-gauge type compact force sensor (model LPR-A-1KNS1, Kyowa Electronic Instruments Co., Tokyo). Fig. 2 shows the force sensor used as a hand-held dynamometer (HHD). The sensor was used as an HHD to measure EJT values in the upper limbs, and it was attached to the measurement chair to measure EJT values in the lower limbs. The measurement chair was specially designed for making upper and lower joint torque measurements. Fig. 3 shows measurement of EF. Signals from the force sensor were processed with a low-pass filter at a cutoff frequency of 20 Hz, and peak values were recorded. Moment-arm length was measured with an anthropometer. The validity and reliability of this 'hand-held dynamometer method' for EJT measurements of EF were confirmed before the study (Hisamoto et al., Journal of the society of biomechanisms 2004). GS values were measured with a digital grip-strength meter (model ED-100PNS, Yagami Co., Nagoya, Japan).

Figure 2: Hand-held dynamometer (HHD)

Figure 3: Measurement of elbow flexion torque (source: http://www.nite.go.jp/)

2. 3. PROCEDURE

Measurements were performed in a laboratory of the National Institute of Technology and Evaluation (NITE), Japan. Since the laboratory needed to be comfortable and relaxed enough to prevent exposing the subjects to physical and psychological stress, we conducted the measurements in a large laboratory with background music, in which the temperature and humidity were adjusted to a comfortable level for each subject. All of the measurements were made on a single day. The EJT measurements were made after the examiner measured the subject's blood pressure and filled out a questionnaire on daily living. GS was measured on the subject's right side. The subjects performed two trials for each of the GS and EJT measurements, and the average values were calculated.

EJT values were measured with each joint forming 3 to 4 different angles, because EJT values vary with the angle formed by the joint. However, this paper focuses on the data at the angle of each joint at which the largest EJT value was obtained, except the wrist joint and the ankle joint. The EJT values of the wrist joint and the ankle joint were measured at zero degrees. The posture of the subjects during the EJT measurements is described below.

WP and WD measurements were made with the subjects seated and the shoulder joint at 0 degrees and the elbow joint at 90 degrees. EF and EE measurements were made with the subject seated with the shoulder joint at 0 degrees and the forearm in the hammer grip position. SF and SE measurements were made with the subject seated with the elbow joint at 0 degrees and the forearm in the hammer grip position. AP and AD measurements were made with the subject seated with the hip joint at 90 degrees and the knee joint at 90 degrees. KF measurements were made with the subject in the prone position and the hip joint at 0 degrees. KE measurements were made with the subject seated and the hip joint at 90 degrees. HF and HE measurements were made with the subject in the supine position and the knee joint at 90 degrees. The angle between the trunk and the thigh was adjusted to 90 degrees whenever the subject was in the seated position.

The EJT values were measured on the subjects' right side, after orientation and a visual demonstration of the muscle measurements. Two trials were conducted, and the average values were calculated. Each trial consisted of a 4- to 6-second contraction. The contraction was made with maximal effort but was conducted in expiration to prevent accidents caused by sudden changes in blood pressure.

3. RESULTS AND DISCUSSIONS

3. 1. REPRESENTATIVENESS OF THE SUBJECTS

Since the purpose of this study was to measure age-related differences in muscle strength in the Japanese population, it was vital that the subjects represented Japanese population in terms of muscle strength. The representativeness of the subjects of this study was verified by measuring their GS values and comparing them with the data obtained in the "physical and motor fitness survey" conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. Annual measurements have been made by the MEXT since 1964, and the number of subjects annually has ranged from approximately 30,000 to 70,000. The MEXT data consist of about 20 parameters, including body height, body size, body weight, time for 50-meter run, long-jump scores, and GS data.

Comparison of the GS values obtained in this study with the MEXT data showed no remarked differences between their absolute values, and that the curves representing age-related differences were similar. The GS values in the MEXT data used in this study were obtained from 37,878 subjects in 2002.

3. 2. AGE-RELATED CHANGES IN THE EXTREMITY JOINT TORQUE VALUES OF HEALTHY JAPANESE

The results of measurements in about 1,000 subjects showed significant differences in muscle strength between the men and women. Examination of differences among age groups revealed the largest EJT values in the subjects in their 30s, 40s, or 50s in both men and women. As assumed, the younger group of both men and women tended to have lower EJT values than the subjects in the age groups in their 40s and over.

A post-hoc analysis of each EJT value was conducted using the Dunnett *t* test based on the EJT values of women in their 20s statistically to confirm that women in their 20s had lower EJT values than women in the age groups in their 40s and over. The results are shown in Table 1. The statistical tests were performed with SPSS software for Windows. (Hisamoto et al. Journal of Gerontechnology 2005)

Table 1: *P* values on Dunett *t* test

comparison of age groups			WP	WD	EF	EE	SF	SE
30-39	>	20-29	0.596	0.451	0.503	0.473	0.569	0.195
40-49	>	20-29	0.282	0.224	0.156	**0.037**	0.632	0.117
50-59	>	20-29	**0.041**	**0.010**	**0.047**	0.059	0.171	**0.033**
60-69	>	20-29	0.179	0.264	0.393	0.259	0.653	0.938
70-79	>	20-29	0.883	0.982	0.986	0.707	0.983	0.992
comparison of age groups			AP	AD	KF	KE	HF	HE
30-39	>	20-29	0.808	0.951	0.954	0.833	0.113	0.438
40-49	>	20-29	0.507	0.823	0.695	0.132	0.072	0.134
50-59	>	20-29	0.746	0.987	0.988	0.853	**0.009**	0.270
60-69	>	20-29	0.845	1.000	1.000	1.000	**0.001**	0.797
70-79	>	20-29	0.977	1.000	1.000	1.000	0.114	0.984

Fig. 4 shows the age-related differences in absolute EJT values for WP, WD, EF, EE, SE and HF in women, and the EJT values of the women in their 20s were significantly lower than those of the women in their 40s, 50s, and/or 60s for all six EJT parameters. The EJT values for WP were lower in the women in their 20s (5.4±2.1 Nm) than in the women in their 50s (6.5±1.8 Nm). The EJT values for WD of the women in their 20s (5.6±1.5 Nm) were lower than in the women in their 50s (6.8±1.6 Nm). The EJT values for EF of the women in their 20s (23.7±6.2 Nm) were lower than in the women in their 50s (26.9±4.3 Nm). The EJT values for EE of the women in their 20s (12.0±3.7 Nm) were lower than in the women in their 40s (14.2±4.5 Nm). The EJT values for SE of the women in their 20s (22.0±8.1 Nm) were lower than in the women in their 50s (26.1±7.2 Nm). The EJT values in HF for the women in their 20s (73.7±18.1 Nm) were lower than in the women in their 50s (79.7±15.9 Nm) and their 60s (77.3±22.4 Nm).

The results of these statistical analyses show that healthy Japanese women in the 20s age group have significantly lower EJT values in the upper limbs, i.e., for WP, WD, EF, EE, and SE, than women in the 50s or 40s age groups ($p < 0.05$, Dunnett *t* test), and in the lower limbs, lower values for HF than in the 50s and 60s age groups (both $p < 0.01$, Dunnett *t* test). These findings can be attributed to disuse and/or inactivity in younger women.

In healthy Japanese men, on the other hand, the EJT values were not statistically significantly lower in the 20s age group than in the older age groups. The fact that individual differences were slightly greater in men than in women may be one reason why no statistically significant differences were seen in men.

We then examined the EJT values and the result of the questionnaire on daily living and found a slight trend toward a correlation, but it was not remarked.

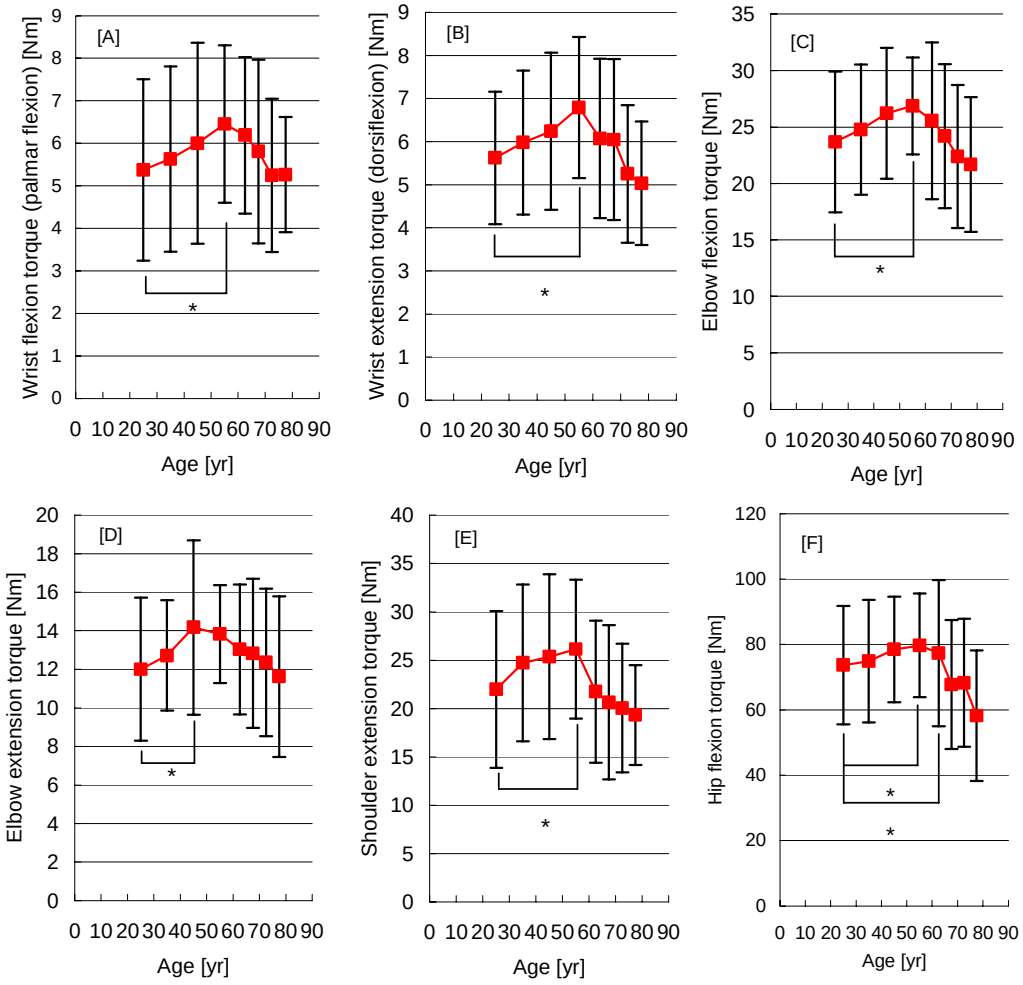

Figure 4: Age-related differences in EJT values in women (* p<0.05 in Dunnett *t* test)

3. 3. COMPARISON WITH OTHER DATABASE FOR HEALTHY JAPANESE

In this study we measured the EJT values of healthy Japanese to analytically study muscle strength in the upper and lower limbs and utilize the data to design products and environments, and no similar data have ever been reported.

We retrospectively reviewed the GS values in the above-mentioned MEXT data as muscle strength data for any trend toward a decline in muscle strength in the group of young women, as

shown by the EJT data obtained in this study. Fig. 5 and Fig. 6 show age-related differences and age-related changes in the GS values among the healthy Japanese women extracted from the MEXT data collected during the 30-year period between 1967 and 1997. The number of the subjects in each age group was approximately 200 to 500.

Fig. 5 [A] shows age-related differences in GS measured in 2002. As a whole, the curve for the age-related difference in the GS values peaks between the ages of 30 and 40 years, the same as the age-related differences in EJT, but the peak is not as sharp as the EJT peak. Fig. 5 [B] shows the age-related differences in GS measured from 1967 to 2005. On the whole, the trend in Fig. 5 [B] is similar to the trend in Fig. 5 [A] in the age groups below 40, but differences are seen between the years.

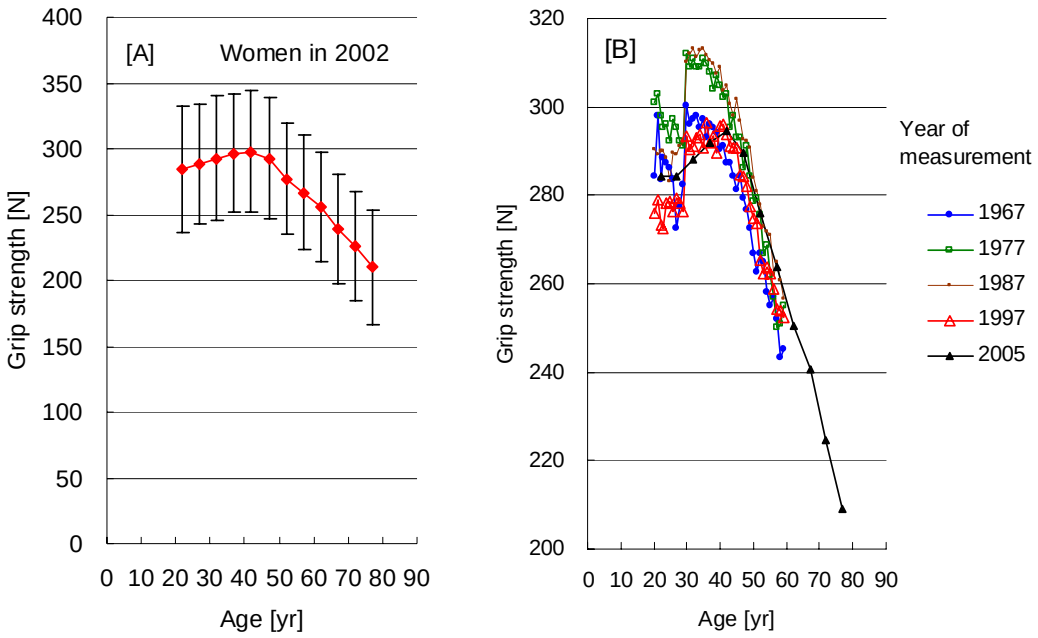

Figure 5: Age-related differences in GS in women based on MEXT data (1)

The changes in the GS values over time in each age group are shown in Fig. 6. While the GS values of women in the 20-, 30-, and 40- year-old age groups declined from 1982 to 1987, the GS values of women in the 50-, 55-, and 59- year-old age groups did not show any significant decline. Decrease of muscle strength in terms of GS in the younger group can be concluded to have started in 1982.

The most important finding, however, was that muscle strength in women in their 20s started to decline around 1977, and that was followed by the same decline in those in their 30s and those in their 40s around 1983. This suggests that a decline will be seen in the older age group decades later.

Fig. 7 shows age-related changes in GS values according to the year of birth of subjects. Focusing on women in their 20s, GS was approximately 295 N in women born in 1955. GS decreased to approximately 280 N in women born in 1970, and in women born in 1975 even further, to 275 N. It is doubtful whether the age-related changes in these age groups will yield the same curve as in the changes in the age group of women born in 1955.

The MEXT data show that muscle strength in terms of GS values is decreasing more in women in their 20s than in other generations. This corroborates the results of the measurements described in this chapter.

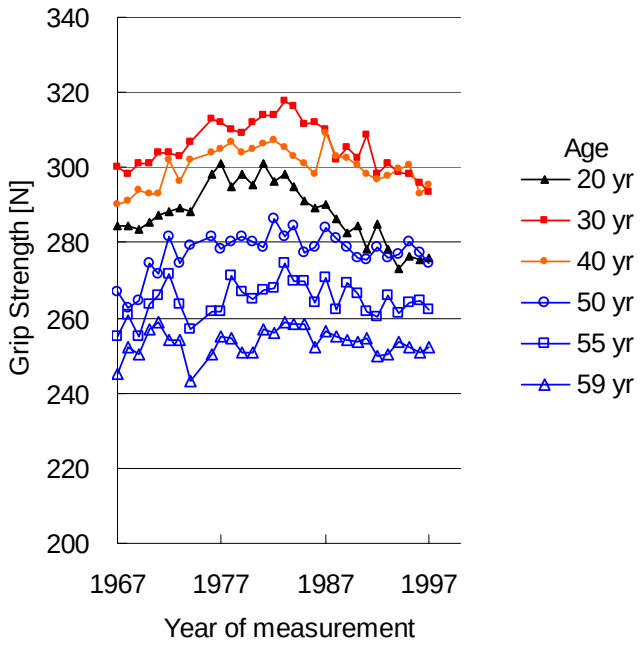

Figure 6: Age-related differences in GS in women based on MEXT data (2)

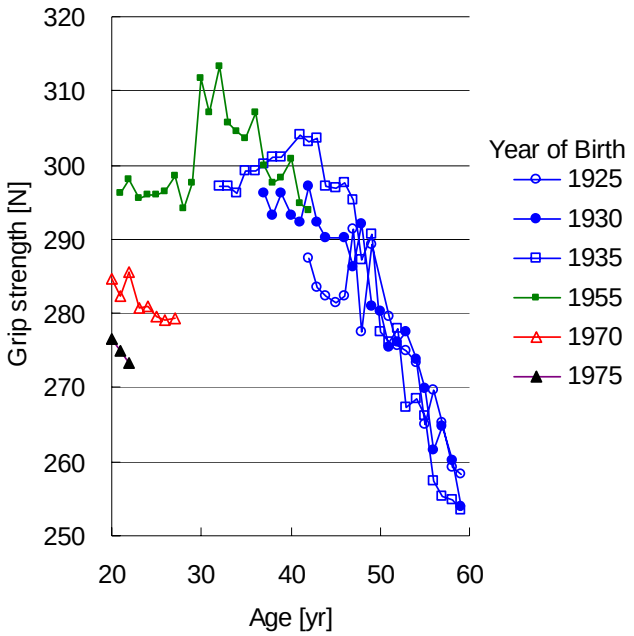

Figure 7: Age-related change in GS in women based on MEXT data

3. 4. ISSUES CONCERNING THE MUSCLE STRENGTH OF JAPANESE

As is widely known, Japan has become a highly aged society, and older Japanese persons will have to depend on themselves from now on. From the standpoint of physical independence, the muscle strength of the extremities has a great impact on ADL, and thus whether older persons in Japan in the future will have adequate muscle strength is an important question. In other words, the question is whether women in their 20s in Japan today will be able to lead an independent life 40 or 50 years later, and the answer may have a huge impact on the country's future economy.

The results of the measurements in this study revealed that healthy women in their 20s have statistically significantly lower EJT values than older women. Recently young people in Japan, including high school students and university students, are often seen wearily leaning on walls or sitting on the floor instead of sitting strait on chairs in classrooms, train stations, and in trains, probably because of weak muscle strength. Although it cannot be concluded from the results of this study, it seems that the over-automated and excessively labor-saving society in Japan is largely attributable to lack of muscle strength among younger age groups.

As a result of automation and energy-saving technology ranging from home appliances, including washing machines, vacuum cleaners, and refrigerators, elevators, and vehicles, our daily life has become more comfortable and convenient, but excessive automation and energy-saving have prevented us from using our muscles to do housework, our jobs, and everyday tasks. To make matters worse, it seems that many young Japanese women go on diets and engage less in sports.

Of course, in terms of “universal design” or “design for all”, the automation and energy-saving technologies are particularly important to the highly aged societies like that in Japan. However, it seems necessary to provide the people who are enjoying the benefits of civilization with optional opportunities to use their muscles.

The concept of designing products and buildings in a way that provides users with a chance to use their muscles is called “design for fitness”, and based on this concept, it will, for example, be possible to give users options by building a variety of staircases for different levels of exercise, reducing the number of elevators in buildings, adding washing machines with manual wringers to the product lineup, and build additional sidewalks with barriers parallel to public sidewalks.

4. CONCLUSIONS

The results of EJT measurements in healthy Japanese showd that the women in their 20s have significantly lower EJT values than women in their 50s or 40s in terms of the five EJT values in the upper limbs (WP, WD, EF, EE, SE) and one EJT value in the lower limbs (HF). Whether these women in their 20s in Japan today will be able to lead an independent life 40 or 50 years later will have a huge impact on the country’s future economy.

Indeed, as reflected by recent scenes of teenagers sitting on the floor of subway cars, young people in Japan today recently tend to have less physical strength than in the past, and this phenomenon may be caused by decreased muscle strength in the young age groups.

Electric-washing machines, electric vacuum cleaners, and refrigerators have been on the market in Japan since 1954, and they have made daily life more comfortable and convenient. However, over-automated and excessively labor-saving equipment have diminished opportunities for muscle training during housework and in daily life, and many women in Japan are on diets. People instinctively seek a more comfortable and easier life, and technology makes this possible. However, a comfortable life is not always good for human health.

The fact that young women do not use their muscles (disuse contraction) is a possible reason for the decline in their muscle strength, although that cannot be concluded from the results of this study alone. A survey across ages (follow-up survey) is required to study the problem. On the assumption that muscle disuse and inactivity are major factors in the decline of muscle strength, the so-called concept “design for fitness” will be effective in increasing muscle strengths, because opportunities to use muscles will be provided to users of products and buildings.

5. FUTURE TASKS

Since a longitudinal study of EJT values in Japanese is needed to confirm that women 20 to 29 years of age in Japan today will have difficulty in leading an independent life. Additional measurements of more than 1,000 subjects will be made from 2008 to 2009 by NITE in Osaka, Japan. The parameters measured will mainly be EJT values and the range of motion (RoM) of joints in the limbs. Additional items are currently being considered.

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