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Sportology and High Intensity Interval Walking Training in Aging Society

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Abstract

Faced with social problems such as global warming and rapidly aging society, the solutions have been expected in "sportology". Humans became widely distributed on the earth from their birth by acquiring abilities to walk in an upright position and to adapt themselves to various natural environments. However, seeking a 'comfortable environment' in modern civilization has deteriorated these genetic characteristics of humans, and the consumption of resources and energy to acquire such a 'comfortable environment' has induced global warming-associated natural disasters and the destruction of social order. To halt this vicious cycle, we may reactivate the genetic characteristics in humans by doing sports.

To assess this, we have developed a health promotion program for middle aged and elder people, Jukunen Taiikudaiiku Program, in cooperation with the Japanese government, developed high-intensity interval walking training (IWT), and examined the physical and mental effects on 4,000 people for these 5 years. We found that IWT for 4 months increased physical fitness by 10-20%, decreased the indices of life-style related diseases by 10-20%. Since a prescription of IWT can be conducted by using an IT network system called e-Health Promotion System, the participants in the program were able to receive the prescription even if they lived remote from trainers, enabling them to perform IWT at their favored places and times, and also at low cost. Moreover, we found some single nucleotide polymorphisms closely related to inter-individual differences in the responses to IWT. Finally, we assessed a cost vs effect relationship of IWT and found that 60,000 JPY investment per year for individuals reduced their health care cost by 120,000 JPY, 20% of total health care cost per year for the population.

These results suggest that exercise prescription promote health by reactivating the genes unique for human beings, which is quite matched to the goal of "sportology".

Introduction

One of the serious problems in advanced aging society is high health care cost for elderly people. In Japan, the population over 65 years old is estimated to increase from 20.8% in 2006 to 30.5% in 2025 (<http://www.ipss.go.jp/index-e.html> (09/07/16)). Consequently, health care cost increased from 17.1 trillion JPY (~171 billion USD) to 56 trillion JPY (~560 billion USD) in 2025 (http://www1.mhlw.go.jp/english/wp_5/vol1/p2c3s2.html (09/07/16)).

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Figure-1 Total lifestyle related disease (LSD) score and peak aerobic capacity for walking ($\text{VO}_{2\text{peak}}$) before and after interval walking training in males (A) and females (B). When the subjects were divided equally into 3 groups according to $\text{WVO}_{2\text{peak}}$, the score was lower in higher $\text{WVO}_{2\text{peak}}$ groups. After interval walking training for 4 months, the score decreased as $\text{WVO}_{2\text{peak}}$ increased in every group. *'s : vs. before training at $p < 0.05$, #'s : vs. Middle group at $p < 0.05$, +'s : vs. High group at $p < 0.05$. From Morikawa *et al.*, 2009.

To prevent this, the Japanese government has issued the law to reform medical system for treatment to preventive medicine (Health Insurance Bureau, 2007), where people over 40 years old were obligated to receive health check and, if abnormal remarks are indicated, they are encouraged to receive exercise as well as nutritional prescription at a health care office close to their home. However, although exercise prescription should be done based the individual physical fitness (Armstrong *et al.*, 2006), no guidelines have been provided by the government.

To solve this problem, we started a health promotion program by exercise for people ≥ 40 years old named "Jukunen Taiikudaigaku Program" since 1997 and developed 3 techniques for exercise training by middle-aged and older people : 1) interval walking training (IWT), 2) portable calorie meter and 3) e-Health Promotion System. By using these, we have accumulated the database (DB) on the effects of interval walking training on the indices of age and life-style related diseases (LSD) in more than 4,000 subjects with health care cost in a part of them. Moreover, we have accumulated the DB on DNA in more than 1,400 subjects to exam-

ine whether genetic variance caused any inter-individual variation in responses to the training which would be useful to develop an appropriate exercise prescription met with individual genetic characteristics in future.

In this review, we would like to introduce the achievements by the Jukunen Taiikudaigaku Program.

Interval walking training

Moderately paced walking at 10,000 steps/day, every day has been believed to prevent life-style related diseases in middle-aged and older people. However, the walking may not be intense enough to increase physical fitness including peak aerobic capacity ($\text{VO}_{2\text{peak}}$). Indeed, a higher intensity of aerobic exercise more than $50\% \text{VO}_{2\text{peak}}$ has been recommended in recent guidelines to increase $\text{VO}_{2\text{peak}}$ in older people (Armstrong *et al.*, 2006). Therefore, in 2003, we started to study the effects of IWT, to repeat fast walking above 70% peak aerobic capacity for walking ($\dot{\text{WVO}}_{2\text{peak}}$) for 3 min intermitted by slow walking below $40\% \dot{\text{WVO}}_{2\text{peak}}$ at the target of 5 sets per day, more than 4 days/

Figure-2 Lifestyle related disease (LSD) score for each criterion : hypertension, hyperglycemia, high BMI, and dyslipidemia, in males (A) and females (B) . When the subjects were divided equally into 3 groups according to $\dot{W}VO_{2peak}$ before training, the score was higher in the order of hypertension, hyperglycemia, high BMI, and dyslipidemia in every group. After training, all scores except for dyslipidemia decreased by 10-40%. *'s : vs. before training at $p < 0.05$. From Morikawa *et al.*, 2009.

week, for 5 months, on physical fitness for middle-aged and older people (Nemoto *et al.*, 2007) . The reasons for adopting “interval” walking was that most subjects could not accomplish a training regimen by continuous fast walking ≥ 15 min/day, ≥ 4 days/week, for 5 months in our preliminary study (unpublished data) .

To determine $\dot{W}VO_{2peak}$, after baseline measurements at rest for 3 minutes, subjects with a triaxial accelerometer, as details below, on the mid-clavicular line of the waist walked on a flat floor at 3 graded subjective velocities:slow, moderate, and the fastest for 3min each while 3-dimensional accelerations with the device (JD Mate, Kissei Comtec, Matsumoto, Japan) and heart rate (HR) with a near infrared ear pickup probe were measured at 20-millisecond interval and recorded with 5-second memories as average value. The total impulse from an accelerometer was transferred to a computer and converted to oxygen consumption rate. $\dot{W}VO_{2peak}$ and peak HR are those for the last 30 seconds at the fastest velocity. We confirmed that the peak HR was ~ 140 beats/min, almost reaching the age expected maximal HR and that $\dot{W}VO_{2peak}$ (ml/min, y) was quite identical to that determined by graded cycle ergometer exercise simultaneously determined on each subject. Thus, we can de-

termine peak aerobic capacity on many subjects at once in the field with no limitation by instruments;treadmill and cycle ergometer.

Before the start of IWT, subjects were invited to a community office near their homes and received instruction in the exercise program for the first 2 weeks. Once subjects had learned the program, they could choose the time at which to perform it each day. A beeping signal from the device alerted subjects when a change of intensity was scheduled and another melody told them the time when walking intensity reached the target level every minute. Every 2 weeks subjects visited a local community office, and data from the tracking device were transferred to a central server at the administrative center through the Internet for automatic analysis by e-Health Promotion System and reporting. The details for this system are described below. Trainers used these reports to track daily walking intensity and other parameters given in to instruct subjects on how best to achieve the target levels. If the targets were not met, the trainers encouraged the subjects to increase their efforts to achieve them.

As a result, $\dot{W}VO_{2peak}$ increased by $\sim 10\%$ and knee extension and flexion forces increased by 17% and 13%, respectively, while systolic and dia-

systolic pressures decreased by ~ 10 mmHg and ~ 5 mmHg, respectively. On the other hand, their changes were all minimal after the standard walking training; moderate intensity continuous walking at 40% $\dot{WVO}_{2peak}$ for 60 min/day, 4 days/week, for 5 months, which was similar to those after the sedentary life for the same period (Nemoto *et al.*, 2007). Moreover, we found in the study that $\dot{WVO}_{2peak}$ was significantly correlated with isometric knee extension force ($R^2 = 0.49$, $p < 0.0001$), suggesting that thigh muscle strength is a key determinant for $\dot{WVO}_{2peak}$ in subjects of this age. Further, these results indicate that increased $\dot{WVO}_{2peak}$ induced a marked reduction in blood pressures.

Although there were several epidemiological studies suggesting the merits of increased physical fitness to decrease the incidence of LSD including hypertension (Blair SN, *et al.*, 1984), there have been few intervention studies by exercise training suggesting the linkage between them in a large population of middle-aged and older people. This might be because there have been no exercise training regimens to increase physical fitness broadly available for middle-aged and older people with less limitations of time and places.

Therefore, by using the techniques which we had developed, we examined the effects of IWT on physical fitness and the indices of LSD on 198 men and 468 women aged ~ 65 years old in 2005 and 2006 (Morikawa *et al.*, 2009). They performed IWT, ~ 60 min/day, ~ 4 days/week, for 4 months on average. We counted the scores of LSD before and after IWT according to the criteria in the health care guideline for Japanese by the government (Health Insurance Bureau, Ministry of Health, Labor, and Welfare, Japan 2007); 1) systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg, 2) triglyceride ≥ 150 mg/dl or blood high density lipoprotein cholesterol ≤ 40 mg/dl, 3) blood glucose ≥ 100 mg/dl, 4) BMI ≥ 25 kg/m². Therefore, the full score was 4 points when met with all criteria.

To analyze the results, we divided the subjects into 3 groups according to $\dot{WVO}_{2peak}$ in females (Fig. 1-A) and males (Fig. 2-B). The LSD scores decreased as $\dot{WVO}_{2peak}$ increased and, moreover, when $\dot{WVO}_{2peak}$ increased after training, the LSD score decreased in both genders. Further, when

look at the LSD score in each criterion in females (Fig. 2-A) and males (Fig. 2-B), the hypertension score was 0.7-0.8, suggesting that 70-80% of subjects met the criterion in both genders. Similarly, 40-60% and 20-50% of subjects were in hyperglycemia and high BMI, respectively, in both genders. After training, subjects met each criterion decreased by 5-30% in hypertension, 10-40% in hyperglycemia, and 10-30% in high BMI but with no significant reduction in blood lipids. These results suggest that increased $\dot{WVO}_{2peak}$ decreased blood pressures, blood glucose, and BMI in that order while the effects on blood lipids were modest.

To examine the effects of IWT on health care cost, we compared clinical expenditure between 166 participants (85 males and 81 females) in the program and counterbalanced 2,353 sedentary people (1,205 males and 1,148 females) aged ~ 67 years old who joined the National Health Insurance (unpublished data). Before IWT, the health care cost per person for the latter 6 months of 2004 was 87,649 JPY on average in the IWT group, similar to 87,746 JPY in the sedentary group, and for the first 6 months of 2005, it increased to 95,932 and 97,949 JPY, respectively, but with no significant difference between the groups. However, for the latter 6 months of 2005, the health care cost continued to increase to 119,173 JPY in the sedentary group while that in the IWT group remained unchanged as 96,272 JPY, 22,901 JPY lower than the sedentary group with significance ($p < 0.05$). Thus, 23.8% of health care cost was saved by performing IWT.

Portable calorie meter

We have developed a new portable calorie meter with which energy expenditure can be precisely measured even when they walk on inclines (Yamazaki *et al.*, 2009). First, we measured $\dot{WVO}_2$ by respiratory gas analysis and vector magnitude (VM, G) from triaxial accelerations in middle-aged and older males and females aged ~ 63 years old during graded walking on a treadmill while the incline was varied from -15% to $+15\%$. They walked at subjectively slow, moderate and fast speeds on level and uphill inclines and in addition to these, at their fastest speed at 0% incline. Simi-

larly, they then walked on downhill inclines for 3 min each. We determined a regression equation to estimate $\dot{V}O_2$ from VM and theoretical vertical upward speed (Hu, m/min) and downward speed (Hd, m/min) for the last 1 min of each trail as $\dot{V}O_2 = 0.0044VM + 1.365Hu + 0.553Hd$.

Second, to validate the precision of the equation, we measured VM and altitude changes with a portable device (JD Mate) equipped with a triaxial accelerometer and a barometer in middle-aged and older subjects walking on an outdoor hill, and compared the estimated $\dot{V}O_2$ by the equation stated above with the value simultaneously measured by respiratory gas analysis. We found that the estimated $\dot{V}O_2$ (y) from the equation was quite identical to the measured $\dot{V}O_2$ by respiratory gas analysis during walking on an outdoor hill. Thus, we have developed the device to estimate $\dot{V}O_2$ precisely during walking regardless of geography where subjects walk. Moreover, subjects can perform high-intensity exercise training $\geq 70\%W\dot{V}O_{2peak}$ not only by fast walking on a flat place but also by slow or moderate speed of walking on inclines or stairs.

e-health promotion system

Another reason for hindering us from extending exercise prescription for individuals to nationwide is the personnel cost for trainers who have the ability. To solve the problems, we have been developing the e-Health Promotion System (Nose *et al.*, 2009). The participants in the program visit local health care institutes near their homes: a local community office and a drug store, every 2 weeks, transfer their walking records from the JD Mate to a central sever computer, and receive a trend graph of their achievements. According to the records, the staff; nurses, dietitians, pharmacists or trainers, give them exercise and nutritional prescriptions while referring to the DB in the server computer about the effects of IWT for 5 months on physical fitness and the indices of LSD in 4,000 subjects and that for more than 5 month in 1,000 subjects. If participants have the facilities at their own homes, they can receive the same service through the Internet without going out.

Individual genomic variance

Recently, we have started to analyze individual genomic variance in relation with inter-individual variation in response to IWT (Mori *et al.*, 2009, Masuki *et al.*, 2010). Masuki *et al.* (2010) assessed whether single nucleotide polymorphism rs1042615 of the vasopressin V1a receptor altered the indices of LSD in the subjects and, if so, whether it also altered the effects of IWT. CC, CT, and TT carriers of rs1042615 (42, 118, and 64 men; 113, 263, and 154 women, respectively) performed IWT, ≥ 4 days/wk, for 5 months. Before IWT, BMI and diastolic blood pressure for men were both higher in TT than in CC; however the differences disappeared after IWT despite similar training achievement between groups. Moreover, after IWT, BMI and DBP decreased more in TT than in CC with a greater decrease in low-density lipoprotein (LDL) cholesterol in TT than CC. The decreases in DBP and LDL cholesterol were still greater in TT even after adjustment for their pretraining values. On the other hand, for women, these parameters before IWT and their changes after IWT were similar between CC, CT, and TT. Thus, polymorphism rs1042615 of the V1a receptor altered BMI and DBP in middle-aged and older men, and the training-induced responses of DBP and LDL cholesterol, whereas women did not show any of these responses. These results suggest that single nucleotide polymorphism rs1042615 of the vasopressin V1a receptor was involved in interindividual variance in responses to IWT in middle-aged and older men.

According to the outcome of these studies, we are developing a computer program to predict the effects of IWT on the physical fitness and the indices of LSD according to not only physical but also genetic characteristics of participants before training. If the program becomes available by the staff in the field, they would be able to give participants exercise and nutritional prescriptions more fitted for individuals even though they are not specialized in the subjects very much. This would increase the number of participants in IWT.

In conclusion, the IWT may significantly contribute the exercise prescription fitted for individual

physical fitness broadly available in middle-aged and older people by using the JD Mate and the e-Health Promotion System. Moreover, IWT is such a simple intervention by exercise that it would enable us to develop exercise prescriptions more fitted for individuals including genetic characteristics.

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