Seasonal influence on adherence to and effects of an interval walking training program on sedentary female college students in Japan

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ABSTRACT

Habitual exercise training is recommended to young people for their health promotion, but adherence may be influenced by atmospheric temperature (T_a) if performed outdoors. We compared the adherence to and the effects of a home-based interval walking training (IWT) program on sedentary female college students between winter and summer. For summer training over 176 days, 48 subjects (18-22 yr) were randomly divided into two groups: the control group (CNT_{summer}, n=24), which maintained a sedentary lifestyle as before, and IWT group (IWT_{summer}, n=24), which performed IWT while energy expenditure was monitored by accelerometry. For winter training over 133 days, another group of 47 subjects (18-24 yr) was randomly divided into CNT_{winter} (n=24) and IWT_{winter} (n=23), as in summer. The peak T_a per day was 26±6°C (SD) (range of 9-35°C) in summer, much higher than 7±5°C (range of -3-20ºC) in winter ($P<0.001$). During a ~50-day vacation period, participants walked 2.1±0.3 (SE) days/week in IWT_{summer}, less than 4.2±0.3 days/week in IWT_{winter} ($P<0.001$), with half of the energy expenditure/week for fast walking during the winter vacation ($P<0.02$), whereas both IWT groups walked ~2 days/week during a school period ($P>0.8$). After training, the peak aerobic capacity and knee flexion force increased in IWT_{winter} ($P<0.01$) but not in CNT_{winter} ($P>0.3$). Conversely, these parameters decreased in the summer groups. Thus, the adherence to and effects of IWT on sedentary female college students in Japan decreased in summer at least partially due to a high T_a.

Key words: interval walking training; sedentary female college students; adherence; seasonal influence

INTRODUCTION

Home-based walking training programs have been recommended to young people for their health promotion, but which season, summer or winter, allows for a higher adherence rate to the program in which greater effects can be obtained outdoors remains unknown.

Many studies have investigated the seasonal variation of adherence to an exercise program in children (Brasholt et al. 2013; Kolle et al. 2009; McCrorie et al. 2015), young adults (Hamilton et al. 2008; Levin et al. 1999), and the elderly (Dasgupta et al. 2010; Newman et al. 2009), suggesting that adherence was higher in the summer than in the winter (Chan et al. 2006). However, these studies were conducted in high latitude regions (>40 °N) where the atmospheric temperature (T_a) was comfortable for walking in the summer, but it was too low in the winter. On the other hand, in Japan, the T_a has been increasing for the last decade, likely due to global warming, and the incidence of heat illness has increased to ~50,000 cases per year during mid-summer in this country (Nakai et al. 2015). Therefore, the first aim of this study was to compare adherence to a home-based walking training program in sedentary female college students between summer (May-Nov.) and winter (Nov.-Apr.) in Matsumoto (~36 °N), located in the center of the Honshu Island of Japan.

Another aim of this study was to examine the effects of interval walking training (IWT) on physical fitness in sedentary female college students. We developed the IWT for middle-aged and older people to promote their health, repeating more than 5 sets of fast walking, equivalent to more than 70% of peak aerobic capacity ($\dot{V}O_{2peak}$), and slow walking, equivalent to ~40% $\dot{V}O_{2peak}$, for 3 min each per day, for more than 4 days per week (Nemoto et al. 2007). We suggested that 5-month IWT increased $\dot{V}O_{2peak}$ (Nemoto et al. 2007), accompanied by improved symptoms of lifestyle-related diseases such as hypertension, hyperglycemia, obesity, and dyslipidemia (Nemoto et al. 2007; Morikawa et al. 2011). On the other hand, no studies have examined the effects of IWT in young people since their physical fitness has been assumed to be higher than in middle-aged and older people and the exercise intensity of fast walking during IWT may be too low to acquire similar effects as in older people (ACSM 2017). However, as shown in the present study, the $\dot{V}O_{2peak}$ values in sedentary female college students are almost equal to those in older males aged ~63 yr, whose $\dot{V}O_{2peak}$ increased by 9% and isometric knee extension and flexion forces increased by 13% and 17%, respectively, with 5-month IWT (Nemoto et al. 2007). These results suggest that 5-month IWT increased physical fitness in sedentary female college students when it is done above a given adherence as in older people.

Accordingly, in the present study, we examined the hypotheses that the adherence to and the effects of IWT were greater in winter than in summer in sedentary female college students in Japan.

METHODS

Subjects and grouping

Fig. 1 shows a time line of the present study. The procedure of this study was approved by the Institutional Review Board on Human Experiments, Matsumoto University. The subjects were recruited from sedentary female students who had not joined any exercise/sports activities after school. To recruit participants, we displayed a poster in classrooms where students visit regularly and handed out leaflets. The inclusion criteria were that subjects had no habitual exercise training and no overt symptoms in lifestyle-related diseases, including hypertension, hyperglycemia, obesity, and dyslipidemia.

After the experimental protocol was fully explained, 47/320 responders for the winter intervention gave their written informed consent and enrolled in the study. After the pre-training measurements, we randomly divided the 47 subjects into two groups: the control group (CNT, n=24) and IWT group (IWT, n=23), maintaining a sedentary lifestyle as before and performing IWT for 5 months, respectively. Similarly, for the summer intervention, 48/217 responders gave their written informed consent, and we randomly divided them into CNT (n=24) and IWT (n=24). The baseline values are presented in **Table 1**.

Protocol

As shown in **Fig. 1**, for the winter intervention, IWT was performed between Nov. 11, 2011, and Apr. 6, 2012, including a period from Nov. 11, 2011, to Feb. 8, 2012, for school and a period from Feb. 9 to Apr. 6, 2012, for vacation. For the summer intervention, IWT was performed between May 7 and Nov. 16, 2012, including periods from May 7 to Aug. 6 and from Sep. 27 to Nov. 16, 2012, for school and a period from Aug. 7 to Sep. 26 for vacation. Before training, we had the subjects come to a gym at Matsumoto University on a day assigned to the individuals and measured their physical characteristics and $\dot{V}O_{2peak}$ by a graded cycling exercise and then moved to Shinshu University to measure isometric knee extension and flexion forces with a dynamometer. Then, the subjects started IWT after a brief practical introduction. We recorded the time of day when they started daily training, the exercise intensity, and the exercise duration during IWT; the details are described below. Similarly, after training, we measured the same variables again.

Interval walking training

Subjects were instructed to repeat more than 5 sets of fast ($\geq$70% $\dot{V}O_{2peak}$) and slow (~40% $\dot{V}O_{2peak}$) walking for 3 min each, for more than 4 days/week. Training intensity was monitored with a tri-axial accelerometer (JD Mate; Kissei Comtec, Matsumoto, Japan) carried on the midclavicular line of the right or left waist. A beeping signal alerted the subjects when a change of intensity was scheduled, and another melody told them when their walking intensity had reached the target level every minute. Every 2 weeks, the subjects visited a health care office in the university, and the walking record from the tracking devices was transferred to a central server at the administrative center through the internet for automatic analysis and reporting. The trainers used the reports on exercise intensity and other parameters (**Table 2**) to instruct the subjects how best to achieve the target levels. The system has been highlighted not only by the academic society (Nose et al. 2009; Joyner and Nose 2009) but also by mass media (The New York Times 2015) because similar training effects as training using machines, such as a treadmill and a cycle ergometer, can be attained at lower costs relative to personnel and instrumental support. The T_a for the daytime during training was 2±5 (SD)°C and 3±5°C whereas the relative humidity was 70±17% and 67±20% in the school and vacation periods, respectively, for winter training, and 18±7°C and 24±4°C with a relative humidity of 69±18% and 70±15% in the school and vacation periods, respectively, for summer training.

Number of subjects for the analyses

As in **Fig. 1**, one subject in the winter IWT group and 4 subjects in the summer IWT group dropped out due to a loss of interest in the training program, judging from their achievements that the training for a month was almost null from first month of training. Therefore, we analyzed 22/23 and 20/24 subjects in the IWT groups for the winter and the summer, respectively.

Measurements

$\dot{V}O_{2peak}$.

We measured $\dot{V}O_{2peak}$ using a cycle ergometer in an upright position in a laboratory at a room temperature of ~25°C. After measurements at rest for 3 min, the subjects started pedaling at 60 revolutions/min without loading. The exercise intensity was increased by 30 W every 3 min until it reached 120 W, and above this intensity, it was increased by 15 W every 2 min until they could not maintain the rhythm due to exhaustion. We determined the oxygen consumption rate ($\dot{V}O_2$) every 10 s (Aeromonitor AE 260; Minato, Tokyo) and monitored the electrocardiograph (ECG) continuously during the graded exercise. We determined the $\dot{V}O_{2peak}$ by averaging the three largest consecutive values at the end of exercise. During the measurements, we recorded the heart rate (HR) with the ECG every min. The criteria for the determination of the $\dot{V}O_{2peak}$ were that the subjects could not keep the rhythm, the respiratory exchange ratio was >1.1, and the HR reached the age-predicted maximum value. The peak HR was adopted at the $\dot{V}O_{2peak}$.

Isometric knee extension and flexion forces

Isometric knee extension and flexion forces were measured on each side of the knee with a dynamometer (Cybex CN 77, CSMi, Boston), and the 2 measurements were averaged for reporting. These measurements before and after training were performed by the same investigator according to the same protocol.

$\dot{V}O_2$ during IWT measurements with calorimeter

We estimated $\dot{V}O_2$ during IWT using the calorimeter (JD Mate, Kissei Comtec, Matsumoto), which is equipped with a tri-axial accelerometer and a barometer to monitor the vector magnitude and changes in altitude, respectively. Using these variables, we developed the logic to estimate energy expenditure precisely during walking, even when subjects walk on inclines (Yamazaki et al. 2009).

Regarding the precision to estimate the $\dot{V}O_2$ (ml/kg/min) from this logic, Yamazaki et al. (2009) suggested that the estimated $\dot{V}O_2$ (y) was almost identical to the measured $\dot{V}O_2$ (x), which was pooled from 11 subjects who walked on inclines in the field with varied slopes ($y = 0.969x$, $r = 0.879$, $P<0.001$). The mean difference was -0.20 ml/kg/min, and the 95% prediction limits were ± 6.95 ml/kg/min over the range of 2.0–33.0 ml/kg/min in the Bland-Altman analysis. Thus, the exercise intensity during IWT measured with the device was reliable enough to detect any significant differences in the training achievement among the groups in the present study.

Analyses

We analyzed the achievements in IWT for the periods of school and vacation separately, assuming that lifestyles and social activities were much different between these periods.

Adherence rate to IWT

We calculated the adherence rate to IWT of each subject using the following formula: training days per week/the target training days per week (4 days) x 100%. In addition, we compared the adherence to IWT between seasons by calculating fast and slow walking time (min/walking day), energy expenditure during fast and slow walking (mlO_2/walking day), and intensity during fast and slow walking (mlO_2/min) in **Table 2.**

$T_{a\ OPP}$ and $T_{a\ IWT}$

To examine the influence of the T_a on adherence to the IWT program, we needed to exclude the effects of lifestyle habits and social activities, which differ among individual subjects. For example, according to the report by the Japanese Government (Ministry of Public Management, Home Affairs, Posts and Telecommunications 2001), 10% of college students get up before 6:00, 36% before 7:00, 62% before 8:00, and 77% before 9:00. On the other hand, 12% of college students go to bed before 23:00, 44% before 0:00, and 83% before 2:00. In addition, 72% of students work part-time, and 15% of them work from 19:00-21:00 and 5% after 23:00. Thus, the time of day that college students could start IWT varies according to their individual life rhythms and social activities other than the T_a. To exclude these factors, we performed the following analyses.

The bottom panel of **Fig. 2** shows an hourly distribution of the time of day to start IWT in Subject #1, who performed IWT for 38 days during the 57-day winter vacation period. To generate the figure, for example, on day 1, when the subject walked for more than 1 min, we counted it as one, and even if she repeated the walk more than once for a given hour bin, i.e., 13:00-13:59, we counted it as one walk for the 13-hr bin for the day. Then, we summed the frequency of the time of day for each day for 38 days on which she performed IWT. After a similar procedure in other subjects, we generated the frequency distribution of the time of day to start IWT in all subjects during the winter vacation and also during the summer vacation (**Fig. 3**).

As shown in the bottom panel of **Fig. 2**, since the earliest time bin to start IWT was 8:00-8:59 and the latest time bin was 19:00-19:59 in Subject #1, we determined the T_a ($T_{a\ OPP}$) every time of day from 8:00 to 19:59 for 38 training days (**Fig. 4 A**), which can be regarded as the T_a at which she had the opportunity to perform IWT with less influence from her life rhythm and social activities. Then, we determined the hourly frequency distribution of $T_{a\ OPP}$ for every 1°C bin for the subject (**Fig. 4 C**). **Fig. 4 B** shows the relationship between the T_a ($T_{a\ IWT}$) at the time of day for Subject #1 to actually start IWT, and **Fig. 4 D** shows the hourly frequency distribution of the $T_{a\ IWT}$. After similar procedures in the other subjects, we determined the hourly frequency distributions of $T_{a\ OPP}$ and $T_{a\ IWT}$ in all subjects in the winter and summer training periods, respectively (**Fig. 5 A&C**).

Since the hourly frequency of $T_{a\ IWT}$ was significantly lower than that of $T_{a\ OPP}$ above 25°C of T_a (**Fig. 5C**), we determined the relationship between the hourly frequency to start IWT and the corresponding $T_{a\ OPP}$ (**Fig. 6**).

Statistics

A one-way ANOVA was used to examine any significant differences in physical characteristics, $\dot{V}O_{2peak}$, and knee extension and flexion forces before training between the groups (CNT vs. IWT) (**Table 1**) and the training achievements between winter and summer (**Table 2**). A one-way ANOVA for repeated measures was used to examine any significant effects of training (before vs. after) on the variables in each group (**Table 1 & Fig. 7**) and to examine any significant differences in the adherence rate per week of IWT during summer and winter vacations. This model was also used to examine any significant differences in training achievements between school and vacation periods (**Table 2**) and the T_a between the mean values of $T_{a\ OPP}$ and $T_{a\ IWT}$ in the winter and summer, respectively (**Fig. 5 B & D**). A two-way [group (CNT vs. IWT) and training (before vs. after)] ANOVA for repeated measures was used to examine any significant effects of group on the variables with a [group x training] interaction analysis (**Table 1**). This model [group and time of day] was also used to examine any significant differences in the hourly frequency of IWT performance every time of day between winter and summer vacations (**Fig. 3**) and the hourly frequency between $T_{a\ OPP}$ and $T_{a\ IWT}$ for every 1°C in the winter and summer, respectively (**Fig. 5 A & C**). After confirming significant differences by the ANOVAs, Fisher's least significant difference test (**Fig. 5 C** & **Fig. 6**) was used for any pairwise comparisons as a post hoc test. The standard Y-minimized regression equation was determined between the hourly frequency to start IWT and the corresponding $T_{a\ OPP}$ (**Fig. 6**). When we examined any significant differences in the change in the $\dot{V}O_{2peak}$ after training between the groups, we adjusted for the change by an analysis of covariance (ANCOVA) using the pre-training value as a covariate after confirming that it significantly affected the change in the $\dot{V}O_{2peak}$ (**Fig. 7**). The statistical power ($1-\beta$) is presented in the text at $\alpha = 0.05$ when the key variables in the present study were significantly different between the CNT and IWT groups. All values are expressed as the means ± SE, except where noted. The null hypothesis was rejected at $P<0.05$.

RESULTS

Table 1 shows the physical characteristics, the $\dot{V}O_{2peak}$, and the knee extension and flexion forces before and after training in the winter and the summer interventions, respectively. In the winter intervention, the $\dot{V}O_{2peak}$ increased by 6% in the IWT group ($P=0.009$) whereas it remained unchanged in the CNT group ($P>0.3$), with a significant interactive effect of [group x training]

(P=0.007). Similarly, the isometric knee flexion force increased by 9% in the IWT group (P=0.009, 1-β=0.80) whereas it remained unchanged in the CNT group (P>0.9), but with no interactive effect of [group x training] (P>0.2) in the winter intervention. The isometric knee extension force tended to increase in the IWT group whereas it decreased in the CNT group, with a significant interactive effect of [group x training] (P=0.015). Conversely, in the summer intervention, the $\dot{V}O_{2peak}$ decreased in both groups (both, P<0.009), with no significant interactive effects (P>0.2). The knee extension force remained unchanged in both groups (both P>0.1), with no interactive effect of [group x training] (P>0.30). The knee flexion force decreased in the CNT group (P<0.001) but not in the IWT group (P>0.25); there was no interactive effect of [group x training] (P>0.09).

Fig. 7 shows the change in the $\dot{V}O_{2peak}$ after training in winter (upper panel) and in summer (lower panel) after adjusting for the pre-training value by ANCOVA. We found that the $\dot{V}O_{2peak}$ increased in the IWT group (P=0.009), whereas it remained unchanged in the CNT group for the winter intervention, with a significant difference in the change between the groups (P=0.007, 1-β = 0.80). Conversely, for the summer intervention, the $\dot{V}O_{2peak}$ decreased after training in both groups (both, P<0.001), with no significant difference in the change between the groups (P>0.2).

Table 2 shows the training achievements in the IWT groups in the winter and the summer interventions. The walking days/week for summer vacation was half that of winter vacation (P<0.001, 1-β=1.00), whereas the values for the school period were similar between the seasons (P>0.8). Since the fast walking time/walking day was nearly similar between the summer and winter vacations (P>0.4), the energy expenditure/week during the summer vacation was half that of the winter vacation (P<0.02, 1-β=0.67). Since the slow walking time/walking day during the summer vacation was half that of the winter vacation (P<0.006), the energy expenditure/week during the summer vacation was one-third that of the winter vacation (P<0.001, 1-β=0.99). Conversely, no significant differences were observed in the fast walking time/week and the energy expenditure during fast walking/week for the school periods between the seasons (both $P>0.6$).

As a result, the adherence rate was 53±7% during the summer vacation, which was significantly lower than 106±7% during the winter vacation ($P=0.001$, $1-\beta=1.00$). The adherence rate during the school period was 54±7% in summer and 61±8% in winter, with no significant difference between seasons ($P>0.5$). Overall, the adherence rate throughout the intervention was 63±4% during summer, which was significantly lower than 76±7% during winter ($P=0.022$).

In addition, we confirmed that the adherence rate every week was almost constant throughout the training with no significant difference between weeks in summer and winter (both $P>0.15$): 52±10% and 90±13% for the first week and 48±9% and 115 ±10% for the last week of the training during the summer and winter vacations, respectively. Furthermore, the SD for the weekly adherence rate in each subject was 33±3% and 38±3% during the summer and winter vacations, respectively, with no significant difference between seasons ($P=0.30$).

The black columns in **Fig. 3** show the hourly frequency of the time of day for 22 subjects to start IWT during winter vacation for 47 days (upper panel) and for 20 subjects during summer vacation for 51 days (bottom panel). The solid and broken lines indicate the T_a and relative humidity over 24 hrs during winter and summer vacations, and the white and gray areas indicate the periods before and after sunset, respectively. As in the figure, the total frequency to start IWT in the summer was 36% of that in winter ($P<0.001$). In addition, as indicated by the arrows in the figures, the frequency distribution has two peaks: ~10:00 and ~17:00 in winter and ~9:00 and ~20:00 in summer, suggesting that most subjects started IWT 4 hrs after sunrise in both seasons while they started IWT 1 hr before sunset in the winter, and 2 hrs after sunset in the summer.

To investigate the possible involvement of the T_a in the delayed time to start IWT during summer vacation compared with winter vacation, we determined the hourly frequency of the $T_{a\ OPP}$ every hour within the time range during which subjects had the possibility to perform IWT with less effects of their life rhythms and social activities (**Fig. 5**) and the hourly frequency of the $T_{a\ IWT}$ when the subjects actually started IWT. As shown in the figure**,** the frequency distribution of the $T_{a\ IWT}$ showed a downward shift by ~1°C compared to the $T_{a\ OPP}$ for summer vacation but not for winter vacation. As a result, the $T_{a\ IWT}$ was ~1°C lower than the $T_{a\ OPP}$ during summer vacation ($P=0.016$, $1-\beta=0.72$) but not during winter vacation ($P>0.7$), suggesting that the subjects preferred a ~1°C cooler T_a to start IWT during summer vacation.

Finally, as in **Fig. 6**, the hourly frequency to start IWT (*y*) was significantly and negatively correlated with the corresponding $T_{a\ OPP}$ (*x*) above 25°C during summer vacation ($P=0.008$), suggesting that the frequency to start IWT decreased as T_a increased more than 25°C.

DISCUSSION

The major findings in the present study are that the adherence rate to IWT was lower in summer than in winter and that the $\dot{V}O_{2peak}$ and isometric knee flexion force increased after IWT in winter, whereas both generally decreased in summer in sedentary female college students.

Subjects

The physical characteristics and the $\dot{V}O_{2peak}$, isometric knee extension and flexion forces reported in this study (**Table 1**) were similar to those previously reported in age-matched sedentary female Japanese populations (Omasu et al. 2004; Laboratory of Physical Fitness Standards 2007; Miura et al. 2009; Miyatake et al. 2009). Thus, the characteristics of the subjects in this study generally reflected those of this age group in the Japanese population.

Why IWT for sedentary female college students?

According to the guideline provided by American College of Sports Medicine (ACSM 2017), young adults are recommended to perform aerobic exercise training at an intensity of more than 60% of the $\dot{V}O_{2peak}$ for 20-60 min/day, for more than 3 days/week, to promote their physical fitness and health. However, more than 80% of the total students do not belong to any sports activities after school, so performing such a high intensity of exercise training may be difficult. Accordingly, the development of exercise training programs throughout their lives has been needed (Garber et al. 2011; Sallis et al. 1999). Previously, we developed IWT for middle-aged and older people to promote their physical fitness and health and suggested that the adherence rate to IWT for the first 5 months was 90±39% in 696 subjects (Masuki et al. 2015), which was much higher than the rates reported in previous studies (Iwane et al. 2000), and that the symptoms of lifestyle-related diseases were improved by ~20% with an increased physical fitness of ~15% on average (Nemoto et al. 2007; Morikawa et al. 2011). Based on these reports, in the present study, we examined the possible application of IWT to sedentary female college students and the seasonal variation of their adherence to the training and found that the adherence rate to IWT was higher in winter than in summer, resulting in greater increases in $\dot{V}O_{2peak}$ and knee extension force in winter, as expected from the recommendation by the ACSM guidelines (ACSM 2017).

Why was there a lower adherence rate in summer than in winter?

In the present study, the adherence rate was significantly lower in the summer than in the winter. On the other hand, physical activity, which was evaluated from the walking steps per day in a given period, was suggested to be higher in the summer than in the winter in children (Brasholt et al. 2013; Kolle et al. 2009; McCrorie et al. 2015), young adults (Hamilton et al. 2008; Levin et al. 1999), and the elderly (Dasgupta et al. 2010; Newman et al. 2009). Accordingly, when we analyzed the relationship between the mean T_a and the walking steps during the interventions after pooling the results from the previous studies across all generations (Dasgupta et al. 2010; Hamilton et al. 2008;

McCrorie et al. 2015; Newman et al. 2009; Loucaides et al. 2004), we found that walking steps per day (y) is positively correlated with the mean T_a (x) (r = 0.64, P=0.013), with a regression equation of $y = 315\,x + 5837$ over the range of -1 – +26°C of the mean T_a.

Although the present study was conducted in the ranges of 8-31°C of the average peak T_a for the daytime during the summer and winter vacations (**Fig. 3**), likely covering the thermal condition stated above, the adherence rate was significantly lower in summer than in winter ,with a significant and negative correlation between the hourly frequency to start IWT and a corresponding $T_{a\ OPP}$ above 25°C during the summer vacation (**Fig. 6**).

One possible reason for this may be that IWT included fast walking at more than 70% of the $\dot{V}O_{2peak}$ to acquire increased physical fitness (ACSM, 2017), and the intensity may accelerate the increase in body temperature during walking; however, when we estimated a possible increase in core body temperature during IWT at the exercise intensity and duration shown in **Table 2**, it did not increase to the risky level for heat illness (Haghson et al. 1983) if subjects had been moderately acclimatized to heat and they could sweat at least 200 ml during the walking period. Indeed, as in **Table 2**, the fast walking time/walking day during summer vacation was not significantly shorter than that during winter vacation. These results suggest that the lower adherence rate in the summer was unlikely a result of increased core body temperature during fast walking.

Another possible reason for the lower adherence rate in the summer vacation compared to the winter vacation is that subjects might want to spend more time on other social events specific for the summer vacation, such as recreation or a trip to cooler places with their family or friends, instead of IWT. In addition, the forthcoming school days after Sep 27 might influence the adherence. However, we found that the SD of the hourly frequency to start IWT per week was constant throughout the summer vacation, suggesting that the training was not interrupted by any irregular social events. In addition, we found that the lower adherence rate per week during the summer vacation compared to the winter vacation started from the first week of training and maintained that level thereafter until the end of the training period, suggesting that the adherence was not influenced by the forthcoming school days.

A final possible reason for the lower adherence rate during the summer vacation compared to the winter vacation is the behavioral body temperature regulation that humans display to avoid a high T_a when it increases above the thermoneutral condition (28-32°C) at which sweating starts (Inoue et al. 2010). The contribution ratio of core temperature to the mean skin temperature for behavioral temperature regulation is suggested to be 1 to 1, whereas that for thermoregulatory responses, such as increased skin blood flow and sweating, is 9 to 1 (Frank et al. 1999), suggesting that behavioral thermoregulation occurs before the core temperature increases by sensing the T_a with thermo-sensors on the skin surface. These results suggest that the frequency to start IWT was reduced at the time of day when the T_a increased more than the thermoneutral condition.

This idea can be supported by the results in **Fig. 3**, showing that the peak frequency of the time of day to start IWT was 2 hrs after sunset in the summer while 1 hr before sunset in the winter, suggesting that the heat influx into the body by the radiation from the sunshine could be reduced by ~1.5 kcal/min in the summer compared with that if they started IWT 1 hr before sunset, as in the winter. In addition, as shown in **Fig. 5**, the $T_{a\ IWT}$ was ~1°C cooler than the $T_{a\ OPP}$ in summer, suggesting that the subjects preferred a lower $T_{a\ OPP}$ in summer. Conversely, in winter, the $T_{a\ IWT}$ was almost identical to the $T_{a\ OPP}$, suggesting a lesser influence of behavioral temperature regulation on the frequency to start IWT. Indeed, we found that the frequency to start IWT decreased as $T_{a\ OPP}$ increased more than 25°C (**Fig. 6**). These results suggest that the lower adherence rate during the summer vacation compared to the winter vacation was caused by the subjective feelings of the subjects to avoid an exposure to a hot environment, which may be stronger than their motivation to perform IWT.

$\dot{V}O_{2peak}$ and thigh muscle strength

$\dot{V}O_{2peak}$ increased by 6% and isometric knee flexion force increased by 9% in the IWT group in winter whereas these changes did not occur in summer.

Again, Nemoto et al. (2007) suggested that IWT for 5 months increased $\dot{V}O_{2peak}$, isometric knee extension and flexion forces by 13% and 17%, respectively, in middle-aged and older people aged ~63 yr, whose $\dot{V}O_{2peak}$ and thigh muscle strength before training were almost equivalent to those in the young subjects of the present study. The lower increases in $\dot{V}O_{2peak}$ and thigh muscle strength in winter for the present study can be explained by the lower training achievement (**Table 2**) compared to the previous study in which subjects performed IWT, ~50 min/day (~30 min for fast walking + ~20 min for slow walking), for 4.5 days/ week on average (Nemoto et al. 2007). The reason for the lack of increases in $\dot{V}O_{2peak}$ and thigh muscle strength in the summer group might be that the frequency and duration of fast walking (≥70% $\dot{V}O_{2peak}$) during IWT did not reach the levels required to increase $\dot{V}O_{2peak}$ and thigh muscle strength (ACSM2017; Hickson et al.1982; Hickson et al.1981).

Perspectives

The detailed reasons for the lower adherence rate in the present study compared to the previous study on middle-aged and older people (Nemoto et al., 2007) require further research, but one possibility is that the program was not attractive enough for young subjects to enhance their motivation as it was for middle-aged and older people. Joseph et al. (2015) examined adherence to their original exercise program designed to fascinate young students by 4 types of sports (e.g., Zumba, kickboxing). They instructed 27 sedentary female college students with obesity to freely join the program that was available to them before and after school on weekdays, with a target of 150 min for 6 months, and reported that 56% of the students completed the target. However, their program may require more personnel and instrumental supports than the current program, resulting in higher expenses, which will make the extension of their program to a larger population of sedentary college students difficult. In the present study, we confirmed that 5-month IWT increased physical fitness in young people at a much lower cost than machine training if the exercise is performed above a given frequency and duration. Therefore, we may develop the application program and include the concept of the current training system, which is available through the social network system, so that sedentary female college students are willing to perform IWT even in summer.

Conclusion

IWT increased the $\dot{V}O_{2peak}$ and isotonic knee flexion force in sedentary female college students in winter since they performed IWT above a given intensity and duration during the winter vacation. The lower adherence to IWT during the summer vacation, with no increases in the $\dot{V}O_{2peak}$ and isotonic knee flexion force, might be partially due to the behavioral body temperature regulation mechanisms to avoid a hot environment, but it is unlikely that their core body temperature increased too much during IWT. Therefore, if they increase their motivation to perform IWT by some interventions, they will perform IWT without heat illness to obtain the benefits.

GRANTS

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DISCLOSURE

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

A.T., S.M., and H.N. conception and design of research; A.T, S.M., and K.N. performed experiments; A.T., S.M., and H.N. analyzed data; A.T., S.M., and H.N. interpreted results of experiments; A.T., S.M., and H.N. prepared figures; A.T., S.M., and H.N. drafted manuscript; A.T., S.M., and H.N. edited and revised manuscript; A.T., S.M., K.N., and H.N. approved final version of manuscript.

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FIGURE LEGENDS

Fig. 1:

Timeline of the study. * Physical characteristics, $\dot{V}O_{2peak}$, and thigh muscle strength were measured before and after training. See the text for further details.

Fig. 2:

The hourly frequency of the time of day to start IWT during winter vacation for 57 days in Subject #1. The bottom panel shows the sum of the frequency for 38 days in which the subject performed IWT. See the details in the text.

Fig. 3:

The black columns show the means and the SE bars of the hourly frequency of the time of day for 22 subjects to start IWT during winter vacation for 47 days (upper panel) and for 20 subjects during summer vacation for 51 days (bottom panel). The solid and broken lines indicate the mean atmospheric temperature (T_a) and the relative humidity (RH), with respective SD ranges during 24 hrs for the winter and summer vacation periods. The white and gray areas indicate the periods before (day time) and after sunset (night time), respectively.

Fig. 4:

A: The hourly T_a from 8:00 to 19:59 for 38 days in which Subject #1 performed IWT (the bottom panel of **Fig. 2**). **B**: The hourly T_a at the time of day for 38 days when the subject started IWT. **C**: The hourly frequency distribution of the T_a ($T_{a\ OPP}$) from 8:00-19:59 for 38 days in which the subjects performed IWT. **D**: The hourly frequency distribution of the T_a ($T_{a\ IWT}$) at the time of day to start IWT for 38 days in which the subjects performed IWT.

Fig. 5:

The hourly frequency distributions of $T_{a\ OPP}$ and $T_{a\ IWT}$ in 22 subjects in the IWT group during winter vacation (left upper panel) and in 20 subjects in the IWT group during summer vacation (left bottom panel) are presented as a % of the total frequency in each season. The mean $T_{a\ OPP}$ and $T_{a\ IWT}$ are also presented in winter (right upper panel) and summer (right lower panel). * indicates significant differences vs. the $T_{a\ OPP}$ at the corresponding time of day (left lower panel) and vs. mean $T_{a\ OPP}$ (right lower panel) during summer vacation at $P<0.05$.

Fig. 6:

The relationship between the hourly frequency to start IWT vs. the corresponding $T_{a\ OPP}$ above 25°C during the summer vacation. The hourly frequency was significantly and negatively correlated with the corresponding $T_{a\ OPP}$ with a regression of $y = -0.41x + 12$ ($r = -0.81$, $P=0.008$). Each symbol indicates the mean value for 20 subjects. C.D., critical difference in $T_{a\ OPP}$ is shown by the x bar, and hourly frequency for starting IWT shown is by the y bar at the level of $P<0.05$ using Fisher's LSD test.

Fig. 7:

The change in the $\dot{V}O_{2peak}$ ($\Delta\dot{V}O_{2peak}$) after training in the winter (upper panel) and in the summer (lower panel) after adjusting for the pre-training value by ANCOVA. The means and the SE bars for 24 and 22 subjects in the CNT and IWT groups in the winter and for 24 and 20 subjects in the CNT and IWT groups in the summer, respectively. *, ** indicate significant differences vs. the pre-training values at $P<0.05$ and $P<0.01$, respectively. ## indicates significant differences vs. the CNT group at $P<0.01$.

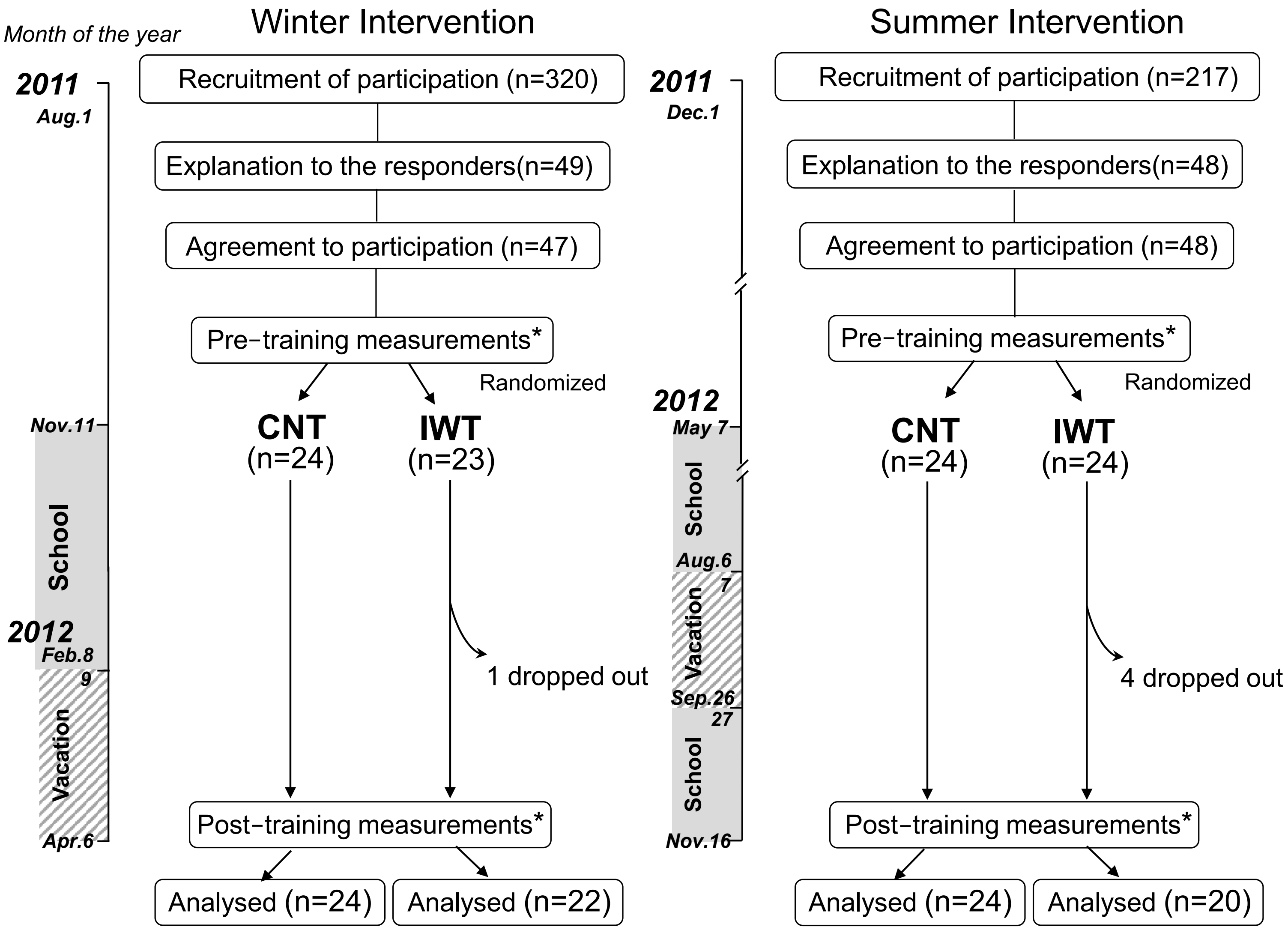
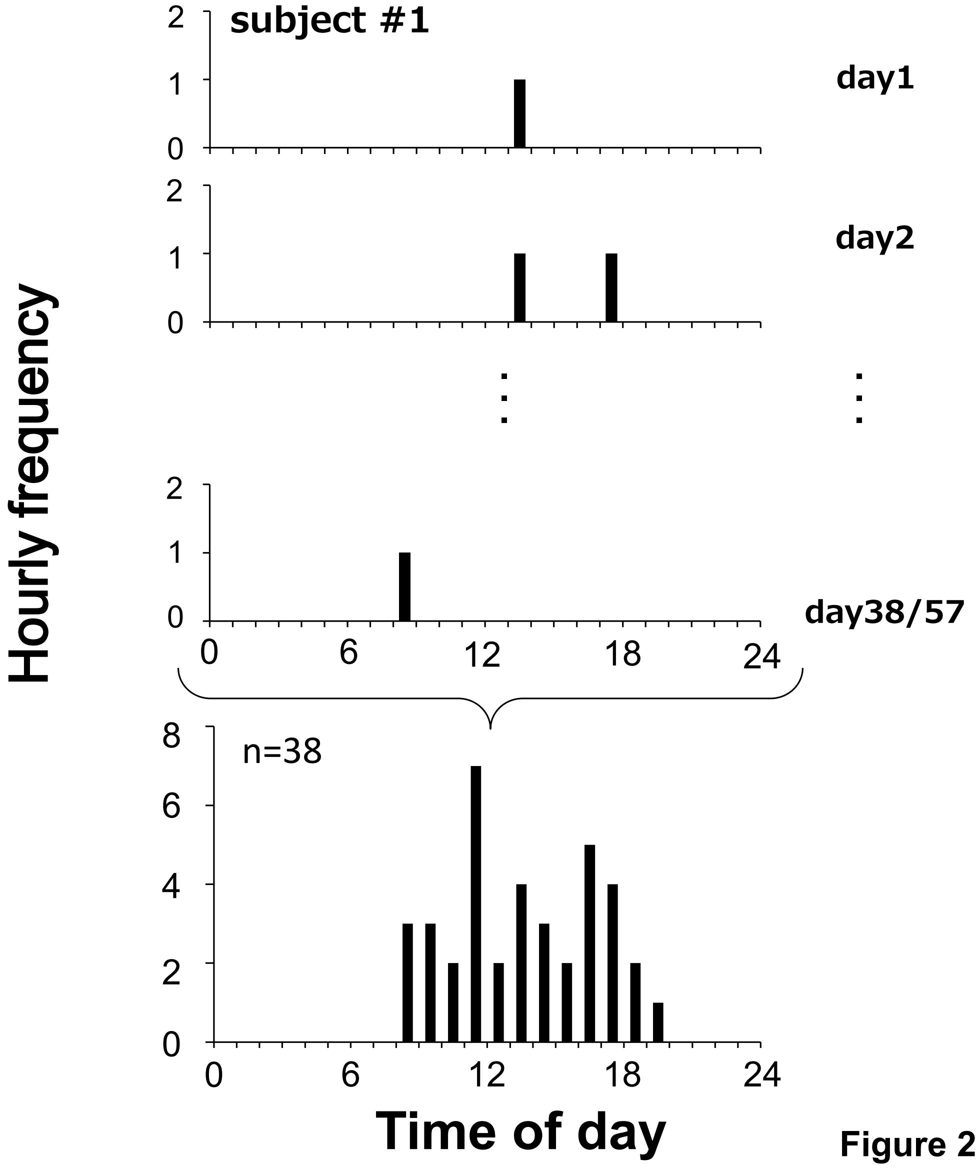


Figure 1. Tanabe et al.

Winter



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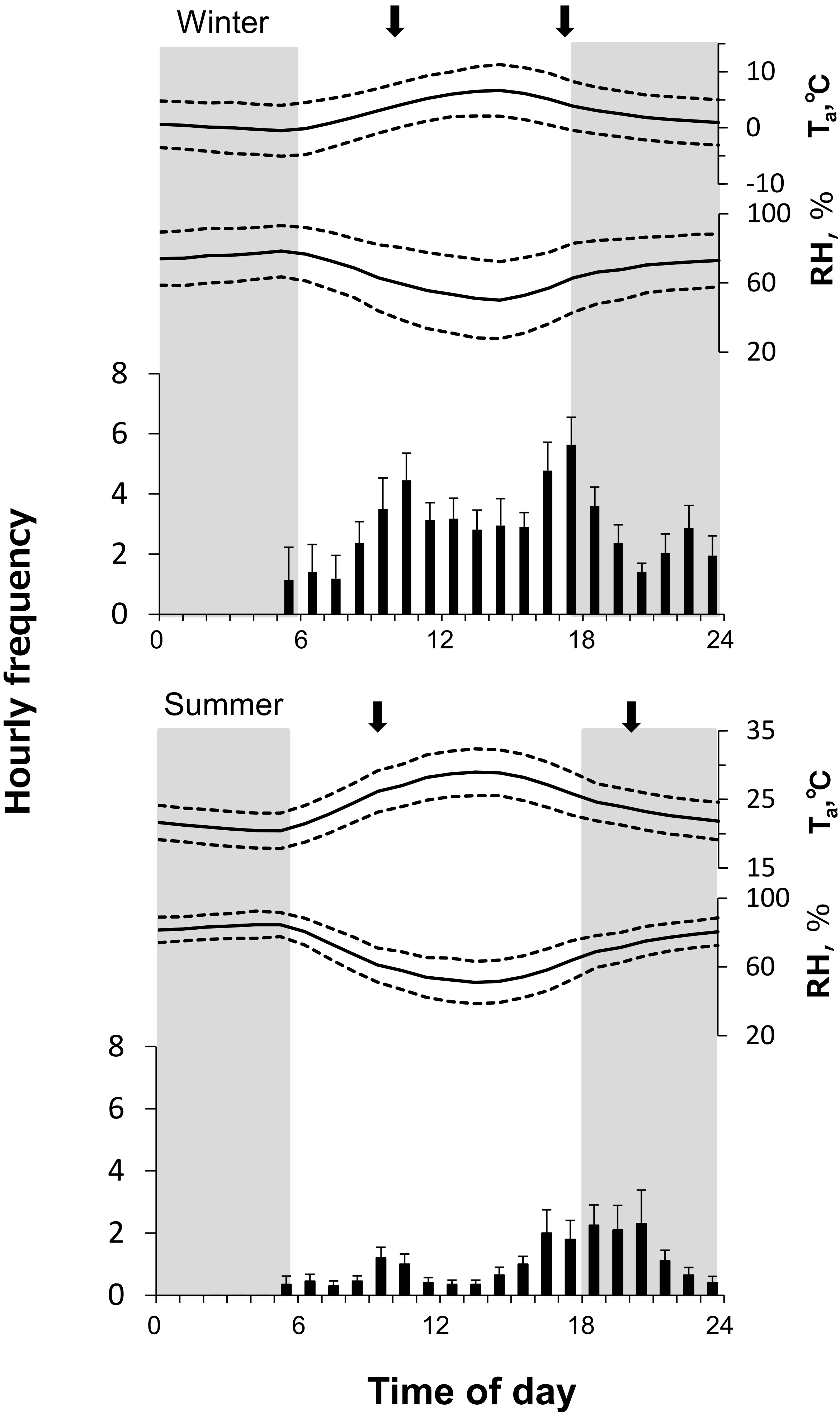

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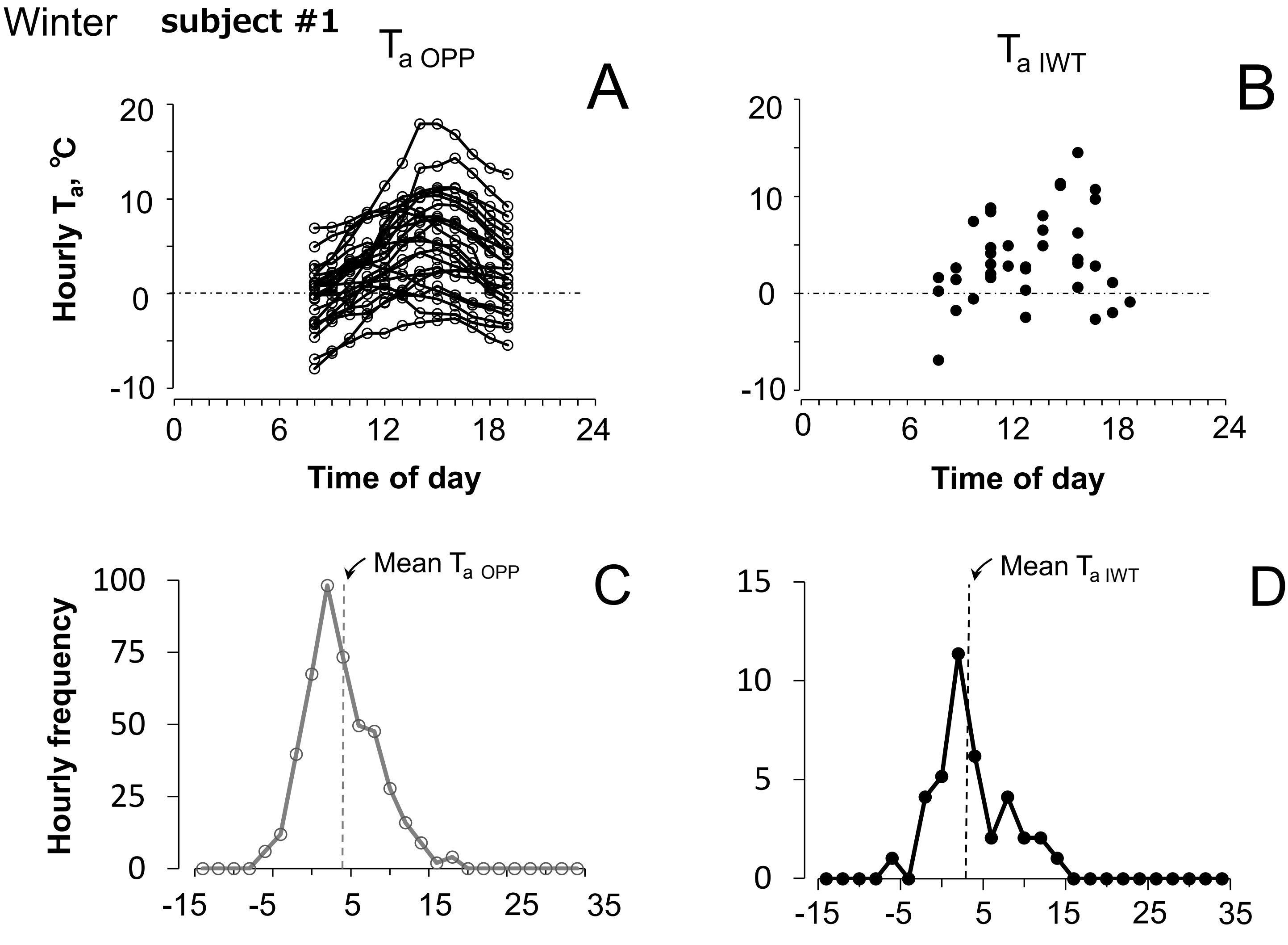

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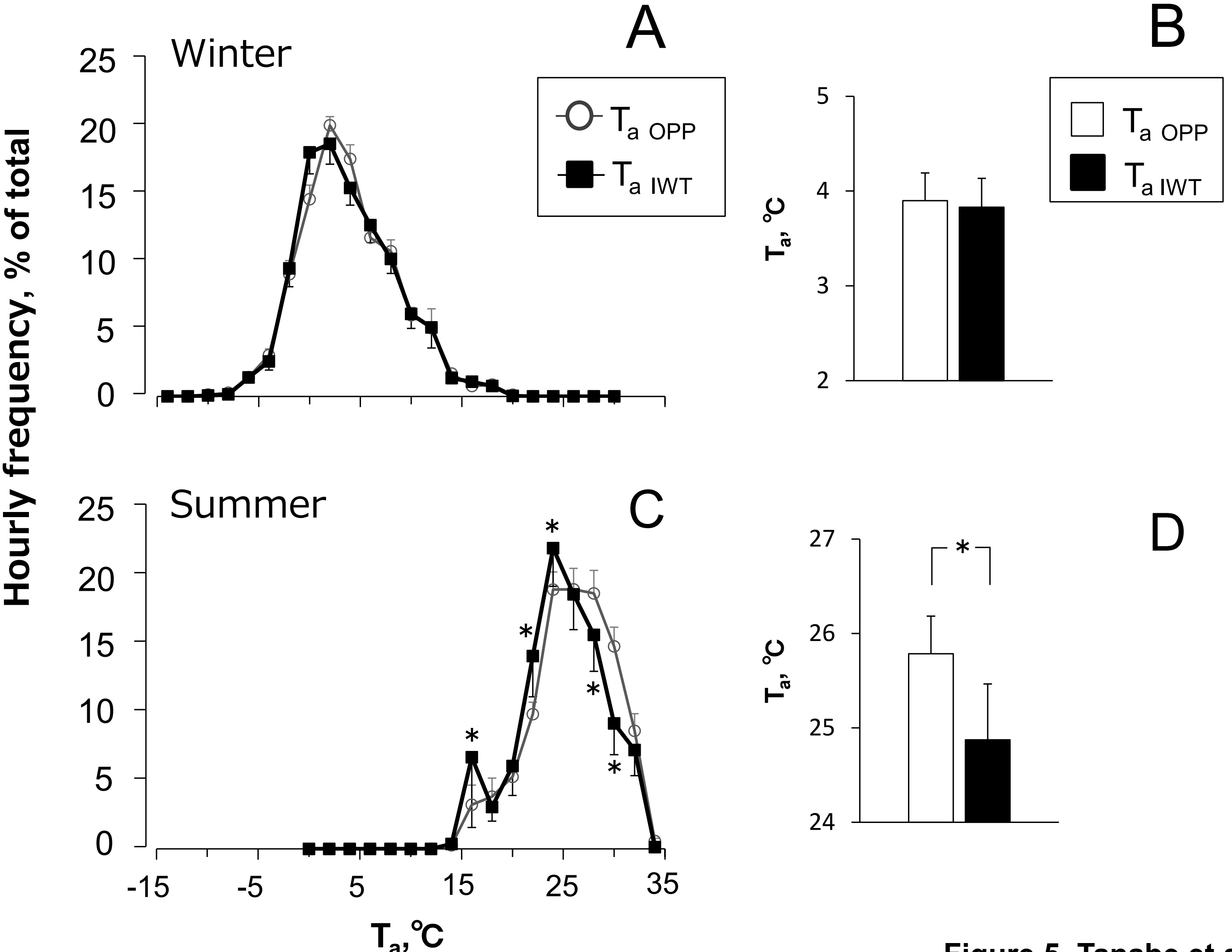

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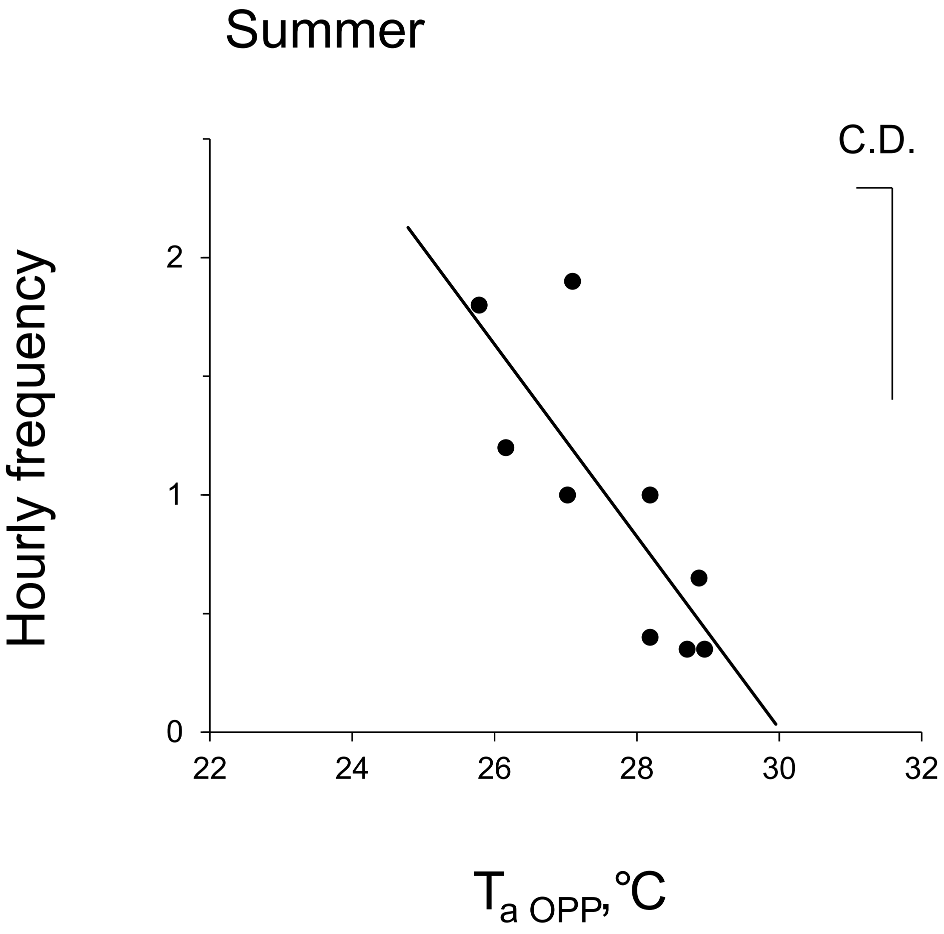

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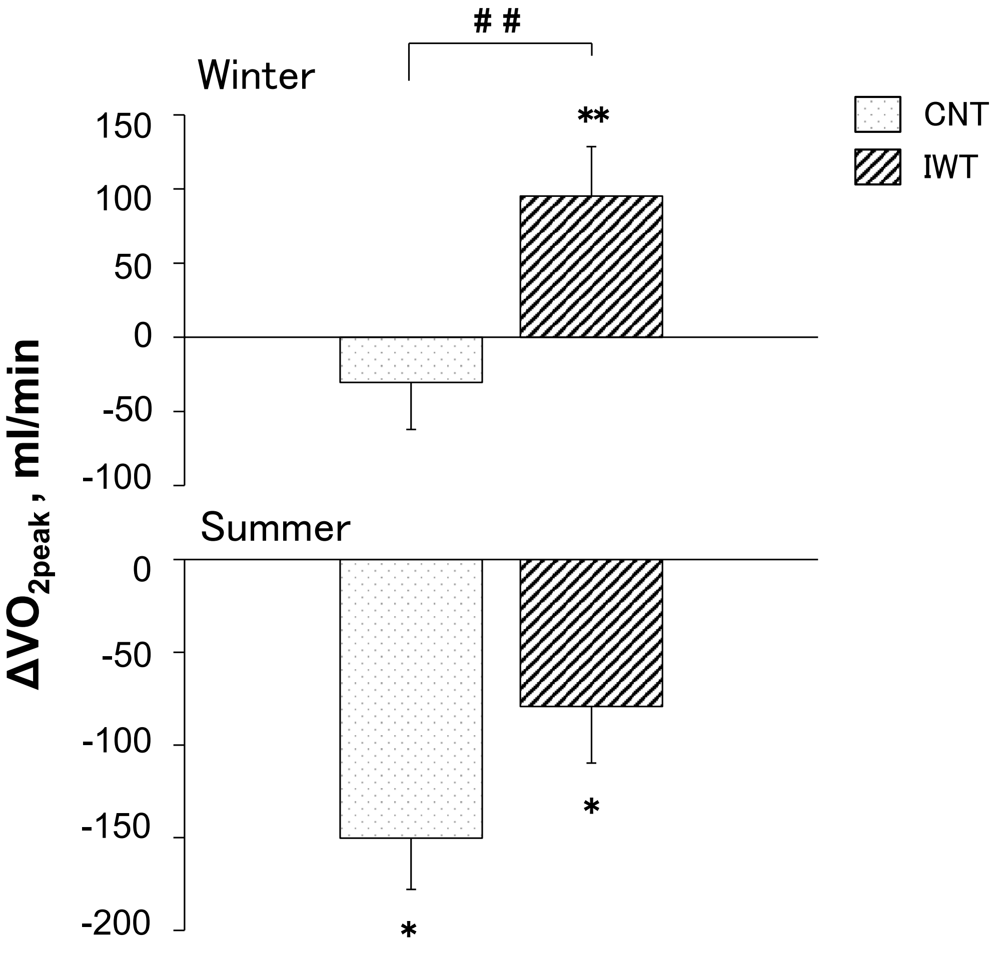

Figure 7. Tanabe et al.

Table 1: Physical characteristics, peak aerobic capacity and thigh muscle strength before and after training

	Winter training					Summer training				
	CNT (n = 24)		IWT (n = 22)		*P* value	CNT (n = 24)		IWT (n = 20)		*P* value
	Before	After	Before	After	Group × training	Before	After	Before	After	Group × training
Age, yrs	20 ± 1	NA	20 ± 2	NA	NA	20 ± 1	NA	20 ± 1	NA	NA
Height, cm	156 ± 4	NA	158 ± 4	NA	NA	159 ± 5	NA	157 ± 4	NA	NA
Weight, kg	51.2 ± 1.3	52.0 ± 1.5	55.2 ± 2.0	55.5 ± 2.1	NS	53.2 ± 1.2	53.4 ± 1.2	53.0 ± 1.7	52.1 ± 1.3	NS
Body mass index, kg/m^2	20.9 ± 0.5	21.2 ± 0.5	22.0 ± 0.8	22.1 ± 0.8	NS	20.9 ± 0.4	21.0 ± 0.4	21.5 ± 0.6	21.2 ± 0.5	NS
Resting HR, beats/min	74 ± 3	79 ± 3	76 ± 2	77 ± 3	NS	76 ± 2	73 ± 2	80 ± 4	74 ± 3	NS
Peak HR, beats/min	181 ± 2	180 ± 2	184 ± 2	185 ± 2	NS	186 ± 2	187 ± 2	181 ± 2	185 ± 2**	NS
$\dot{V}O_{2peak}$, ml/min	1811 ± 73	1781 ± 74	1822 ± 82	1923 ± 86**	0.007	1764 ± 54	1621 ± 54***	1848 ± 78	1760 ± 68**	NS
Isometric										
F_{EXT}, Nm	142 ± 6	135 ± 5*	155 ± 7	159 ± 7	0.015	148 ± 6	154 ± 5	136 ± 5	137 ±6	NS
F_{FLX}, Nm	54 ± 3	54 ± 4	53 ± 3	58 ± 3**	NS	63 ±3	54 ± 2***	55 ± 5	51 ± 3	NS

The values are the means ± SD for age and height and the means± SE for the other valuables. CNT, control group; IWT, interval walking group; HR, heart rate; $\dot{V}O_{2peak}$, peak aerobic capacity during the graded cycling test; F_{EXT}, knee extension force; F_{FLX}, knee flexion force; NA, not applicable; NS, not significant. The P values indicate a significant interactive effect by a 2-way ANOVA [group × training (before vs. after)] for repeated measures and a one-way ANOVA [before vs. after training] for repeated measures. $^{*, **, ***,}$ vs the values before training in each group at P<0.05, P<0.01, and P<0.001, respectively.

Table 2: Training achievements

	Winter training (n = 22)			Summer training (n = 20)		
	Total	School	Vacation	Total	School	Vacation
Walking days per week	3.1 ± 0.3	2.4 ± 0.3	4.2 ± 0.3†††	2.1 ± 0.3$^{\sharp}$	2.2 ± 0.3	2.1 ± 0.3$^{\sharp\sharp\sharp}$
Fast walking						
Time, min/walking day	12 ± 2	10 ± 2	13 ± 2	11± 1	11 ± 2	11 ± 2
§Energy expenditure, mlO_2/walking day	14512 ± 1728	13110 ± 1861	16743 ± 2195	14757 ± 2076	14471 ± 2083	15829 ± 2453
§Intensity, mlO_2/min	1342 ± 65	1354 ± 65	1319 ± 68	1343 ± 55	1341 ± 55	1331 ± 61
Slow walking						
Time, min/walking day	32 ± 5	26 ± 3	36 ± 6	16 ± 2$^{\sharp\sharp}$	16 ± 2$^{\sharp\sharp}$	16 ± 2$^{\sharp\sharp}$
§Energy expenditure, mlO_2/walking day	20086 ± 2337	17446 ± 1797	21631 ± 3048	11933 ± 1539$^{\sharp\sharp}$	11962 ± 1575$^{\sharp}$	10901 ± 1442$^{\sharp\sharp}$
§Intensity, mlO_2/min	661 ± 33	685 ± 30	666 ± 41	730 ± 34	734 ± 34	741 ± 37

The values are the means ± SE. §Resting oxygen consumption is not included. Winter training days; total (n= ~133), school (n= ~85) and vacation (n= ~47). Summer training days; total (n= ~176), school (n= ~125) and vacation (n=51). ††† Significant differences between school days during winter training at $P<0.001$. $^{\sharp, \sharp\sharp, \sharp\sharp\sharp}$ Significant differences from the corresponding value during winter training at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.