Comparison of Activity Level in Daily Life with Heart Rate: Application to Elderly Persons of Different Ambulatory Abilities

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Abstract

Objectives: Normal activity monitoring methods are mainly useful for relatively healthy and able-bodied people, but are not necessarily appropriate for elderly persons who may have difficulty in walking, or for the frail who may be bedridden. The purpose of this study was to examine 24-hour heart rate recording for the comparison of activity levels in daily life of elderly persons of different ambulatory abilities.

Methods: Forty-two elderly females (mean, 82.1 years old) volunteered to participate in this study. The subjects were divided into four groups on the basis of their ambulatory status, and their 24-hour heart rate recordings were compared with their results of activity assessments.

Results: The results of activity assessments showed a tendency to decrease as the ambulatory ability of the group decreased. The “total heart beats”, calculated as the sum of all heart rates over 24 hours, were almost the same among the four groups, and therefore did not show a similar tendency. However, the “total excess-beats product (TEBP)” correlated with the results of activity assessments. TEBP was calculated as the sum of all differences in beats between each heart rate in 24 hours and the mean heart rate during sleeping at night. Therefore, TEBP may reflect a more active state than the bedridden state.

Conclusions: These results suggest that comparison of activity levels in daily life using 24-hour heart rate recording might be possible by the calculation of TEBP, and that this method might be useful for the comparison of the activity levels of elderly persons of different ambulatory abilities.

Key words: heart rate, activity level, daily life, elderly person, ambulatory ability

Introduction

It is now widely recognized that elevating and maintaining activity level in daily life is important for promoting health

and physical fitness, and that this is particularly effective for the elderly for preventing disuse syndrome (1–4). Activity level in daily life provides an indication of how actively a person leads his or her daily life, and various methods, such as physical activity monitoring using a pedometer or an accelerometer (5–8) and daily activity investigations by “time-and-motion” studies or questionnaire-based methods (9–11), have been developed. Each of these methods has particular merits, but they tend to be useful mainly for relatively healthy and able-bodied people. They are not necessarily appropriate for elderly persons who may have difficulty in walking, or for the frail

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who may be bedridden (12), because these methods usually measure impulse/acceleration attributable to dynamic movements, such as walking, or record active behavior, such as that in various sports. One alternative approach, the doubly labeled water method (13–15), does not depend on the subject's walking ability, but this method is difficult to carry out in a clinical setting, particularly because of its high cost (16).

User-friendly heart rate monitors have become commercially available, and these can be used easily and conveniently for 24-hour heart rate recording, even in disabled patients. We carried out 24-hour heart rate monitoring in elderly persons and compared heart rate with activity levels in daily life, independent of walking ability. The subjects were divided into four groups on the basis of their ambulatory status, and their 24-hour heart rate recordings were compared with those of the assessment of the ability to perform daily activities and of the time-and-motion study.

Materials and Methods

Forty-two elderly female volunteers were enrolled in this study. On the basis of their ambulatory status, they were divided into four groups: those living at home and could independently walk indoor/outdoor (home-walking group, $n=11$); those living in a facility and could only walk independently indoor (facility-walking group, $n=10$); those living in a facility and could walk with difficulty, but could independently propel their wheelchair (w/c-independent group, $n=11$); and those living in a facility, could walk with difficulty, and were dependent on other people for wheelchair locomotion (w/c-dependent group, $n=10$). There was no change in the main ambulatory status of the subjects for at least one year prior to the study. The criteria for enrollment in the study are as follows: 1) subjects are not taking beta blockers; these drugs may significantly influence heart rate (17) (subjects taking calcium antagonists are not excluded, since these drugs only have at the most a minor effect on heart rate; for reference, each group included 5–7 subjects who took calcium antagonists); 2) subjects do not have dementia to the extent that they might remove the measuring equipment from their body, which would prevent the measurement of heart rate; 3) subjects do not have heart disease to the extent that the doctor of the facility would forbid their participation in

the study; and 4) subjects are in good health on the day of measurement. One additional criterion for the home-based subjects is that they are sufficiently intelligent to record the time-and-motion study by themselves. Diagnoses for the subjects in each group are shown in Table 1; this information was obtained from clinical records of facility residents, and from the home-based subjects themselves.

The mean age of all groups was 82.1 ± 7.4 years (age range, 68–95 years), and those of individual groups were 81.3 ± 9.3 , 84.1 ± 7.5 , 82.0 ± 5.5 and 81.2 ± 7.6 years for the home-walking group, facility-walking group, w/c-independent group, and w/c-dependent group, respectively. There were no significant differences in the mean ages among the four groups.

Heart rate was recorded by the minute over 24 hours, using a portable heart rate memory equipment (Memory Mac VHM1-016, VINE, Japan) and disposable electrodes (Vitrode D, NIHON KOHDEN, Japan).

To assess the ability of the subjects to perform basic activities of daily living (ADL), we used the Barthel index, in which six activities were examined: eating, grooming, dressing, taking a bath, excreting and ambulating. Furthermore, to assess the ability to perform applied activities parallel to daily living, the method developed by Demura et al. for the elderly at home (the Demura method) (18) was used. This included the assessment of 12 items: walking, running, jumping over a gap, stepping up stairs, standing up from a sitting position on the floor, standing on one leg with the eyes closed, maintaining a standing position on a bus/tram, dressing in a standing posture, buttoning, lifting a futon (mattress) up and down, carrying baggage, and lifting the body into a sitting position from a supine position. The score range of the Barthel index is 0–100, and that of the Demura method is 12–36, in which a score of 12 indicates that none of the examined items can be performed.

In the time-and-motion study, the name and posture (lying, sitting, or standing) and duration of each activity performed were recorded on a study sheet by the minute; this study was carried out for 24 hours in parallel to heart rate recording. For a subject living in a facility, an examiner observed and recorded the subject's activities, whereas a subject living at home recorded her own activities on a study sheet. All subjects were instructed to carry out their daily activities as usual on the day of measurement, except for taking a bath.

Table 1 Diagnoses of subjects in each group

Group name	Diagnoses of subjects
home-walking	Hypertension (5), subarachnoid hemorrhage (1), lower back pain (1), knee pain (1), heart disease (1), cataract (1), sleeplessness (1)
facility-walking	Osteoarthritis (5), hypertension (5), osteoporosis (4), iron deficiency anemia (2), cerebral infarction (1), left hemiplegia (1), fracture of the femur (1), Meniere disease (1), senile dementia (1), senile psychosis (1), postoperative breast cancer (1), heart failure (1), valvular disease of the heart (1), atrial fibrillation (1), cataract (1), stomach ulcer (1), sleeplessness (1)
w/c-independent	Hypertension (6), cerebral hemorrhage (5), senile dementia (4), angina pectoris (3), left hemiplegia (2), cerebral infarction (2), fracture of the femur (2), diabetes (2), cataract (2), osteoporosis (1), stomach ulcer (1), congestive heart failure (1), backache (1), mitral regurgitation (1)
w/c-dependent	Hypertension (7), senile dementia (5), cerebral infarction (4), cerebral hemorrhage (3), diabetes (2), osteoporosis (2), right hemiplegia (2), Parkinsonism (2), cataract (2), osteoarthritis (1), fracture of the femur (1), left hemiplegia (1), depression (1), chronic gastritis (1), amblyopia (1), hypoproteinemia (1), hyperlipemia (1), iron deficiency anemia (1), stomach ulcer (1)

[home-walking]: persons living at home and could walk independently indoor/outdoor ($n=11$). [facility-walking]: persons living in a facility and could walk independently indoor ($n=10$). [w/c-independent]: persons living in a facility, and could walk with difficulty but could independently propel their wheelchair ($n=11$). [w/c-dependent]: persons living in a facility, could walk with difficulty, and were dependent on other people for wheelchair locomotion ($n=10$). Figure in parentheses indicates the number of subjects.

Fig. 1 Scores for Barthel index and Demura method in each group. The score range of the Barthel index is 0–100, and that of the Demura method is 12–36, in which a score of 12 indicates that none of the examined items can be performed. Values shown in the figure are means $\pm$ SD. Although not indicated in the figure, significant differences in Barthel index scores were found between the w/c-dependent group and the walking groups (the home-walking group and the facility-walking group), and in Demura scores between the home-walking group and the wheelchair groups (the w/c-independent group, and the w/c-dependent group).

Analysis of variance and Scheffé's multicomparison method were used to test the significance of means. All statistical analyses were based on two-tailed probabilities, and differences were considered significant at $p < 0.05$. SPSS for Windows (version 12.0J, SPSS Japan) was used for statistical analyses.

The study was performed with approval from the Ethical Committee of Hirosaki University School of Medicine, and with permission from the head (medical doctor) of the facility and non written informed consent from each subject prior to participation.

Results

The scores of activity assessments using the Barthel index and the Demura method are shown in Fig. 1. There was a significant difference in the mean Barthel index scores between the walking groups (the home-walking group and the facility-walking group) and the wheelchair groups (the w/c-independent group and the w/c-dependent group). Furthermore, the difference in the mean Barthel index scores between the w/c-independent group and the w/c-dependent group was also significant ($p < 0.001$). There were also significant differences in the mean Demura scores between the walking groups and the wheelchair groups, and these scores between the home-walking

group and the facility-walking group ($p < 0.001$). Therefore, the scores of both assessments showed that the ability to perform activities in daily life decreased as the ambulatory ability of the group decreased, in the order of the home-walking group, facility-walking group, w/c-independent group and w/c-dependent group.

The activities observed in the time-and-motion study are shown in Table 2. While sitting, several activities, such as eating/tea-drinking, dressing, grooming, conversing, watching TV/video, reading newspaper/book, chanting sutra (praying), and writing were observed for all four groups. In addition, some activities that were unique to each group were noted. For example, some light work, domestic odd jobs, hobby activities, and sitting in a vehicle were observed in the home-walking group, whereas participation in group/individual sessions for rehabilitation, assisted ADL, and assisted wheelchair locomotion were observed in the w/c-dependent group. While standing, there were almost no activities common among the four groups. In the home-walking group, many active activities, such as dressing, grooming, going to the toilet, preparing/setting the table for a meal or for tea, cleaning, washing and hanging out washed clothes, going out/shopping, gardening, walking or taking out the dog, exercising, and going to hospital were observed. On the contrary, in the w/c-dependent group, the activities while standing were limited to "assisted transfer", a

Table 2 Main activities observed in time-and-motion study of each group

Sitting posture	
(in all groups)	eating/tea-drinking, dressing, grooming, conversing, watching TV/video, reading newspaper/book, chanting sutra (praying), writing
home-walking	some light work, domestic odd jobs, hobbies, sitting in vehicle
facility-walking	group session for rehabilitation, self-training, domestic odd jobs in facility
w/c-independent	group/individual sessions for rehabilitation, wheelchair propulsion
w/c-dependent	group/individual sessions for rehabilitation, assisted ADL, assisted wheelchair locomotion
Standing posture	
home-walking	dressing, grooming, going to toilet, preparing/setting the table for meal/tea, cleaning, washing and hanging out of washed clothes, going out/shopping, gardening, walking or taking out the dog for a walk, exercising, going to hospital
facility-walking	dressing, grooming, going to toilet, walking, conversing, self-training, domestic odd jobs in facility
w/c-independent	dressing, grooming, going to toilet, transfer, training for walking
w/c-dependent	assisted transfer

Fig. 2 Time spent in different postures in each group. [night-sleeping]: time spent in lying posture for sleeping at night, [lying]: time spent in lying posture over a whole day, [sitting]: time spent in sitting posture over a whole day, [standing]: time spent in standing posture over a whole day. Values shown in the figure are means±SD. Lying time increased and standing time decreased as the ambulatory ability of the group decreased.

Fig. 3 Total heart beats in each group. Total heart beats, calculated as the sum of all heart rates over 24 hours, showed no significant differences among the four groups, and no relationship with ambulatory ability. Values shown in the figure are means±SD.

passive short-term activity. These results show that the actual performance of activities in daily life also tended to decrease as the ambulatory ability of the group decreased.

The time spent in different postures in each group, determined on the basis of the results of the time-and-motion study, is shown in Fig. 2. In this study, time spent lying down is defined in three ways: time lying down over a 24-hour period (lying time), time lying down at night for sleeping (night-sleeping time), and time lying down except for the night-sleeping time (day-lying time). Hence, lying time consists of both night-sleeping time and day-lying time. Lying time (and also night-sleeping time and day-lying time) increased as the ambulatory ability of the group decreased. For example, the mean lying time in the w/c-dependent group was 16 hours 31 minutes, which was approximately 7 hours longer than the mean in the home-walking group (9 hours 40 minutes). On the other hand, standing time decreased as the ambulatory ability of the group decreased. For example, the mean standing time in the home-walking group was 5 hours 9 minutes, whereas the mean in the w/c-dependent group was only 14 minutes, which was essentially the time for assisted transfer between the bed

and wheelchair, or between the wheelchair and toilet. Hence, the time spent standing by oneself was essentially zero in the w/c-dependent group. On the other hand, the relationship between sitting time and ambulatory ability was not as simple as for lying time and standing time. The mean sitting time fell within a relatively narrow range from approximately 7 to 10 hours for all groups. The longest mean sitting time (9 hours 59 minutes) was observed in the w/c-independent group and the shortest (7 hours 14 minutes) in the w/c-dependent group.

The 24-hour heart rate recording was successfully carried out in all subjects. The “total heart beats”, calculated as the sum of all heart rates over 24 hours (1,440 minutes), are shown in Fig. 3. The mean total heart beats in each group remained within the range from approximately 100,000 to 106,000 beats/day. The mean total heart beats among the four groups showed no significant differences and showed no apparent relationship with ambulatory ability. These data were also used to obtain the mean heart rate over a whole day, which was determined by dividing the total heart beats by 1,440 minutes.

Postural mean heart rates while night-sleeping, day-lying, sitting, and standing are shown (in addition to the mean heart

Fig. 4 Postural heart rate in each group. In each group, the postural mean heart rates while day-lying-down, sitting, and standing time increased in this order, and significant differences were found in the means among the postures, except between sitting and standing in the w/c-dependent group. Although not indicated in the figure, there was a significant difference in mean heart rate between day-lying and standing in each group. The mean heart rates while night-sleeping and over one day were excluded from the statistical analyses. The mean heart rates while night-sleeping and day-lying tended to increase slightly as the ambulatory ability of the group decreased. Values shown in the figure are means±SD.

Fig. 5 Postural excess-beats rate in each group. The excess-beats rate was calculated as the difference in beats between each heart rate and the mean heart rate while night-sleeping, which was used as the basal heart rate. In each group, the postural mean excess-beats rates while day-lying, sitting, and standing increased in this order, and significant differences in these means were observed among the postures, except between sitting and standing in the w/c-dependent group. Although not indicated in the figure, there was a significant difference between day-lying and standing in each group. The mean excess-beats rate for one day tended to decrease as the ambulatory ability of the group decreased. Values shown in the figure are means±SD.

rate over a whole day) in Fig. 4. Postural mean heart rates in each group increased in the order of day-lying, sitting, and standing, and significant differences ($p<0.001$) in the mean heart rates were found except for between sitting and standing in the w/c-dependent group. The mean heart rates while night-sleeping and day-lying tended to increase slightly as the ambulatory ability of the group decreased. For example, the mean heart rate while night-sleeping in the w/c-dependent group was 67.4 beats/minute, which was higher by 5.6 beats/minute than the 61.8 beats/minute in the home-walking group.

On the basis of these data, we calculated the difference in beats between each heart rate and the mean heart rate while night-sleeping as the basal heart rate. Since we were unable to find the proper terminology in the literature to describe this difference in beats, in this paper we hereafter refer to it as the “excess-beats rate”. The excess-beats rate means the excess beats/minute attributable to activities compared with that in the bedridden state. The postural mean excess-beats rates were approximately 1 beat/minute while day-lying, 11–16 beats/minute while sitting and 13–24 beats/minute while standing,

Fig. 6 Total excess-beats product in each group. The total excess-beats product (TEBP) was calculated as the sum of all excess-beats rates over 24 hours, using the mean heart rate while night-sleeping as the basal heart rate. Values shown in the figure are means $\pm$ SD. TEBP tended to decrease as the ambulatory ability of the group decreased.

Fig. 7 Postural excess-beats product in each group. The excess-beats products while sitting accounted for approximately 50% of TEBP in the walking groups and more than 80% in the wheelchair groups. The excess-beats product while standing was most closely related to difference in TEBP among the four groups. Values in the figure indicate means.

averaged over the four groups (Fig. 5). As with the postural mean heart rates, the postural mean excess-beats rates were higher while day-lying, sitting, and standing in this order, and significant differences ($p<0.001$) were obtained among these means, except for between sitting and standing in the w/c-dependent group. The mean excess-beats rate over a whole day tended to decrease as the ambulatory ability of the group decreased.

Because the excess-beats rate is expressed in minutes, it cannot be used as a parameter of the activity level over a whole day. Therefore, the “total excess-beats product (TEBP)” was calculated as the sum of all excess-beats rates over 24 hours (Fig. 6). There were significant differences in the mean TEBP among the groups; between the home-walking group and w/c-dependent group ($p<0.001$), between the home-walking group and w/c-independent group ($p<0.01$), and between the facility-walking group and w/c-dependent group ($p<0.05$). Most importantly, TEBPs tended to decrease as the ambulatory ability of the group decreased. Hence, this tendency was consistent with the results of activity assessments. Figure 7 shows the postural excess-beats products as a function of TEBP of each group. The excess-beats products while sitting

in the home-walking group, facility-walking group, w/c-independent group and w/c-dependent group accounted for 52%, 51%, 82% and 88% of TEBP, respectively; hence, these accounted for approximately 50% and more than 80% of TEBP in the walking groups and the wheelchair groups, respectively. The mean excess-beats products while standing in the home-walking group and the w/c-dependent group were approximately 7,600 beats/day and 200 beats/day, respectively, showing that the values were significantly lower in the groups with lower ambulatory ability, and that the values are closely related to the difference in TEBPs among the four groups.

Discussion

In our subjects, both the ability to perform daily activities and the actual performance of activities observed in their daily life tended to decrease as the ambulatory ability decreased. However, this tendency of a lower activity level in the groups with lower ambulatory ability was not consistent with the total heart beats, calculated as the sum of all heart rates over 24 hours. However, this tendency was consistent with TEBP, calculated as the sum of all excess-beats rates over 24 hours.

The excess-beats rate means the difference in beats between each heart rate in 24 hours and the mean heart rate while night-sleeping, which was used as the basal heart rate.

The lack of significant differences in the mean total heart beats among the four groups, despite the differences in activity level among these groups, and the lack of a relationship between the mean total heart beats and the ambulatory ability of the four groups, may be explained as follows. The inactive life of the lower activity group led to a decrease in circulatory function, which in turn resulted in a higher heart rate than those observed for the other groups, both at rest and during similar activities. This speculation is supported by several early bed rest studies (19–21), in which it was reported that heart rate at rest and during submaximal exercise increases significantly after a prolonged period in a nonactive state, as represented by the bedridden state. For example, in 1948 Deitrick et al. (19) reported that the resting pulse rate while lying in bed increases by 3.8 beats/minute after 6–7 weeks of bed rest, and in 1949 Taylor et al. (20) reported that the pulse in a vertically tilted position (65 degrees) increases by 38 beats/minute after 3 weeks of bed rest. In 1968, Saltin et al. (21) demonstrated that the increase in heart rate at rest and during submaximal exercise after a prolonged bed rest compensates for a decrease in stroke volume, and that the oxygen-transporting ability at rest and during submaximal exercise is maintained by this system.

The above results are from bed rest experiments involving healthy adult males and were conducted under strictly controlled conditions. On the other hand, Shindo (22) showed that heart rate at rest increases as bed rest time becomes longer, even under conditions of habitual life; he carried out his investigation over a 6-month period in a special geriatric nursing care facility. According to this study, for elderly persons whose bed rest time increases by less than 2 hours/day, resting heart rate while sitting in a chair increases by 0.4 beats/minute on average. For elderly persons whose bed rest time increases by more than 5 hours/day, resting heart rate increases by 3.2 beats/minute on average.

In our study, lying time and heart rate while lying tended to increase as ambulatory ability decreased. For example, the mean lying time increased by approximately 7 hours and the mean heart rate while night-sleeping increased by 5.6 beats/minute in the w/c-dependent group compared with those in the home-walking group. A 5.6 beats/minute increase in basal heart rate means an increase of 8,064 beats in a whole day; consequently, the increase in basal heart rate might be the main reason why there were no significant differences in the mean total heart beats among the four groups, despite the differences in activity levels. Further studies are needed, however, to confirm that the mean total heart beats of different ambulatory groups always stay within a range of approximately 100,000 to 106,000 beats/day.

TEBP reflects the total excess beats attributable to the activities over 24 hours compared with the mean heart rate while night-sleeping, which was used as the basal heart rate. Therefore, the TEBP in the most inactive state, such as in the bedridden state over a whole day, is assumed to be almost zero. In many studies using healthy subjects, exercise intensity

or activity level is usually evaluated on the basis of values during sitting rest time. However, for elderly persons with difficulty in walking or for frail elderly persons with a tendency to take a lot of bed rest, activities while sitting, including quiet sitting, are very important for maintaining and promoting their health and physical fitness. Ueda et al. (23) suggested that an increased activity level in daily life should be commenced by decreasing daytime lying time and achieving a minimum daytime sitting time to recover from the deconditioning state. In our study, the sitting time in the w/c-dependent group was approximately 7 hours, and the excess-beats product while sitting was approximately 4,600 beats/day. These excess beats were mostly due to activities such as taking the meals three times each day (breakfast, lunch, and supper) in the dining room, and by participating in group or individual sessions for rehabilitation in the therapy room. These activities require wheelchair locomotion between their room and the dining room or therapy room, and while taking a meal or participating in a rehabilitation session, they usually sit more than 1 hour in a chair/wheelchair. Therefore, if these opportunities are not offered in the facility, the excess-beats product while sitting will be very small. In this group, nearly 90% of TEBP was observed while sitting, and thus it is essential to evaluate the activity level in daily life based on values while lying down.

In this study, the mean heart rate while night-sleeping was used as the basal resting heart rate, since this is the lowest heart rate in a whole day. It can also be used to obtain a reliable and stable mean value, because a large amount of heart rate data can be collected during night-sleeping time, and the determination of night-sleeping time essentially only requires knowledge of the time the subject went to bed and the time the subject got up in the morning.

One of the merits of activity level evaluation using heart rate is that heart rate sensitively reacts to changes in posture because of changes in blood flow and muscle activity occurring to maintain an antigravity posture. Therefore, heart rate significantly increases in the order of static lying, static sitting and static standing; likewise oxygen uptake, which is the most reliable parameter of activity level (24). Contrary to this, differences in static posture cannot be identified by methods that detect physical movement and acceleration. In addition, heart rate is extremely sensitive even to very light physical motion in the same posture (25). Consequently, in this study, significant differences in postural mean heart rates and also postural mean excess-beats rates were found between different postures. Because of these characteristics of heart rate, any activities such as light exercise while lying on the bed, quiet sitting in a wheelchair waiting for a meal, and gait training using parallel bars can be evaluated using TEBP.

The disadvantages of the 24-hour heart rate monitoring method include the requirement for a 24-hour attachment of portable heart rate memory equipment to the body that prevents taking a bath during the measurement period, and several limitations attributable to subject conditions. For example, this method cannot be used for persons with problems associated with heart rate including the use of a pacemaker, and for persons who meet the exclusion criteria indicated in this study. At the beginning of our investigation on the

activity of elderly persons, we measured oxygen uptake, because we considered that the measurement of heart rate was inappropriate for elderly persons. However, the measurement of oxygen uptake was inappropriate for examining the activity level over a whole day; thus we changed to the measurement of heart rate, which is highly correlated with oxygen uptake, and our results suggest that measurement of heart rate is appropriate even for elderly persons if the subjects are carefully selected on the basis of the exclusion criteria.

In this study, the activity levels of the four groups of different ambulatory abilities were compared and individual tendencies of the groups were found. However, a correlation between activity level and TEBP in subjects within a group was not found. This is because differences in scores in the Barthel index and Demura method were too small to show any relationship. For example, the Barthel index score for all subjects in the home walking group was 100, showing no differences among the subjects. Therefore, further investigations are required to determine the accuracy and use of TEBP as an individual parameter, taking into consideration individual differences in the reaction of heart rate to activity type.

The exact TEBP required for the health promotion of elderly persons is another subject that needs further study. Although, a TEBP of about 16,000 beats/day observed in the home-walking group might be appropriate as a target, we need to consider that an elderly person who has a high resting heart rate might have only a small reserve of physical fitness. For example, an inverse correlation between resting heart rate and health/physical fitness level has been reported: in 1976, Cooper et al. (26) showed that the physical fitness of persons

with high resting heart rate is poor and that of persons with low resting heart rate is excellent. Since then, many epidemiological studies (27–29) have been published that show high mortality of persons with high resting heart rates due to cardiovascular disorder, cancer and other diseases. Palatini et al. (29) showed that an elevated resting heart rate may be a strong predictor of cardiovascular death in elderly men aged 65 years or older. Therefore, in elderly persons with high resting heart rate, it will be necessary to increase their activity level (TEBP) cautiously in small steps, and to improve gradually their physical fitness, while avoiding the risk of overload.

In summary, the tendency for a decreased ability to perform daily activities and the actual performance of these activities was found in subjects with lower ambulatory ability. This tendency was clearly shown by TEBP calculated on the basis of the mean heart rate while night-sleeping. This suggests that TEBP can be used as a parameter for comparing activity levels in daily life of elderly persons of different ambulatory abilities.

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References

- (1) Bortz WM II. Disuse and aging. *JAMA*. 1982;248:1203–1208.
- (2) Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kamoert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med*. 1993;328:538–545.
- (3) Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health. A recommendation from the centers for disease control and prevention and the American College of Sports Medicine. *JAMA*. 1995;273:402–407.
- (4) Mazzeo RS, Cavanagh P, Evans WJ, Fiatarone M, Hagberg J, McAuley E, et al. ACSM position stand on exercise and physical activity for older adults. *Med Sci Sports Exerc*. 1998;30:992–1008.
- (5) Saris WHM, Binkhorst RA. The use of pedometer and actometer in studying daily physical activity in man. Part I Reliability of pedometer and actometer. *Eur J Appl Physiol*. 1977;37:219–228.
- (6) Montoye HJ, Washburn R, Servais S, Ertl A, Webster JG, Nagle FJ. Estimation of energy expenditure by a portable accelerometer. *Med Sci Sports Exerc*. 1983;15:403–407.
- (7) Bassey EJ, Dallosso HM, Fentem PH, Irving JM, Patrick JM. Validation of a simple mechanical accelerometer (pedometer) for the estimation of walking activity. *Eur J Appl Physiol*. 1987;56:323–330.
- (8) Richardson MT, Leon AS, Jacobs DR Jr, Ainsworth BE, Serfass R. Ability of the Caltrac accelerometer to assess daily physical activity levels. *J Cardpulm Rehabil*. 1995;15:107–113.
- (9) Montoye HJ. Estimation of habitual physical activity by questionnaire and interview. *Am J Clin Nutr*. 1971;24:1113–1118.
- (10) Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. *Can J Appl Sport Sci*. 1985;10:141–146.
- (11) Sequeira MM, Rickenbach M, Wietlisbach V, Tullen B, Schutz Y. Physical activity assessment using a pedometer and its comparison with a questionnaire in a large population survey. *Am J Epidemiol*. 1995;142:989–999.
- (12) Noda M, Soma M, Saito K, Tsushima E, Kida K, Mita R, et al. The characteristics of walking and pedometer readings of the fragile elderly people. *Bull Sch Allied Med Sci Hiroasaki Univ*. 2001;25:155–163.
- (13) Schoeller DA, Santen EV. Measurement of energy expenditure in humans by doubly labeled water method. *J Appl Physiol*. 1982;53:955–959.
- (14) Starling RD, Matthews DE, Ades PA, Poehlman ET. Assessment of physical activity in older individuals: A doubly labeled water study. *J Appl Physiol*. 1999;86:2090–2096.

- (15) Schoeller DA. Recent advances from application of doubly labeled water to measurement of human energy expenditure. *J Nutr.* 1999;129:1765–1768.
- (16) Usutani S. Recent trend in estimating energy expenditure in Japan. *Nippon Eiseigaku Zasshi.* 1992;47:881–839. (Article in Japanese)
- (17) Van Herwaarden CLA, Binkhost RA, Fennis JFM, Van't Laar A. Effects of propranolol and metoprolol on haemodynamic and respiratory indices and on perceived exertion during exercise in hypertensive patients. *Br Heart J.* 1979;41:99–105.
- (18) Demura S, Sato S, Matsuzawa J, Noda Y, Miyaguchi H, Tada N, et al. The examination of ADL items effective for the assessment of the daily life activities for the elderly at home. *Jpn J Physiol Fitness Sports Med.* 2000;49:237–246. (Article in Japanese, with English abstract)
- (19) Deitrick JE, Whedon GD, Shorr E. Effects of immobilization upon various metabolic and physiologic functions of normal men. *Am J Med.* 1948;4:3–36.
- (20) Taylor HL, Henschel A, Brozek J, Keys A. Effects of bed rest on cardiovascular function and work performance. *J Appl Physiol.* 1949;2:223–239.
- (21) Saltin B, Blomqvist G, Mitchell JH, Johnson RL Jr, Wildenthal K, Chapman CB, et al. Response to exercise after bed rest and after training: A longitudinal study of adaptive changes in oxygen transport and body composition. *Circulation.* 1968;38:1–78.
- (22) Shindo S. The influence of the hours of staying out of bed on physical fitness of severely disabled elderly persons. *JPN J Phys Ther Occup Ther.* 1988;22:827–830. (Article in Japanese, with English abstract)
- (23) Ueda B, Okawa Y. Occupational therapists and disuse syndrome. *JOT.* 1991;25:912–919. (Article in Japanese)
- (24) Noda M, Soma M, Kanazawa Y, Kida K, Mita R, Ishimochi R, et al. The relationship of oxygen consumption and heart rate during rest, intermittent incremental loading exercise and recovery. *Bull Sch Allied Med Sci Hiroasaki Univ.* 2000;24:73–81. (Article in Japanese)
- (25) Noda M, Otaku R, Kikuchi A, Asahi S, Kida K, Mita R, et al. Comparison of oxygen consumption at rest and during very light motion in lying, sitting and standing posture. *JJAOT.* 2003;22:506. (Article in Japanese)
- (26) Cooper KH, Pollock ML, Martin RP, White SR, Linnerud AC, Jackson A. Physical fitness levels vs selected coronary risk factors. A cross-sectional study. *JAMA.* 1976;236:116–169.
- (27) Dyer AR, Persky V, Stamler J, Paul O, Shekelle RB, Berkson DM, et al. Heart rate as a prognostic factor for coronary heart disease and mortality: Findings in three Chicago epidemiologic studies. *Am J Epidemiol.* 1980;112:736–749.
- (28) Wannamethee G, Shaper AG, Macfarlane PW. Heart rate, physical activity, and mortality from cancer and other noncardiovascular diseases. *Am J Epidemiol.* 1993;137:735–748.
- (29) Palatini P, Casiglia E, Julius S, Pessina AC. High heart rate: A risk factor for cardiovascular death in elderly men. *Arch Intern Med.* 1999;159:585–592.