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Original Article

Functional Age and Bouts of Physical Activity in Middle-Aged to Older Japanese Adults; Yurin-Study

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Abstract

Purpose: To examine the relationship between the functional age (FA) and the objectively measured daily physical activity (PA).
Methods: The subjects of the present investigation were 15 males and 22 females (68±6 yr.). The Anti-Aging-Dock determined the 5 components of FA (Bone age; BA, Hormone-age; HA, Muscle-age; MA, Nervous system-age; NA, Vascular-age; VA). Each participant wore an electronic pedometer (HJ-720IT, Omron Corporation, Kyoto-city, Kyoto Japan) in order to determine daily number of steps ($STEP_{day}$) and the time and steps for PA lasting longer >10-min at >60 steps·min^{-1} of the step rate ($Bout_{time}$ and $Bout_{step}$). The HA was evaluated by using the standard aging curve of serum DHEA-s and IGF-I concentration.
Result: Simple correlation coefficient showed that the HA significantly associated with $STEP_{day}$ and $Bout_{step}$ in female subjects ($p<0.05$). A multiple regression analysis showed that the $Bout_{step}$ and Age came out significant parameter of the HA.
Conclusions: The HA significantly associated with steps $Bout_{step}$ independently from the $STEP_{day}$ in middle-aged to older female adults. The bouts of PA lasting >10-min may be an effective PA to protect the age-associated changes in hormonal functions.

KEY WORDS: Aging, Pedometer, Accelerometer, Exercise, Public health

Introduction

An active lifestyle is an important protect factor for chronic disease morbidity and mortality in aging [1)]. One of the main determinants of the levels of physical activity (PA) is age [2)], and the PA frequently decreased with increasing age [3)]. However, older individuals can still obtain a desirable amount of PA as a result of an appropriate intervention [4)]. Furthermore, a prospective cohort study suggested that elderly women could lengthen their life by increasing and maintaining PA levels [5)]. Therefore, older individuals should improve their PA level as well as younger- and middle-aged adults in order to elicit positive health benefits.

A consensus statement [6)] recommended that older adults need moderate-intensity aerobic PA for a minimum of 30 min on five days each week or vigorous intensity aerobic PA for a minimum of 20 min on three days each week in order to promote and maintain health. Furthermore, for older adults who are not active at recommended levels, plans should include a gradual approach to increase PA over time using multiple bouts of PA (>10 min) [6)].

The functional age (FA), determined by the Anti-Aging-Dock, is a useful tool for diagnosing the degree of aging [7)]. The FA is consisted of five parameters in regard to the psychological and physiological indicator, such as the Bone-age (BA), Hormone-age (HA), Muscular-age (MA), Neurological-age (NA), and, Vascular-age (VA). Although previous studies suggested that the exercise program could improve some of the components of FA [8-12)], the changes of the FA after the interventions were inconsistent. These studies mainly used the pedometer-based intervention, thus the exercise prescription had limited to advice the increases in the total amounts of the walking activities. The exercise intensity and the duration are the important determinants of the effects of the exercise intervention [4,13)], Therefore, the walking speed was associated with survival in older adults [14)]. Researchers have also found evidence that older individuals who had participated in the moderate intensity PA on most days of week had a better physical function than older adults who were active throughout the day [15)]. As previously mentioned, the bouts of PA, such as PA lasting at least 10 minutes, have also been recommended in order to obtain the health benefits, rather than the shorter PA [6)]. In the best of our knowledge, the relationships between the FA and the bouts of PA remain unclear. Based on these findings, we hypothesized that the bouts of PA will have a greater effect on FA than the total amount of PA.

Thus, the primary objective of the present investigation was to examine the relationship between each of 5 components of FA and the objectively measured daily PA such as the daily number of steps ($STEP_{day}$) and the bout of PA lasting longer than 10 minutes.

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Methods

Subjects

Fifteen men and twenty-two women, aged from 56 yr. to 79 yr., participated in the present investigation. The characteristics of subjects were shown in ***Table 1***. Subjects were recruited from the Senior Club of Yurin School District, a school district in the Shimogyo district of Kyoto-city, Japan, using bulletin boards in the district. The former Yurin Elementary School (Former-Yurin Sho) is used as a community center. All participants were independently living, and were free from any severe chronic diseases. After explaining the study design and requirements, all subjects signed a consent form. All procedure of the present study was approved by the ethics committee of the Doshisha University.

Physical Activity Assessment

All subjects wore an electronic pedometer (HJ-720IT, Omron Corporation, Kyoto-city, Kyoto Japan) on their waist level just above the leg continuously for 14 days, except while sleeping and bathing. At the end of the data collection period, the device was retrieved, and the data were downloaded into a computer. This type of pedometer is a reliable method of recording the number of steps under controlled and free-living conditions [16-19]. In the present investigation, the daily time (**min·day^{-1}**) and the number of steps (**steps·day^{-1}**) for bout of PA ($Bout_{time}$ and $Bout_{step}$) were assessed in addition to the $STEP_{day}$. The bout of PA was defined as the consecutive PA lasting longer than 10 minutes at least 60 steps·min^{-1} of the minute-by-minute stepping rate. However, it must be noted that, the bouts of PA allowed including the interruptions. Limited to one minute, the minute-by-minute stepping rate might drop below 60 **step·min^{-1}** during a bout.

Functional Age

The FA was determined following the previously described procedures [7,9]. The MA was determined based on the muscle mass determined by a bioelectrical impedance analyzer (Physion MD, NIPPON SHOOTER Ltd, Chiyoda-ku, Tokyo, Japan). The HA was evaluated by using the standard aging curve of the serum dehydro-epiandrosterone sulfat (DHEA-s) and insulin-like growth factor-1 (IGF-1). The NA was evaluated according to the results of the Wisconsin card-sorting test. The VA was determined based on photo-plethysmogram (Dynapulse SDP-100, Fukuda Denshi Co., Ltd., Bunkyo-ku Tokyo, Japan). Finally, the BA was determined by the bone mineral density assessed by ultrasound bone densitometer (A-1000, GE Yokogawa Medical Systems Ltd, Hino-city, Tokyo, Japan). Further details can be found in the previous publications [7,9].

Date Analusis and Statistics

Linear regressions analyses were performed for either the FA and the several index of PA, including the bout of PA and the daily total amount of PA, to investigate the ability and contribution for the FA. In addition, a multiple stepwise regression analysis was used to investigate the contribution of the FA to the index of PA and characteristics of subjects. Pearson's correlation coefficients (r) as well as product correlation coefficient (r^2) were calculated. The difference between men and women was analyzed using the Mann-Whitney-U test. All statistical analyses were performed by using the StatView software program (version 5.0.1, SAS Institute, Cary, NC, USA). The data are expressed as the mean with standard deviation. Statistical significance was set at $p < 0.05$.

Results

The characteristics of the subjects are presented in ***Table 1***. The height and body weight were significantly higher in men compared with that in women ($p<0.05$). The number of steps and the time for the bout of PA are shown in ***Table 2***. In regard to the indexes of PA, although marginal difference was found in $STEP_{day}$ ($p=0.07$), All variables did not differ significantly between men and women. The BA was significantly younger in male subjects compared with that in female subjects ($p<0.05$, ***Table 3***). The MA, HA, NA, and VA did not differ significantly between men and women.

Table 1 Characteristics of subjects in Yurin-study

	All	Women	Men
Age (yr.)	68.0 ± 8.0	68.0 ± 6.0	67.0 ± 6.0
Height (cm)	159.3 ± 7.3	155.1 ± 5.0	165.3 ± 5.7 **
Body weight (kg)	58.6 ± 10.0	54.9 ± 8.2	64.1 ± 10.1 **
Body mass index (kg·m^{-2})	23.0 ± 2.8	22.8 ± 2.8	23.4 ± 2.7
Waist circumfluence (cm)	85.0 ± 9.0	86.0 ± 9.0	85.0 ± 10.0

Data are expressed as mean with standard deviation (mean±SD).
Significant difference compared with that in women ($p<0.01$).

Table 2 Number of steps and time for bout and non-bout of physical activity in Yurin-study

	All	Women	Men
Daily number of steps (steps·day^{-1})	8691 ± 3822	7811 ± 1886	10072 ± 5479
$Bout_{step}$ (steps·day^{-1})	3114 ± 73611	2508 ± 1514	4067 ± 5459
$Bout_{time}$ (min·day^{-1})	45 ± 55	45 ± 58	44 ± 53

Data are expressed as mean with standard deviation (mean±SD).
There are no significant difference between men and women.
$Bout_{step}$; The number of steps for the bout of physical activity,
$Bout_{time}$; The time for the bout of physical activity.

Table 3 Functional age in Yurin-study

	All	Women	Men
Muscular age (yr.)	55 ± 7	56 ± 7	56 ± 7
Bone age (yr.)	59 ± 14	64 ± 13	53 ± 13*
Hormone age (yr.)	70 ± 8	71 ± 8	68 ± 7
Neurological age (yr.)	63 ± 15	62 ± 15	65 ± 16
Vascular age (yr.)	65 ± 9	65 ± 8	65 ± 9

Data are expressed as mean with standard deviation (mean±SD).
Significant difference compared with that in women ($p<0.05$).

There were no significant relationship between the FA and the indexes of PA in men. In contrast, the HA significantly associated with the $STEP_{day}$ and the $bout_{step}$ in female subjects ($p<0.05$, ***Fig. 1***). Furthermore, the marginal significant relationships were found between $STEP_{day}$ versus the BA and the $bout_{step}$ versus the MA ($p = 0.06$ and $p = 0.09$).

Table 4 shows the results of the multiple stepwise regression analysis for the HA and PA in female subjects (***Table 4***). Because the significant relationship did not found in male subjects, the multiple stepwise regression analysis was limited to the female subjects. In addition to the several indexes of PA ($STEP_{day}$, $Bout_{step}$ $Bout_{time}$) and age were included to the independent variables, because age significantly associated with the HA ($p<0.05$). As the regard to the index of the PA, all indexes

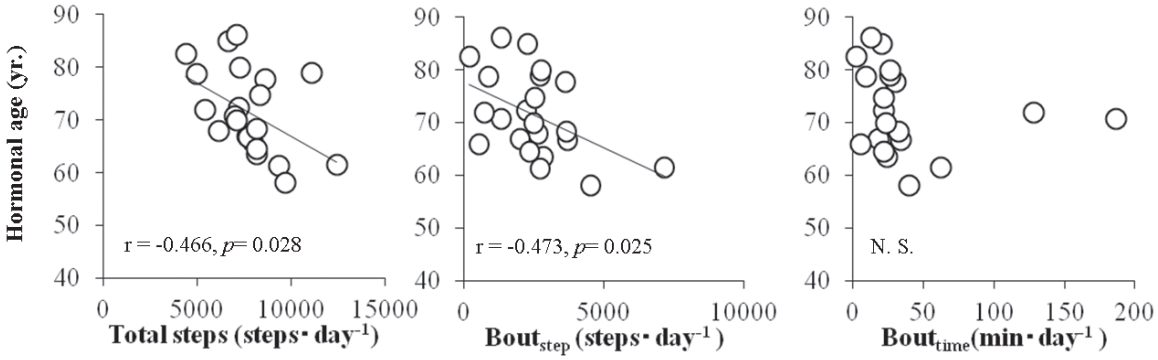

Fig. 1. Relationships between hormonal age and bout and non-bout of physical activity in Yurin-study.
Bout$_{step}$; The number of steps for the bout of physical activity, Bout$_{time}$; The time for the bout of physical activity.

(STEP$_{day}$, Bout$_{step}$ Bout$_{time}$) were included to the independent variable. The Bout$_{step}$ accounting for 22.4% of the total variance (*Table 4*). The total amount of age also account for 13% of the variance in the HA, respectively.

Table 4 ***Multiple stepwise regression analyses for hormone age and daily physical activity in female subjects in Yurin-study***

Dependent variable	Medaled variable [a]	SEE	R^2
Hormone age	Step 0. Bout$_{step}$	7.3	0.224*
	Step 1. Bout$_{step}$＋Age	6.5	0.354**

*p<0.05, **p<0.001
Bout$_{step}$; The number of steps for the bout of physical activity, SEE; standard error of mean.
[a] Calculated Variables: The analysis employed 4 variables: age, the daily number of steps, the number of steps for the bout of physical activity, the time for the bout of physical activity.

Discussion

The present investigation examined the relationships between the FA and the bout or nonbout of PA in middle-aged to older adults. As results, the HA significantly associated with STEP$_{day}$ and the Bout$_{step}$ in female subjects. Thereafter, the multiple regression analysis showed that the Bout$_{step}$, rather than STEP$_{day}$, was a significant contributor of the HA. These results indicate that the higher number of the Bout$_{step}$ associated with the younger HA independent from the STEP$_{day}$ in middle-aged to older female adults. However, the relationships between the indexes of PA and the FA except for the HA remains unclear in particular male adults. These finding suggested that the middle-aged to older women should be encouraged to participate in the PA lasting longer than 10 min at the stepping rate of >60 steps·min^{-1} in order to improve the hormonal distribution including the IGF-1. Although the significant relationship with Bout$_{step}$ was limited to the HA, the Bouts of PA may elicit several health benefits, because IGF-I is an important metabolic biomarker associated with a variety of health- and exercise-related outcomes [21].

The original aspects of the present investigation were to demonstrate the relationships between the FA with the bout and non-bout of PA. In particular, the bout of PA significantly associated with the HA independently from STEP$_{day}$ in female subjects. These results of the present investigation was supported by the previous findings [9,12]. As results of the pedometer-based walking program, the FA, including the HA, did not differ significantly by increasing STEP$_{day}$ in middle-aged to older adults [9,12]. In contrast, Mochizuki *et al.* [11] showed that the standardized exercise program (40 **min·time^{-1}**, 3 **times·wk^{-1}**) could successfully improved the components of the HA such as IGF-1 and DHEA-s. These findings apparently indicate that the accumulating the continuous bout of PA may be preferable strategy to obtain the younger HA rather than the increases in STEP$_{day}$ by taking the intermittent PA.

In regard to the relationship between the HA and the Bout$_{step}$, although the present investigation cannot explain the physiological mechanism, these results might depend on the IGF-1 responses to PA. Because, the HA was evaluated based on the IGF-1 and DHEA-s, and the additional analysis showed that the IGF-1 significantly associated with the Bout$_{step}$ (***Fig. 2***). Therefore, the relationships between the HA and the Bout$_{step}$ may depends on the IGF-1 rather than DHEA-s. Several experimental studies showed that the serum IGF-1 response to

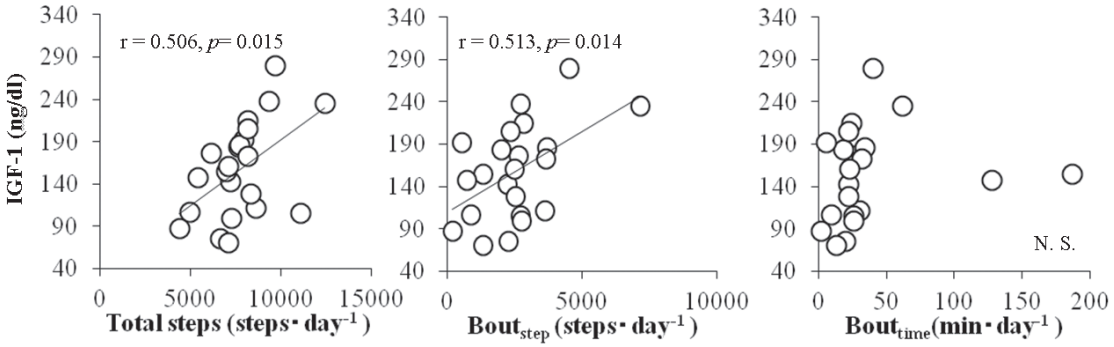

Fig. 2. Relationships between insulin-like growth factor 1 age and bout and non-bout of physical activity in Yurin-study. Bout^{step}; The number of steps for the bout of physical activity, Bout^{time}; The time for the bout of physical activity.

the aerobic exercise depended on the intensity and duration [22,23]. The brief exercise leads to small but significant increases in circulating IGF-I, and these responses may be influenced by exercise intensity [22]. Furthermore, the moderate intensity PA of long duration may modulate the bioavailability of IGF-1 [23]. In the present investigation, the bout was defined as the PA lasting longer than 10-min at 60 steps·min^{-1} of stepping rate. The stepping rate is a practical indicator of the exercise intensity [17], and the PA at 60 steps·min^{-1} or higher would be classified as the locomotive activity such as walking and running. In contrast, the PA at <60 steps·min^{-1} is corresponded to the lifestyle activity such as the housekeeping, dinning, gardening etc [24]. Furthermore, the duration of PA was mainly less than <30-sec, and the frequency of the PA lasting >10-min was very rare under the free-living condition [25]. Based on these findings, the $Bout_{step}$ is considered as "a spontaneous exercise" rather than "the usual activity of daily living". Therefore, it is reasonable to assume that the serum IGF-1 closely associate with the $Bout_{step}$ rather than $STEP_{day}$.

There are some limitations in regard to the present investigation. First, the number of participant used in the present investigation was relatively small, and were limited to mainly healthy subjects. Second, due to the potential limitation with this device, the $Bout_{step}$ (60 steps·min^{-1}, >10 min) did not completely reflect the intensity and the bouts duration of PA. Not only stepping rate but also stride length contributes to the exercise intensity, and the $Bout_{step}$ allows including the interruptions. Furthermore, the Omron pedometer could be a useful device for the continuous bouts of moderate-intensity walking, but it does not measure all steps taken throughout the day due to the underestimation for very light intensity PA[19]. Third, the $Bout_{step}$ and age are account for only 35% of the variations in the HA. The additional determinants of the HA, such as the nutritional and genetic factors, may be examined in the future studies. Finally, the type and position of the pedometer used in the present investigation does not allow for collection of upper body activity and thus may underestimate total PA.

In summary, the present investigation examined the relationships between the FA and the bout and non-bout of PA in middle-aged to older adults. As results, the higher number of the $Bout_{step}$ associated with the younger HA independent from $STEP_{day}$ in middle-aged to older female adults. These findings suggest that the middle-aged to older women should be encouraged to participate in the PA lasting longer than 10 min in order to improve the hormonal distribution including the IGF-1. The relationships between the indexes of PA and the FA except for the HA remains unclear in particular male adults. Future study should assess the effects of the bout of PA on the several health outcomes in a larger heterogeneous sample.

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