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Exercise for fitness does not decrease the muscular inactivity time during normal daily life

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The time spent in sedentary behaviors has been shown to be independent of exercise in epidemiological studies. We examined within an individual whether exercise alters the time of muscular inactivity within his/her normal daily life. Quadriceps and hamstring muscle electromyographic activities and heart rate were measured during 1 to 6 days of normal daily living of ordinary people. Of 84 volunteers measured, 27 (15 men, 12 women, 40.7 years ± 16.5 years) fulfilled the criteria of having at least 1 day with and 1 day without exercise for fitness (total of 87 days analyzed, 13.0 h ± 2.5 h/day). Reported exercises varied from Nordic walking to strength training and ball games lasting 30 min–150 min (mean 83 min ± 30 min). Exercise increased the time spent at moderate-to-vigorous muscle activity (6% ± 4% to 9% ± 6%, $P < 0.01$) and energy expenditure (13% ± 22%, $P < 0.05$). Muscular inactivity, defined individually below that measured during standing, comprised 72% ± 12% of day without and 68% ± 13% of day with exercise (not significant). Duration of exercise correlated positively to the increase in moderate-to-vigorous muscle activity time ($r = 0.312$, $P < 0.05$) but not with inactivity time. In conclusion, exercise for fitness, regardless of its duration, does not decrease the inactivity time during normal daily life. This is possible by slight modifications in daily non-exercise activities.

The continuum between total inactivity and being continuously physically active contains several health-related nuances that have been vividly discussed in the scientific community (e.g., Haskell et al., 2007; Katzmarzyk, 2010; Powell et al., 2011; Thyfault & Krogh-Madsen, 2011). The terms sedentary behavior, nonexercise activity, daily-life physical activity, leisure-time physical activity, physical exercise, exercise for fitness, and sports are all included in this continuum. While the most significant effects on health are achieved by doing physical activity with high enough intensity (Haskell et al., 2007), it is now recognized that any activity that decreases inactivity time may benefit health. Indeed, recent reports show compelling evidence that even nonexercise-type activities play an important role in maintaining metabolic health (Olsen et al., 2008; Krogh-Madsen et al., 2010; Stephens et al., 2011).

One reason why inactivity and nonexercise activity have gained growing attention is because the proportion of time spent doing purposeful exercises usually consists of only a fraction of day leaving much time for sedentary activities (Hamilton et al., 2007). Objectively measured physical activity data shows that people spend in USA and Australia, on average, 7.7 h/day and 8.1 h/day in sedentary behavior, respectively (Healy et al., 2008; Matthews et al., 2008).

Biological, psychological, social, and environmental factors that specify the physical activity behavior may affect sedentary time and exercise time independently, or dependently. Epidemiological studies based on questionnaires have (Salmon et al., 2000; Hu et al., 2003; Sugiyama et al., 2008; Dunstan et al., 2010) or have not found associations between sedentary behavior and physical activity (Clark et al., 2010; Burton et al., 2012). While these studies are based on large populations in a cross-sectional manner, it is not known how the sedentary behavior varies between days with and without physical exercise within an individual. The present study examined whether a purposeful physical activity i.e., exercise for fitness alters the time spent in sedentary behavior using objective measure of quadriceps and hamstring muscle electromyographic (EMG) activity. We used the intuitive hypothesis that exercise would increase the time spent in moderate-to-vigorous intensity and decrease the muscle inactivity time. Because the muscle activity provides an accurate but local measure of activity and inactivity, we also used heart rate (HR)-derived energy expenditure (EE) analysis to examine whether the systemic response to exercise yields a similar result.

Materials and methods

This study was part of a project '*Muscle loading during physical activity and normal daily life: correlates with health and well being (EMG 24)*' that uses novel textile EMG electrodes embedded into shorts (Finni et al., 2007) in assessing physical activity and detailed inactivity parameters in free living individuals. In the project, over 100 healthy volunteers with an age range from 20 to 76 years old have been measured both in controlled laboratory conditions and during 1–6 days of their normal daily life (Project web-site, 2011). The study was approved by the ethics committee of the University of Jyväskylä and the subjects signed an informed consent prior to any measurements.

Subjects

Subjects were recruited by advertisements distributed to public places and different workplaces. We received a total of 245 contacts from volunteers of which 122, meeting the inclusion criteria of being healthy with ability to independently perform daily tasks, were measured. Exclusion criteria were major illness such as cancer or other chronic condition such as diabetes or cardiovascular disease, or acute trauma and body mass index over 35. Sufficient data with good quality was obtained from 84 subjects of whom 27 (15 men, 12 women) fulfilled the criteria of having at least 1 day with and 1 day without exercise for fitness during the days of physical activity measurement. Characteristics of these subjects are shown in Table 1.

Study protocol

The protocol included assessments in the laboratory and physical activity measurements during normal daily life in the normal living environment of each individual. In the laboratory, anthropometrics, questionnaires of physical activity and medical history were collected and subjects over 40 years. were screened by a medical doctor. Further, the subjects performed the following tasks while HR and quadriceps and hamstring muscle EMG were measured: lying down quietly, sitting, standing, squatting, and stair negotiation. Maximal isometric voluntary contraction (MVC) of knee extensors and flexors with knee joint angle of 140° (David 200, David Health Solutions, Helsinki, Finland) were measured and the best trial of three attempts was further analyzed.

On another day, the subjects performed a special treadmill test with 3-min steps. All subjects started the test by walking at 4 km/h, 5 km/h, 6 km/h, and 7 km/h. The 5 km/h load was performed both at level and with 4° decline and incline. From this onward, subjects who were under the age of 29 years and also older subjects who were accustomed to run, performed one running load (10 km/h for female subjects and 12 km/h for male subjects). The next step for all participants was walking 5 km/h with an 8°-ascent. After walking for 3 min with this load, it was estimated how close the participants were to their maximal oxygen consumption (VO_{2peak}). If two out of three of the following criteria were fulfilled, participants continued with the same load until exhaustion: (a) VO_{2peak} over 85% of estimated maximum; (b) HR over 90% of estimated maximum; and (c) Borg rating of perceived excretion over 16. If two out of three of the criteria were not fulfilled, participants continued the test by walking 7 km/h with a 10°-ascent until exhaustion. This special protocol provided a possibility to measure HR and EMG in conditions that can occur during normal daily life (walking in different terrains) and was also used to validate the activity measures against EE (Tikkanen et al., 2010).

The physical activity measurements during normal daily life were performed either after the laboratory assessments or on a separate day but not after the treadmill test. On each measurement day, the subjects came in the morning to the laboratory where the HR and EMG recording devices were put on and set to record. Then they left for their normal living environments with instructions to live normal daily life as usual. To control the reliability of the EMG signal, the subjects were asked to perform reference tests containing lying down, standing, and squatting. The tasks were practiced in the laboratory and specific instructions were given for squatting to be repeatable. The subjects were told to remove the equipment when taking a shower or swimming, or before bedtime at the latest.

During the days of physical activity recordings, the subjects marked down in half-hour blocks the activities that they had performed, including sitting, standing, walking, bicycling, and exercise for fitness, if any.

From the 27 subjects, a total of 87 days were measured, of which 10 were weekend days. There were 43 days without and 44 days with exercise for fitness. When more than one sedentary day (range: 1–4 days) or day with exercise for fitness (range: 1–4 days) was recorded, the days were averaged, respectively (see Table 1 for the mean number of days analyzed). The mean recording time for day with (13.4 ± 2.8 h) and without exercise (12.5 ± 2.0) did not differ significantly.

Data assessment

In the laboratory, body weight and height were measured. Physical activity history was assessed using a 12-month questionnaire from where the activity levels as metabolic equivalent (MET)-h/week were calculated (Lakka & Salonen, 1997; Finni et al., 2009).

Table 1. Subject characteristics and number of days with and without exercise that were used in the analysis

Mean ± SD	All ($n = 27$)	Men ($n = 15$)	Women ($n = 12$)	Young (< 52 years. $n = 18$)	Older (>52 years. $n = 9$)
Age (years.)	40.7 ± 16.5	42.3 ± 16.9	38.8 ± 16.8	30.8 ± 8.3	60.7 ± 8.8
Height (cm)	174.0 ± 7.8	179.1 ± 5.8	167.4 ± 4.3#	173.2 ± 8.2	175.4 ± 7.1
Weight (kg)	71.4 ± 13.7	80.6 ± 11.1	60.0 ± 5.0#	67.2 ± 10.9	79.8 ± 15.4*
PA level (MET-h/wk)	6.8 ± 5.0	6.4 ± 5.5	7.3 ± 4.6	6.6 ± 3.8	7.0 ± 7.1
VO2 max (mL/min/kg)	45.4 ± 11.1	44.5 ± 13.1	46.2 ± 9.5	51.8 ± 6.6	33.4 ± 6.9*
Number of sedentary days	1.4 ± 0.8	1.7 ± 0.7	1.2 ± 0.8	1.5 ± 0.8	1.2 ± 0.6
Number of days with exercise	1.5 ± 0.8	1.4 ± 0.6	1.6 ± 0.9	1.5 ± 0.7	1.6 ± 1.0

Young and older groups contain two lower and the upper age tertile, respectively. PA level as MET-h/week was calculated from a 12-month leisure-time PA questionnaire. Number of days refers to the mean number of days measured from each individual. SD = standard deviation; PA = physical activity; MET = metabolic equivalent.

#Significantly different between genders ($P < 0.001$).

*Significantly different between young and older ($P < 0.001$).

Blue Sensor electrodes (size L, Ambu, Ballerup, Denmark) were placed over the right upper chest and left lower chest for recording of ECG signal (Alive Technologies, Gold Coast, Australia). The ECG signal was stored into secure digital card that was attached to the waist of the subjects. During the treadmill test, respiratory gases were analyzed using OxygonPro (VIASYS Healthcare Gmbh, Hoechberg, Germany).

Shorts measuring muscle activity from right and left quadriceps and hamstring muscle groups (Myontec Ltd, Kuopio and Suunto Ltd, Helsinki, Finland) were then put on. Size of the shorts (extra small to large) was chosen to be tightly fitted to the individual to ensure proper skin contact during the entire day. The detailed description of the shorts with textile electrodes used in the present study has been reported previously (Finni et al., 2007). Large textile electrodes, consisting of conductive yarns with silver fibers, located obliquely over the quadriceps (2.5×9.5–14 cm) and hamstrings muscles (1.5×7.5–8 cm) and ground electrodes (2×29–33 cm) located vertically on the lateral sides of the shorts over the iliotibial band. The large area of the electrodes provided a global measure of muscle activity from the four main locomotor muscle groups providing rectified averaged EMG comparable with typical bipolar electrodes as validated previously (Finni et al., 2007). The EMG signal from the electrodes was stored into a 52 g module located in waistline. Conductivity enhancing gel (Redux Electrolyte Crème, Parker Laboratories Inc, Fairfield, NJ, USA) was applied onto the electrode contact areas but the skin was not prepared in any other way. After every measurement day, the shorts were washed either by hand or in the washing machine.

Signal processing

EMG

The recording module included signal amplifier, microprocessor, memory and personal computer interface. Raw EMG signal was recorded with 1000 Hz sampling rate and band pass filtered with 50 Hz–200 Hz (−3 dB). After the raw data were rectified and averaged over 100 ms nonoverlapping periods, the data were stored into the module. This procedure allowed recording periods of over 12 h.

The entire EMG data were first visually assessed and corrected for artifacts. The activity diaries and aEMG values during MVC (EMG_{MVC}, see later) were compared with the signal and if nonphysiological signals ($>>100\%$ EMG_{MVC}) were observed the data were operated with four possible options: (a) brief artifacts that were most likely caused by electrical interference were replaced with interpolation technique from values prior to and after the artifact; (b) if artifact occurred during obvious bilateral movement (i.e., walking), the artifact was corrected by copying the data from bilateral channel; (c) in case the artifact was longer than 30 min, the signal was removed from that particular channel, thus the recording time can vary between the four channels; and (d) in case the signal was consistently abnormal or showed a systematic increase or decrease ($> 1\%$ EMG_{MVC}), the particular channel was removed from the analysis.

In addition to artifact removal, continuous baseline shifts were corrected for. The signal baseline was determined as the lowest value in a moving 5-min window, which was then subtracted from the data point preceding the 5-min window. The 5-min window was found to be the best to correct for minor baseline fluctuations without distorting the physiological signal.

Maximal EMG values (EMG_{MVC}) were taken as an average from a 1-s period from the middle of MVC where the signal was most consistent. The EMG signal from each four muscles (right quadriceps, right hamstring, left quadriceps, left hamstring) was normalized to the EMG_{MVC} values that are presented in the results as % EMG_{MVC}. From the tasks performed in the laboratory, the average EMG values during standing were analyzed from the 1-s period. The threshold for inactivity was set to be 90% of standing activity of each individual and each muscle group separately.

The EMG data were run through a custom made Matlab script (MatLab, MathWorks, Naticks, MA, USA) where the EMG data were first normalized to EMG_{MVC} channel by channel. Then, the time spent at different levels of EMG_{MVC} was calculated after which the values from four muscles were averaged. For this study, we chose three categories of activity based on the treadmill test and physical activity measurements: (a) inactivity corresponded to activity below standing as explained earlier; (b) activities below 10% EMG_{MVC} representing nonexercise activities such as normal walking; and (c) activities above 10% EMG_{MVC} representing moderate-to-vigorous activities such as fast walking and running. It should be noted that some daily activities typically categorized as nonexercise activity produced EMG activities greater than 10% EMG_{MVC}. Examples of such activities were squatting to pick something from the floor and stair negotiation.

Day-to-day repeatability of the EMG data were assessed using the reference tests from 20 subjects during 2 days. The reference test consisted of lying down quietly for 15 s, standing quietly for 15 s, and remaining in half-squat position for 15 s. From each task, average EMG values from 10 s period were analyzed. The mean intraclass correlation of all four channels was 0.80 ± 0.37 in lying down, 0.97 ± 0.03 during standing and 0.90 ± 0.07 during half-squat.

HR

The ECG HR signals were first converted to standard data format files containing the HR information as times between the consecutive R–R intervals and then imported into Hyvinvointianalyysi software (Firstbeat Technologies Ltd, Jyväskylä, Finland) for analysis. The measured individual VO_{2peak} and corresponding maximal HR values were fed into the software that has been validated to estimate VO_2 based on HR using neural network model that can also distinguish metabolic and nonmetabolic changes in HR (White paper, Firstbeat Technologies Ltd, 2007), but it should also be remembered that there are many other factors instead of energy demand-regulating HR at close to resting levels and at low nonexercise activity level.

After artifact removal, the mean recording time for HR signal was 11.3 h $\pm$ 1.9 h. The mean HR values and corresponding VO_2 values as $\%VO_{2peak}$ from different tasks were calculated.

The effect of exercise for fitness on daily EE was assessed by categorizing inactivity as EE less than 4 mL/min/kg and further separating the time spent at different levels of EE (expressed as $\%VO_{2peak}$). The levels higher than $50\%VO_{2peak}$ were pooled, because they comprise only a fraction of the day (see Fig. 2). In addition, data between inactivity and $40\%VO_{2peak}$ corresponding approximately to the category of nonexercise intensity (activities below walking at 7 km/h) (see Fig. 1) and data over $40\%VO_{2peak}$ corresponding to moderate-to-vigorous intensity were pooled for presentation in the table format. The total daily EE was calculated as a sum of the instantaneous values and the difference in EE was calculated for each individual as follows: (mean EE during days with exercise – mean EE during days without exercise)/mean EE during days without exercise.

Statistics

Normality of the data were tested with Saphiro–Wilk after which nonparametric tests were chosen. Variables are described as

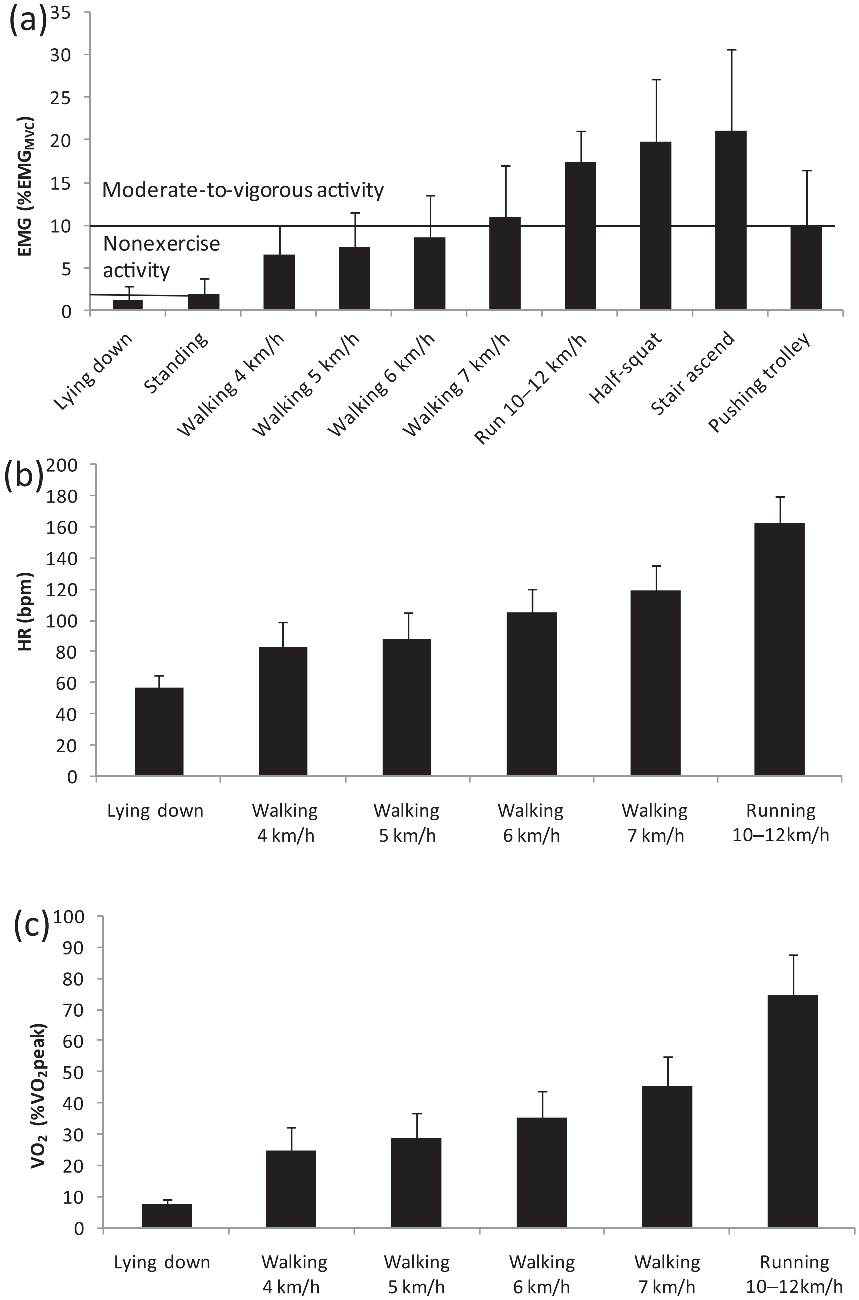

Fig. 1. Classification of different activity levels based on electromyographic (EMG) (a). The tests were performed in the laboratory and inactivity level was set as 90% of standing value of each individual. The level of moderate-to-vigorous activity was set to 10% aEMG values during maximal isometric voluntary contraction (EMG_{MVC}). Mean heart rate (HR) and maximal oxygen consumption (VO_2) values of selected tasks are shown in b and c, respectively.

mean ± standard deviation. Differences between active and passive days were compared with Wilcoxon signed rank test and differences between genders and age groups with Mann–Whitney *U*-test. The age groups were divided into young and older that contained two lower tertiles and the upper tertile based on the subjects' age, respectively. Spearman's rho was used to calculate correlation coefficient between the reported time of exercise for fitness and the difference in the time spent at a given category of muscle activity. This difference in the time spent at a given category of muscle activity was calculated by subtracting the mean of days without exercise from the day with exercise. Level of significance was set to $P < 0.05$.

Results

The exercises the subjects performed within their normal daily life contained strength training (12 times reported), ball games (6), dancing/aerobic (5), cycling (5), cross-country skiing (4), and others such as Nordic walking, running, kayaking, and skating (14). Of these, the older group reported strength training (4), cycling (3), Nordic walking (2), ball games (2), and other exercises (6). Some subjects reported

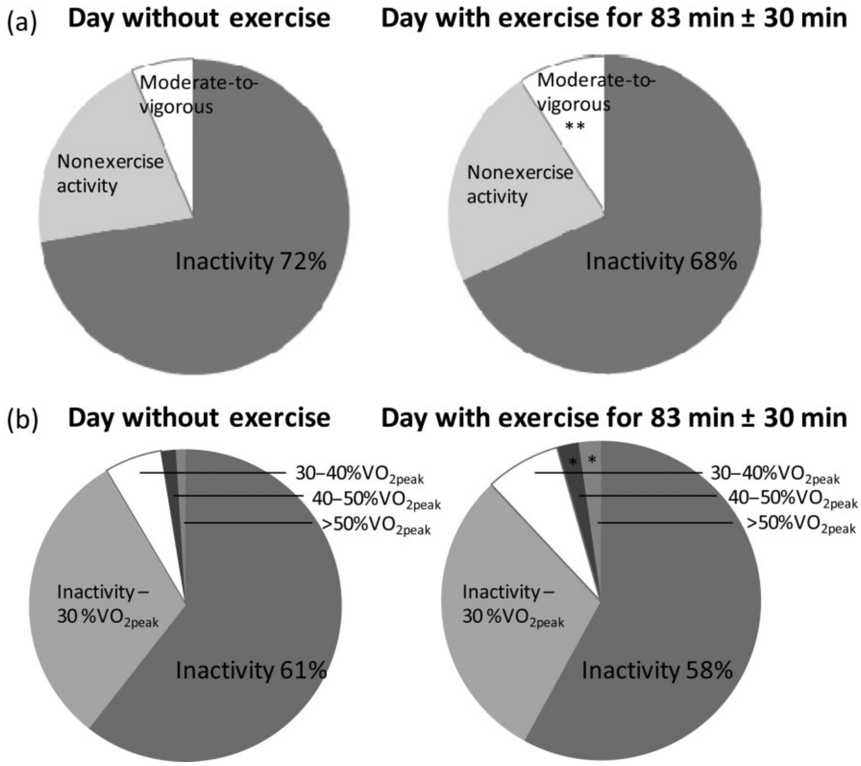

Fig. 2. Distribution of day into different activity levels according to quadriceps and hamstring muscle electromyographic (EMG) activity (a) and energy consumption (b). (a) The time spent at intensity over 10% of maximal EMG (intense) was significantly greater during the day with exercise for fitness ($P < 0.01$) but the inactivity time or time of nonexercise activity did not differ between the days. (b) The heart rate-based energy consumption analysis showed that the time spent at intensities of 40%–50% maximal oxygen consumption (VO_2) and over 50%VO_{2peak} were greater during a day with exercise for fitness ($P < 0.05$) but the lower intensity categories were not affected.

more than one type of exercise for fitness in a day. The duration of the exercises varied from 30 min to 150 min.

Muscle activity and inactivity times

For the entire group, muscle inactivity time or time for nonexercise activity did not differ between the days with and without exercise for fitness but the time spent at moderate-to-vigorous intensity increased slightly on a day with exercise ($P < 0.01$) (Fig. 2). Both young and older had significantly more moderate-to-vigorous muscle activity on the day with than without exercise for fitness (Table 2). In terms of muscle activity, moderate-to-vigorous activity included activities such as fast walking, running, and stair ascend (Fig. 1). The only difference between the age groups was found on a day without exercise where the younger spent more time ($P < 0.05$) at nonexercise intensity than the older.

Men and women did not differ in times spent in any activity category. However, muscle activity measures showed that the time of moderate-to-vigorous activity was increased by exercise in women while in men the increase did not reach statistical significance (Table 2).

The duration of exercise did not have significant association with the difference in inactivity time between the day with and without exercise ($r = -0.15$, $P = 0.32$). The difference in the time spent at moderate-to-vigorous activities between the days with and without exercise had a weak correlation to the time of exercise ($r = 0.312$, $P < 0.05$) and the correlation increased when the type of exercise (endurance, strength or other type) was controlled for ($r = 0.430$, $P < 0.01$).

HR-derived EE

Fig. 1 shows that the muscle inactivity threshold as expressed in HR and relative oxygen consumption was between 60–80 bpm and approximately 10%VO_{2peak}, respectively. The threshold selected for moderate-to-vigorous activity corresponded to 111 ± 11 bpm and 40%VO_{2peak} (Fig. 1).

In terms of EE, the inactivity time was unchanged because of exercise, but a small increase ($P < 0.05$) was observed at levels higher than 40%VO_{2peak} (Fig. 2). This increase was significant only for the entire group and for men (Table 3). Table 3 also shows that the older subjects spent less time ($P < 0.001$) below inactivity threshold and more time ($P < 0.001$) at nonexercise intensity than the younger.

Table 2. The amount of time spent at different EMG levels during a day without (Sedentary) and with exercise for fitness (Exercise)

Time (% of day)	All ($n = 27$)	Men ($n = 15$)	Women ($n = 12$)	Young (<52 years. $n = 18$)	Older (>52 years. $n = 9$)
Inactivity (standing activity*0.9)					
Sedentary	72 ± 12	74 ± 10	70 ± 14	70 ± 12	77 ± 9
Exercise	68 ± 13	68 ± 12	68 ± 14	68 ± 13	68 ± 14
Nonexercise activity (<10% MVC)					
Sedentary	21 ± 11	20 ± 10	23 ± 13	24 ± 11	15 ± 9#
Exercise	23 ± 11	23 ± 11	22 ± 10	23 ± 11	22 ± 11
>Moderate activity (>10% MVC)					
Sedentary	6 ± 4	6 ± 5	7 ± 4	6 ± 3	8 ± 6
Exercise	9 ± 6**	9 ± 6	9 ± 5*	8 ± 5*	11 ± 7*

The EMG represents mean values measured from right and left quadriceps and hamstring muscles. 100% of the day corresponds to 13.4 ± 2.8 h for day with exercise and 12.5 ± 2.0 without exercise.
EMG = electromyographic; MVC = maximal isometric voluntary contraction.
*Significantly different between days with and without exercise for fitness ($P < 0.05$).
**Significantly different between days with and without exercise for fitness ($P < 0.01$).
#Significantly different between young and older ($P < 0.05$).

Table 3. The amount of time spent at different VO_2 levels during a day without (Sedentary) and with exercise for fitness (Exercise)

Time (% of day)	All ($n = 27$)	Men ($n = 15$)	Women ($n = 12$)	Young (<52 years. $n = 18$)	Older (>52 years. $n = 9$)
Inactivity (4 mL/kg/min)					
Sedentary	61 ± 24	60 ± 28	61 ± 20	73 ± 13	35 ± 22#
Exercise	58 ± 28	59 ± 31	57 ± 26	73 ± 16	28 ± 23#
Nonexercise activity (<40% VO_{2peak})					
Sedentary	67 ± 24	38 ± 27	35 ± 21	24 ± 13	63 ± 22#
Exercise	38 ± 28	38 ± 31	37 ± 24	23 ± 14	68 ± 22#
>Moderate activity (>40% VO_{2peak})					
Sedentary	3 ± 2	2 ± 1	4 ± 2	3 ± 2	2 ± 2
Exercise	4 ± 4*	3 ± 2*	6 ± 4	4 ± 5	5 ± 4

VO_2 was estimated based on measured heart rate. 100% of the day corresponds to 11.5 ± 1.8 h for day with exercise and 11.0 ± 2.0 h without exercise.
VO_{2peak} = maximal oxygen consumption.
*Significantly different between days with and without exercise for fitness ($P < 0.05$).
#Significantly different between young and older ($P < 0.001$).

The mean recording time for HR signal was 11.5 ± 1.8 h during the day with and 11.0 h ± 2.0 h without exercise without difference between the days. The total daily EE was 13% ± 22% (range: –27% to 58%) greater on a day with than in a day without exercise ($P < 0.05$). This difference in EE between the days correlated with the duration of the exercise ($r = 0.609$, $P < 0.001$).

Discussion

In normal daily life, each individual has his/her own physical activity continuum, with days containing more sedentary activities and days with more physically demanding activities including purposeful physical activity. The present study compared the activity levels within individuals between days with and without exercise for fitness during normal daily life. Contrary to the hypothesis, we found that exercise for fitness did not decrease the time of muscular inactivity and increased only 3% the time spent at moderate-to-vigorous intensity. Further, we found no association between the length of the exercise and difference in inactivity time between the days with and without exercise suggesting independency between muscle inactivity time and exercise duration.

In addition to the local measure of muscle activity, we estimated the daily EE based on HR in order to get an insight on the systemic effect of exercise. In general, the result was similar to the muscle activity measurements confirming that exercise for fitness increases slightly the time spent at moderate-to-vigorous intensity but does not alter the inactivity time.

Similar finding has been very recently reported using questionnaires to 11 000 Australians (Burton et al., 2012). Burton et al. (2012) showed that sedentary time is independent of almost any level of physical activity. Our objectively measured data from a small sample supports their view that the amount of sedentary behavior may not tell anything about more intense activities that the people may do. In comparison with the epidemiological studies the strength of the present study lies in the within-individual setting where, e.g., the genetic trends may not affect the outcome.

The independency of inactivity time on the time of exercise may be explained so that after moderate or vigorous exercises people need time to recover, which may be done in sitting or lying down (Westerterp, 2001). Furthermore, Hamilton et al. (2007) illustrated in their perspectives that the proportion of time spent in purposeful exercises usually consists of only a fraction of day – 30 min to 150 min in the present study – and thus leaves much time for sedentary activities. Therefore, small increases in the amount of vigorous exercise are not reflected as systematic but random decreases in lighter or sedentary activities. In other words, people behave differently and substitute either lighter and/or sedentary activities when they exercise.

We found no differences in muscle inactivity time between men and women, although women have been reported to take more steps during the day than men in Finland (Hirvensalo et al., 2010). In accordance to the present findings, another 24-h EMG study did not find differences between men and women (Klein et al., 2010). In general, there are reports showing gender differences in daily steps (McCormack et al., 2006), but the evidence is not systematic and may be affected with differences in work and leisure-time behaviors (see Burton et al., 2012). It should be noted that in the present study inactivity time accumulated during both work and leisure times.

Previous studies show that elderly perform daily activities such as stair negotiation closer to their maximal joint torque than young (Hortobagyi et al., 2003). In the present study, there were no major differences between the young and older in the times spent at any particular muscle activity level during normal daily life. In this context, it is important to note that the normalization of EMG in the present study was done not only to the individual isometric maximum but also to the individual standing EMG activity. This was needed to achieve an accurate and functional representation of the inactivity time which would have been much affected if we had selected an absolute or relative threshold (Klein et al., 2010).

On the other hand, daily EE shows significant differences between the age groups in the inactivity and non-exercise activity categories (Table 3). Because of the lower VO_{2peak}, these results underline the fact that elderly need to use a higher % VO_{2peak} to achieve the same MET level as the younger individuals.

Previously, it has been shown that the total daily EE increases because of training. This increase can be twofold when taking into account the increased energy cost both during and after training (Van Etten et al., 1997; Westerterp, 1998). In the present study, the increase in EE due to exercise for fitness was 13% when compared with a day without exercise. Thus, although the inactivity time was unaltered, the slight increase in moderate-to-vigorous activity caused 13% increase in EE, which is an important message of this study. The result that the duration of exercise is positively associated with the difference in EE between the 2 days is very logical and was considered to validate the subjective reporting of the exercise durations.

The health effects of moderate-to-vigorous activity are well established (e.g., Haskell et al., 2009) while the inactivity physiology hypothesis still requires further research on the mechanisms and effects of inactivity on health (Hamilton et al., 2004). In the light of both bed-rest studies (Bergouignan et al., 2011) and emerging evidence showing that even short period of inactivity has adverse effects on metabolism (Stephens et al., 2011), the promotion of physical activity – regardless of the intensity level – is important. More evidence with precise tools such as presently used can provide (either positive or negative) evidence on inactivity- and health-related outcomes in the future.

Methodological considerations

It is important to note that we did not instruct the subjects in any way to perform physical exercises or to spent sedentary days, but to live their normal daily life. Thus, the analysis was performed post hoc from a sample of 84 subjects of which the 27 had both sedentary days and days with exercise for fitness resulting in wide range of activities and duration of exercise. The large range of activities also reflects the fact that the subjects were measured during different seasons.

In this study, the measurements were done mainly on weekdays and, because of the small sample size, it was not feasible to account for differences between week and weekend days or work and leisure. Although the present study involved both young and old subjects, the generalizability of the results remains limited because of the small and selected sample.

The muscle activity measurements present a novel avenue in physical activity measurements and few reports of daily EMG recordings have been reported in humans (Edgerton et al., 2001; Kern et al., 2001; Ochia & Cavanagh, 2007; Klein et al., 2010). EMG in normal laboratory conditions is often recorded using bipolar electrodes having relatively small detection area and interelectrode distance. These signals are typically used both for amplitude and frequency analysis while the present electrodes of very large size are not suitable for frequency analysis. However, because of their large area, the electrodes provide a global measure of muscle activity and are not sensitive to individual fiber recruitment/de-recruitment. In studying physical activity behavior, the main interest is the amplitude of the signal (reflecting intensity of activity) and on the other hand, the silence of the signal (reflecting inactivity). Previously, we showed that the amplitude of these electrodes provide is comparable with the typical bipolar electrodes with similar or even better reproducibility (Finni et al., 2007).

Determination of the silence of the signal – the inactivity – is very important in the present research. Besides signal processing, selection of threshold for inactivity is a crucial decision. In their EMG study with 10 individuals Klein et al. (2010) tested the effect of different thresholds (1%–4% EMG_{MVC}) on the total duration of the EMG. They found a curvilinear decrease in the daily duration of muscle activity when increasing the threshold. In the present study, after testing several different thresholds, we chose to use the individually determined threshold (0.9*EMG during quiet standing) for more accurate and functional representation of inactivity time.

Perspectives

While moderate-to-vigorous exercise has important health benefits (Haskell et al., 2009), the independent nature of inactivity time, as evidenced both in the epidemiological studies (Burton et al., 2012) and in the current within-individual study design, underlines the need for changes in our society's strive to motorize every action to minimize muscular work. While automatic doors and elevators are useful for disabled persons and the elderly, they are a health hazard for majority of the population. In the light of growing evidence, both purposeful exercises with high enough intensity and means to decrease inactivity time should be influenced by health promotion in parallel. Promoting light and socially engaging physical activities may attract also the "exercise-dislikers" to be more physically active.

Key words: sedentary, physical activity, muscle activity, energy expenditure, young, old.

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