METHODS

# Measures of physical activity and their correlates: The Swedish National March Cohort

**Ylva Trolle Lagerros · Rino Bellocco ·
Hans-Olov Adami · Olof Nyrén**

**Abstract** We compared the results of self-estimates of physical activity obtained with a novel instrument (the Energy Expenditure Questionnaire, EEQ) to those obtained from questions typically asked in epidemiological investigations (reference method) in a cohort of 42,150 Swedish men and women, aged 18–94. In the EEQ, participants were asked to report total physical activity by estimating the total time during a typical day and night spent on different physical activity intensity levels from the lowest (corresponding to lying in bed, 0.9 Metabolic Energy Turnover; MET) to the highest, (exceeding the intensity of to shovelling snow by hand, i.e., >6 MET). As a comparison, they also estimated hours per week devoted to household chores, commuting and leisure time physical activities classified as; light, moderate and heavy. The average physical activity estimated with the EEQ was 1.36 MET or 32.6 METh/day or 2,341 kcal/day. In comparison, physical activity estimated with the reference method represented no more than 17% of this amount. The Spearman's correlation coefficient between the two measures was 0.26. Using EEQ, men reported significantly more physical activity than women (mean = 36.3 vs. 30.6 METh/day). Body mass index (BMI) $\geq 25$, education $\geq 12$ years, and age $\geq 60$ years were significantly associated with lower physical activity. Questions focusing on leisure time exercise and a few other selected activities provide estimates of activity that correlate poorly with self-reported total energy output from all physical activity and inactivity. Investigators need to be more explicit about which component of activity they investigate.

## Introduction

Besides smoking, physical activity may be the most important modifiable determinant of chronic morbidity and total mortality [1, 2]. The literature on the positive health effects of physical activity is reasonably consistent only for a few outcomes, such as coronary heart disease [3], colon- and breast cancer [4, 5] and diabetes [6]. Regarding many other diseases, for example cancer of other sites [7] and upper respiratory tract infection [8], findings appear to support causality. Other causal associations may have been underestimated—or overlooked altogether—because physical activity has been misclassified.

There is considerable variation in physical activity, for instance type of activity (muscles deployed, static vs. dynamic exertion), intensity, frequency of strenuous activity, duration, and age at exposure [9]. As opposed to most other exposures, physical activity is difficult to clearly isolate in time; all individuals are constantly engaged in

Y. T. Lagerros (✉)
Unit of Clinical Epidemiology, Karolinska Institutet, T2,
171 76 Stockholm, Sweden
e-mail: ylva.trolle@ki.se

R. Bellocco · H.-O. Adami · O. Nyrén
Department of Medical Epidemiology and Biostatistics,
Karolinska Institutet, Stockholm, Sweden

R. Bellocco
Department of Statistics, University of Milano-Bicocca, Milan,
Italy

H.-O. Adami
Department of Epidemiology, Harvard School of Public Health,
Boston, MA, USA

physical activity when they are awake, albeit sometimes on a very low level. The importance of energy expenditure through changes in posture and small movements associated with daily life has recently been emphasized [10]. Nevertheless, most epidemiological evaluations of physical activity concentrate on some selected activities, for instance sports or organized training [11, 12], or strenuous daily activities [13]. Such activities, however, typically contribute to no more than a small part of total energy expenditure [14]. This may lead to substantial misclassification of total physical activity and hence inconsistent results between studies. In addition, many of these activities are closely linked to other health-related behaviours that may be even more difficult to measure, making removal of confounding a formidable task.

In this study we aimed to compare the physical activity pattern estimated by questions commonly used in epidemiological studies (reference method) to that estimated by a new and validated instrument, the energy expenditure questionnaire (EEQ) [15]. This instrument aims to take all physical activity and inactivity during a typical day into account, regardless of whether the activity is undertaken during leisure time, at work, or as part of every-day household chores.

## Materials and methods

### Study cohort

In September 1997, we assembled a general population cohort of people who took part in Riksmarschen "The National March", a physical activity-oriented promotional and fund-raising event for the Swedish Cancer Society taking place in almost 3,600 Swedish cities and villages. All participants were invited to fill out a 32-page questionnaire, in which they gave background data and physical activity exposure information. The underlying assumption was that the participants would be particularly motivated to provide valid exposure data. Due to the character of this event, the total number of individuals who, in reality were given a questionnaire could not be assessed.

Completed questionnaires were delivered to "Statistics Sweden" for electronic scanning. All participants provided their national registration numbers (NRNs), unique personal identifiers assigned to all Swedish residents. This enables us to follow the cohort through multiple record linkages with existing nation-wide, continuously updated and essentially complete databases.

In total 43,880 participants completed the questionnaire. We excluded 1,706 (3.9%) participants under the age of 18, another 20 participants with invalid NRNs and another four due to clearly inconsistent answers. The research ethics committee at Karolinska Institutet approved the study.

### Assessment of physical activity

In the 32-page, 13-item questionnaire, participants were asked a number of questions about their physical activity. First the participants were asked to indicate the average number of hours per week spent on leisure time physical activities such as sports and exercise or outdoor activities, which were divided into three levels: light (e.g., casual walking), moderate (e.g., walking at a brisk speed, jogging or swimming) and heavy (e.g., vigorous training or competitive sport). The questions first addressed summer activities and were then repeated for the winter. We also inquired about the average number of hours per week devoted to household activities such as cleaning the house or working in the garden, as well as time spent on walking and/or biking to work. These questions were used as reference in our study.

Additionally, as an indirect indicator of physical activity, participants were asked to rank their own relative fitness and relative total physical activity in comparison with the perceived average among their peers of the same age and gender (much worse/less, worse/less, approximately the same, better/more, much better/more).

These questions are commonly used in epidemiologic research, e.g., the question about leisure time activity is similar to the question of leisure time activity used in a study by McTiernan et al. [16] as well as in the Godin Leisure time exercise questionnaire. The latter has been extensively validated against other measures reflecting leisure time physical activity or fitness, such as body composition, maximal oxygen uptake [17, 18], electronic motion sensors [18, 19], workload, four-week leisure time physical activity history (based on the Minnesota Leisure Time Physical Activity Questionnaire) and forced expiratory volume [18]. Self-ratings of the relative level of physical activity, compared to the activity of others of the same age and sex, have been used in several studies [20–23]. The question used as reference in our study is a part of the validated Baecke questionnaire of habitual physical activity [24], the National Health and Nutrition Examination Survey III [25] and the Lipids Research Clinics Physical Activity Questionnaire [26]—in the latter in combination with one or two yes/no questions about regular strenuous activity. Validity was assessed against body composition, maximal oxygen uptake, 4 week leisure time physical activity history [18, 27], accelerometer [18, 23, 27], workload, forced expiratory volume [18], caloric intake and resting energy expenditure [28].

Participants also completed our newly developed EEQ for quantification of total energy output associated with *all* physical activity during a typical 24 h day and night (Fig. 1). This new instrument has nine fixed steps representing 0.9, 1, 1.5, 2, 3, 4, 5, 6, and 8 metabolic energy turnover (MET). One MET corresponds to an energy

**Fig. 1** The energy expenditure questionnaire for self-reports of total energy expenditure



expenditure of 3.5 ml $O_2 \times kg^{-1} \times min^{-1}$ or 1 kcal/kg body weight per hour [29].

The scale steps are based on commonly understood examples of physical activity, which have been previously defined by asking 94 adult volunteers to indicate on visual analogue scales the perception of the intensity of common every-day chores, job-related activities and sport activities. We then ranked the activities according to the average ratings and for each scale step we selected the activities that showed the smallest variation and best corresponded to the absolute level of intensity in MET according to Ainsworth et al's [29] "Compendium of physical activities".

In the final version we selected 2–4 examples of activities for each scale step. The first laboratory-based validation study, using objectively measured work on an ergometer bicycle as gold standard, showed substantial agreement between self-rated and measured MET values (unpublished). In a second validation study [15] a population-based sample of 418 men and women completed the EEQ. Three 24 h recalls by phone served as gold standard. Reproducibility of the EEQ was then assessed via administration of the instrument another three times. Pearson correlation between usual daily energy expenditure as measured by the EEQ and the mean of the three 24 h

recalls was 0.73. Reproducibility showed an intraclass correlation of 0.55.

In order to compare the physical activity exposure patterns emerging with the different methods of inquiry in the present study, we converted answers of leisure time exercise, household and commuting activity questions to METs, based on the estimated oxygen consumption needed for the different levels of activity. Three, 6.0 and 10.0 METs were assigned to the light, moderate and heavy levels, respectively, and 4.0 MET to household and transport-related activity. MET values were multiplied by the number of hours engaged in the particular activity level, to obtain an index of activity. We report activity as the mean intensity, METh/day calculated as MET level times duration (in hours) of the activity divided by 1 day, thus 24 METh/day equals one MET.

## Statistical methods

Because the questionnaire was designed for optical scanning, the participants answered the questions by checking boxes corresponding to fixed response categories. In the case of total physical activity, leisure time, household and commuting activity, the categories represented time spent on different levels/activities. In our calculations, we used the midpoint of each category.

We used the Spearman's correlation coefficient to study correlation between physical activity values obtained with the EEQ compared to the reference questions as well as the correlation between summer and winter leisure time activity. Linear regression models were fitted to study the independent effects of gender, age (categorized into 5-year intervals), BMI (body mass index, weight in kg divided by height in $m^2$, categorized as:<20, 20–22.4, 22.5–24.9, 25–29.9, $\geq$30 kg/$m^2$) and education (divided into 7–9, 11, 12 and >12 years of schooling), on both measures of METh/day (calculated from the EEQ and the reference method).

## Results

Selected characteristics of the participants in the cohort are presented in Table 1. The average age was 51.7 years, with the oldest being 94.5. More women (64.3%) than men participated. Compared to the general Swedish population in 1997, fewer cohort members were smokers (9.4% compared to 19.2% of Swedes aged 16–84) and they were less educated (38.9% had no more than compulsory schooling, compared to 22.2% in Sweden as a whole, according to Statistics Sweden). Table 2 shows response rates for the different ways to assess physical activity. Most missing answers were found for the question about vigorous leisure time activity. The most conceivable explanation

**Table 1** Characteristics of the 42,150 participants in the Swedish National March Cohort

| | |
|---|---|
| Mean age (years) | 51.7 |
| Men | 53.6 |
| Women | 50.6 |
| Women (%) | 64.3% |
| Mean body mass index (kg/m²) | 24.6 |
| Men | 25.1 |
| Women | 24.4 |
| Current smokers (%) | 9.4% |
| Consume 1 alcoholic drink (%) | |
| Never | 11.7% |
| 0–3 times a month | 45.8% |
| ≥ once a week | 41.9% |
| Missing | 0.6% |
| Education (%) | |
| 7–9 years | 38.9% |
| >9–12 years | 32.3% |
| >12 years | 28.1% |
| Missing | 0.7% |

is that those who were never engaged in vigorous activity left the response field blank instead of choosing 0 h.

Household activities, commuting and leisure time physical activity from exercise, sports and outdoor life summed up to on average 0.23 MET or 5.5 METh/day, (0.22 MET or 5.4 METh/day for women and 0.24 MET or 5.7 METh/day for men). This was 17% of the METs estimated by EEQ (Fig. 2). When leisure time physical activity, according to the reference method, was divided into summer and winter, the activity patterns did not differ substantially. During summer, the participants exercised on average 0.01 MET or 0.24 METh/day more, which corresponds to an extra 4 min of casual walking per day (Fig. 3). The Spearman's correlation coefficient between summer and winter leisure time physical activity was 0.69. About 30% of the participants believed that their total activity was comparable to others of the same age and gender, while 57% indicated that they were more or much more physically active. About 40% thought they were as fit as others of the same age and gender, while 47% estimated that their fitness was better or much better.

On average, there was a clear tendency to underestimate number of hours in a day using EEQ; although asked to report physical activity and inactivity during 24 h the participants reported a mean of 18.6 h. About 14% (5,877 participants) estimated a physical activity of less than 12 h. Those who reported more than 12 h of total physical activity had a mean energy expenditure of 2,341 kcal/day. This corresponded to on average 1.36 MET or 32.6 METh/day. When normalizing the reported data to 24 h by multiplying each level-specific value by 24 divided by the

**Table 2** The number and percentage of unanswered physical activity sections among 27,088 women and 15,062 men participating in the Swedish National March Cohort

| Physical activity questions | Left unanswered | | | |
|---|---|---|---|---|
| | Women | | Men | |
| | Number | Percent | Number | Percent |
| Leisure time physical activity | | | | |
|   Summer | | | | |
|     Light | 2,644 | 9.8 | 2,146 | 14.2 |
|     Moderate | 4,292 | 15.8 | 2,789 | 18.5 |
|     Heavy | 6,285 | 23.2 | 3,868 | 25.7 |
|   Winter | | | | |
|     Light | 2,866 | 10.6 | 2,245 | 14.9 |
|     Moderate | 3,994 | 14.7 | 2,770 | 18.4 |
|     Heavy | 7,396 | 27.3 | 4,510 | 29.9 |
| Household and commuting activity | 130 | 0.5 | 88 | 0.6 |
| Total physical activity estimated with the EEQ instrument | 803 | 3 | 300 | 2 |
| Self-rated fitness | 235 | 0.9 | 110 | 0.7 |
| Self-rated total activity | 242 | 0.9 | 122 | 0.8 |
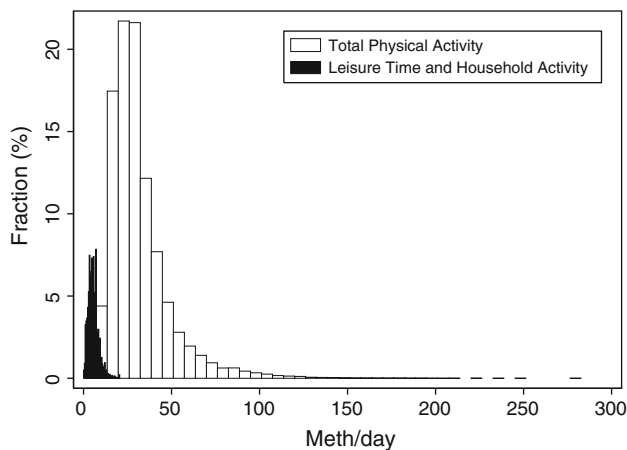


**Fig. 2** The distribution of MET-hours per day from total physical activity measured with the new instrument, compared with the corresponding distribution based on questions about household, commuting and leisure time physical activity. The Swedish National March Cohort

reported total number of hours, and thus assuming that the misrepresentation of time was constant per time unit and independent of the physical intensity level, the mean MET level increased to 1.7, the mean METh/day increased to 40.8 and the mean energy expenditure was 2,923 kcal/day. As a sensitivity analysis, we normalized the data to 24 h by multiplying missing hours with the basal metabolic rate, assuming that the missing time had been sleeping or resting, and found the mean MET to be 1.5, the mean METh/day was 36.0 and the mean energy expenditure was 2,588 kcal/day.

The correlation between total physical activity obtained with the EEQ and the sum of household, commuting and
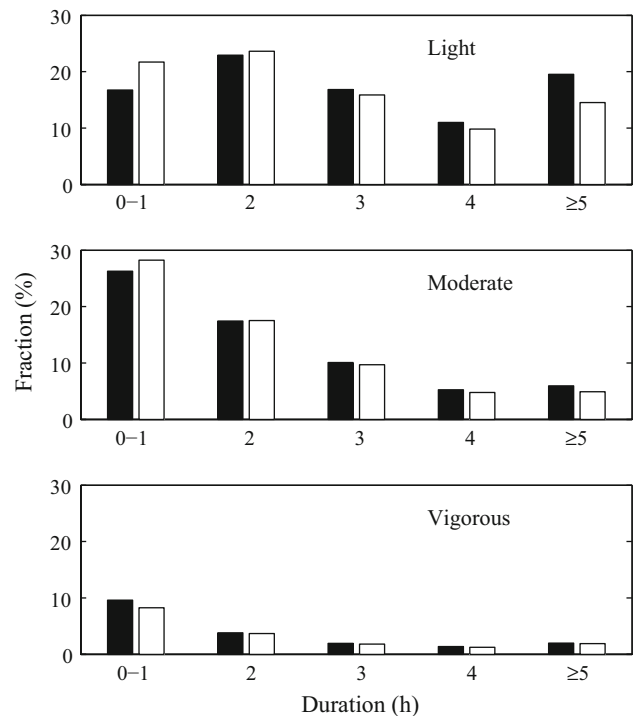


**Fig. 3** Hours of light, moderate and heavy leisure time physical activity during summer (*black*) and winter (*white*). The Swedish National March Cohort

leisure time physical activity from the reference method was poor, Spearman's rank correlation coefficient 0.26. Since EEQ measures both activity and inactivity and the reference method only measures activity, we excluded inactivity (sleeping and sitting) from the EEQ. The Spearman's rank correlation coefficient then became 0.27.

Likewise, Spearman's correlation between self-ranked relative total physical activity in comparison with peers of the same age and gender, in quintiles of METh/day generated by the EEQ was 0.19. The Spearman's correlation between self-ranked relative fitness and quintiles of METh/day was 0.20.

There was a systematic tendency among our participants to rank themselves as more physically active than average in the population; regardless of quintile of METh/day reported via the EEQ, 49–69% indicated that they engaged in more, or much more, physical activity compared to others of the same age and gender. Even among the most sedentary (with the lowest number of METh/day reported via EEQ) 37% self-ranked their fitness to be better or much better than average among their peers.

Multiple linear regression analysis revealed that BMI, education and age were inversely associated with the physical activity level reported using the EEQ. BMI $\geq 25$ ($P = 0.001$), education $\geq 12$ years ($P = 0.000$) and age $\geq 60$ ($P = 0.000$) were significantly linked to lower activity. For the sum of household, commuting and leisure time physical activity, the patterns were similar, but here reported physical activity increased at age 60 ($P = 0.002$) and did not decrease until after the age of 80 ($P = 0.003$).

Using the EEQ, men reported significantly more physical activity than women ($P = 0.000$); on average 1.5 MET or 36.3 METh/day (mean SD $\pm 20.7$) compared to on average 1.3 MET or 30.6 METh/day (mean SD $\pm 15.4$). This gender difference disappeared after adjustment for BMI, education and age, but remained statistically significant in the regression model with total physical activity as the dependent variable.

## Discussion

This cross-sectional analysis in a large Swedish cohort consisting of presumably well motivated volunteers demonstrates that the estimated physical activity level in an epidemiological study is dependent on the mode of inquiry. Not only do questions about hours per week spent on leisure time physical activities (such as sports, exercise or outdoor activities), hours per week spent on household activities and time spent on walking and/or biking to work lead to obvious underestimations of the total number of METh/day; energy output data obtained in this way correlates only weakly with data obtained with by the EEQ instrument that tries to capture all, or most of the energy output, during a typical day.

The reference questions about leisure time, household and commuting activity are all commonly used in epidemiological studies—although they have not to our knowledge been validated together. Therefore, the combined set of reference questions used in our study should not be seen as a complete questionnaire or a gold standard for measuring physical activity, and our study is not a validation study. The purpose was rather to shed light on the fact that different methods of inquiry measure different aspects of physical activity. The results yielded with the different methods correlate only to a moderate extent.

The response rate to the reference questions about leisure time activity was poor and decreased with increased intensity level. This could be due to how these questions were displayed in the questionnaire; because the respondents were required to distinguish between summertime and wintertime, the responses were to be given in a matrix that may have been too complex. Most conceivably, though, respondents not engaged in any leisure time exercise may have skipped the question instead of filling in 0 h. Intriguingly, males were more likely than women to be non-responders, despite the fact that they are more physically active. Earlier studies have shown that women are more willing to respond to questionnaires overall [30–32], and this might also pertain to response pattern of individual questions.

Few studies have investigated the percent of total activity accounted for by leisure time, household- and commuting activity. Our finding that the sum of this activity only represented, on average, 17% of total activity is in close agreement with the results of Orsini et al. [33] who recently showed that inactive leisure time, walking and exercise accounted for 18% of total physical activity and Weller et al. [14], who estimated this figure to 18% as well. The latter study further documented the importance of including non-leisure physical activities in questionnaires. When they analyzed leisure time physical activity results only, the association between physical activity and mortality in women was attenuated.

In a study by Klesges et al. [34], activity recalls were systematically biased because subjects overestimated aerobic activities by over 300% and underestimated sedentary activities when asked to recall activity of the past hour. The tendency to forget sedentary activities was also seen in our study; 4.5% of all participants forgot to report sleep when filling out activity and inactivity during 24 h.

Many participants failed to provide duration of activity estimates that added up to 24 h in the EEQ. Interestingly, a Dutch study validating an instrument in which participants were asked to estimate the time spent on defined activities during 24 h found underreporting of time of a similar magnitude as we did [35]. In another study, face-to-face interviews were used, but here too the average number of hours per day were similarly underreported, with a mean of 19 h/day [36].

The structure of our EEQ, with boxes to check for predefined time intervals on each intensity level dictated by the expected large number of participants and the need for

automated optical scanning of the completed questionnaires, may have been suboptimal. The duration estimates for each activity level were difficult to sum up by the participants at a glance. Furthermore, we used the midpoint of the pre-set categories for calculations—which could be one of the reasons for underestimating duration. In our second validation study [15], duration was not fixed but open–ended and the participants summed up the time spent in different work intensities themselves. In a computerized web version, the time was summed up automatically and the subjects could immediately see if the total time equalled 24 h.

Age 60 and older, grade 1 overweight (BMI $\geq$ 25 kg/ m$^2$) [1] and higher education were linked to lower total physical activity, as measured by our EEQ. It is reasonable to assume that older age leads to less every-day activity. Somewhat unexpectedly, the reference questions about leisure time, commuting and household physical activity indicated that this type of activity increased after the age of 60 and did not decrease until age 80. Although our cohort may be composed of atypically active people, including the pensioners, the most likely explanation is that work-related physical activity was replaced by leisure time and household activity after retirement.

The lower estimate of total physical activity among our overweight participants is consistent with validity of our data, because it appears quite reasonable that obesity hinders physical activity. The finding that participants with higher education undertake less physical activity may, however, seem counterintuitive, but has been reported before [36, 37]. While people with higher education are more likely to engage in leisure time sport activities than low- or uneducated [1, 38, 39], such activities only account for a minor proportion of total activity. Highly educated cannot compensate for the lower physical activity that is linked to sedentary occupations, less time for household activities and a generally more effortless lifestyle. However, we cannot rule out misclassification. In our second validation study, we found that participants with lower levels of education had a tendency to overestimate their total physical activity [15].

Although never used in a large-scale epidemiological study, our EEQ has also been shown to be both valid and reliable [15]. Misclassification by this instrument and/or the reference questions, could explain some of the discrepancies between the MET values obtained with the EEQ and those obtained with the reference questions about leisure time, commuting and household physical activities, but is unlikely to explain why the correlation coefficient was no more than 0.26, particularly since the errors in the respective instruments are probably correlated. The poor correlation between the two measures, therefore, suggests that leisure time, commuting and household physical activities, no matter how well measured, typically constitute a non-representative segment of the total physical activity. Hence, leisure, commuting and household activity is likely to be an imperfect marker of total physical activity. If the latter is the most important determinant of any particular health outcome, then the EEQ would be an accurate method of verifying this association. On the other hand, it is conceivable that more intense activities might account for most of the association between physical activity and health, either directly or through confounding factors due to a healthier lifestyle. In this case, the leisure time questions may result in stronger associations than those obtained with the EEQ. While this new instrument is probably more suited to pick up low intensity daily life activities, it is not designed to capture inter-individual variation such as gesticulation and change in posture. Such physical activity, included in the concept of non-exercise activity thermogenesis (NEAT), has been shown to be an important determinant for the risk of obesity [10].

In conclusion, the evaluation of physical activity as a protective factor against a range of adverse health outcomes in epidemiological studies may be sensitive to how the information about activity was collected. It appears that conventional questions, common to questionnaires in epidemiological studies, which typically emphasize leisure time exercise and a few other selected activities such as commuting and household activity, provide biased estimates of the total energy output from all physical activity and inactivity. To the extent that total energy output is perceived a more important determinant for disease risks than are bouts of physical activity undertaken as leisure time exercise, in the household or walking/biking to work, epidemiological investigators should attempt to collect information about the former. Misclassification of the relevant exposure will otherwise tend to attenuate—or at worst totally cancel—potentially important associations. The use of the EEQ seems to be one practical way of accomplishing this data collection, although further methodological refinements are necessary. Currently available and validated questionnaires about habitual physical activity seem to measure no more than components of physical activity, and investigators need to be more explicit about which component of activity they investigate.

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