Data-based Approach for Developing a Physical Activity Frequency Questionnaire

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Measurement of total energy expenditure may be crucial to an understanding of the relation between physical activity and disease and in order to frame public health intervention. To devise a self-administered physical activity frequency questionnaire (PAFQ), the following data-based approach was used. A 24-hour recall was administered to a random sample of 919 adult residents of Geneva, Switzerland. The data obtained were used to establish the list of activities (and their median duration) that contributed to 95% of the energy expended, separately for men and women. Activities that were trivial for the whole sample but that contributed to ≥10% of an individual's energy expenditure were also selected. The final PAFQ lists 70 activities or group of activities with their typical duration. About 20 minutes are required for respondents to indicate the number of days and the number of hours per day that they performed each activity. The PAFQ method was validated against a heart rate monitor, a more objective method. The total energy estimated by the PAFQ in 41 volunteers correlated well ($r = 0.76$) with estimates using a heart rate monitor. The authors conclude that the design of their self-administered physical activity frequency questionnaire based on data from 24-hour recall appeared to accurately estimate energy expenditure. *Am J Epidemiol* 1998;147:147–54.

data collection; energy metabolism; physical fitness; questionnaires

Studies have shown that physical activity protects against coronary heart disease (1, 2). The greatest benefits seem to occur among moderately active subjects compared with sedentary subjects (3, 4). This is probably because in modern, westernized populations most of the energy is spent in activities of light to moderate intensity, such as office work, watching television, or driving (1, 5, 6). Thus, measurement of total energy expenditure may be crucial to enable us to understand the relation between physical activity and diseases and to frame public health intervention.

Assessment of physical activity is possible through a variety of methods, including motion monitors and ex-

cretion of doubly labeled water (7–9). Questionnaires are more suitable for epidemiologic studies. They require no technical equipment, are less expensive, and do not interfere with subjects' usual activity.

Several questionnaires have been proposed to quantify physical activity since the pioneering work of Paffenbarger et al. (3) (see the commentary on Paffenbarger et al. in reference 10). The advantages and problems of these different questionnaires have been extensively reviewed (5, 6, 11, 12). The most common approach is to rank study subjects in broad categories from sedentary to very active. The focus is on typical activities that differentiate subgroups rather than those that reflect total energy expenditure (3, 13, 14). As a result, the questionnaires correlate well with heavy intensity activities and treadmill performance (5, 12, 15–18) but not with low and moderate intensity activities nor with total energy expenditure.

Measurement of total energy expenditure with the use of a questionnaire raises important methodological problems. While heavy intensity leisure activities, such as soccer, aerobics, or running, are usually performed on a regular basis and are associated with a well-known nomenclature, light and moderate activities tend to vary more and their nomenclature is less standard (e.g., domestic activities, handiwork, or office work). Because these activities are of a routine nature, they may not be well recalled if they have not

been performed during a recent period. The 7-day physical activity recall used in the Five-City Project (19, 20) elegantly addressed these difficulties. It had the strongest relation to the Caltrac monitor (Muscle Dynamics, Torrance, California) ($r = 0.33$) of all of the questionnaires examined in the review by Jacobs et al. (5). However, it was not designed to be self-administered and the estimates of total energy expenditure may still be improved.

The aim of the present work was to develop a self-administered physical activity frequency questionnaire (PAFQ), to measure total and activity-specific energy expenditure in subgroups of the population, with special attention to light and moderate intensity activities (1, 5, 6). The methodology was inspired by the similarity between physical activity and diet from the perspective of behavioral assessment. Quantification of energy intake or expenditure from questionnaires requires the transformation of numerous items (food or activities) into energy equivalents. A food frequency questionnaire was previously developed for the Geneva population (21–23) using the approach proposed by Block et al. (24) to identify food items which are major sources of energy, and their typical serving sizes, from population-based 24-hour recall. Similarly, to create the present PAFQ, the major sources of energy expenditure and their typical duration were identified using 24-hour recall of physical activity.

We describe here, step by step, the development of the instrument and its validation relative to a more objective measure of energy expenditure, a heart rate monitor method.

MATERIALS AND METHODS

Population recruitment for the 24-hour recall

Geneva (city and county) has a population of 395,609 distributed over 242 km^2 of land. Data reported here comprise subjects randomly selected throughout 1994 to represent the 89,000 male and 98,000 female non-institutionalized residents aged 35–74 years.

Subjects were identified from the list of all residents published each year using a standardized procedure. This list includes the first and last name, sex, age, nationality, and address of each resident of Geneva. Random sampling in age-sex-specific strata was proportional to the corresponding frequencies in the population. In the case of nonresponse to a first letter mailed to a potential subject, up to seven phone attempts were made to reach the person at different times of the day and on various days of the week, including Saturday and Sunday. Three more mailings

were sent when a selected individual could not be reached by phone. A person who had not been reached after four mailings and seven phone calls was replaced using the same selection protocol. A systematic check in the following year edition of the population list showed that over 90 percent of "unreachable" subjects did not reside in Geneva any more. On the other hand, subjects who were reached but refused to participate were not replaced. The recruitment of a potential subject lasted from 2 weeks to 2 months.

Data collection

Overall, 897 men and 892 women were selected; 128 men and 113 women were no longer residents of Geneva and an additional 13 men and 3 women had died. Of the 756 men and 776 women eligible, 197 men and 159 women could not be reached. The average percent participation rates for the 24-hour recall among age groups 35–44, 45–54, 55–64, 65–74 years were: women, 85, 75, 75, and 65 percent; and men, 88, 86, 73, and 66 percent. The sample distribution was almost identical to the general population according to age, sex, and nationality (not shown).

All subjects were interviewed by telephone by two public health technicians, a man and a woman, both of whom practiced several sports as nonprofessionals. The interviewers were trained on a full-time basis over a month to use a standardized approach to help participants report activities of the previous day, from the time they awoke until the next day at the same time. All activities and their durations were recorded in detail using a standardized form. Participants were finally asked if it was a usual day and their occupational status, age, weight, and height. Overall, the interview lasted 20 minutes.

Table of energy requirement for physical activity

The energy requirement for any activity was calculated by rating the activity using basal metabolism rate (BMR) multiples. For instance, an activity rating three BMR expends three times the energy required by a fasting individual, sleeping. The BMR is a function of sex, age, weight, and height. The World Health Organization 1986 consensus report (25) provides a detailed list of BMR multiples for activities. These multiples take into account the rest period which is imbedded in the time during which the activity is being performed, e.g., for chopping wood, the intensity is averaged over the time actually chopping, including positioning, windup, blow, and catching breath. Our energy table was based on this report except for 12 activities based on lists of metabolic equivalent (MET) multiples (11, 26), where 1 MET =

energy expended per minute while sitting quietly, equivalent to 3.5 ml of oxygen uptake per kg of body weight/minute for an adult who weighs 70 kg. MET multiples are therefore close to BMR multiples, even though they do not take into account participant sex or height.

Coding and data entry

All physical activities were coded by the interviewers using the table of energy expenditure described above. Coded questionnaires were cross-checked by the interviewers. A private specialized company performed data entry using a double entry system to minimize errors.

Variable definition

Age was categorized in the following age groups: 35–44, 45–54, 55–64, and 65–74 years. Body mass index was computed as reported weight (kg)/height $(m)^2$. Participants were categorized as employed or unemployed (including those retired).

For all participants, the BMR was computed as a function of sex, age, weight (kg), and height (cm) (24). The energy expenditure (EE) for a given activity by one individual was obtained by:

$$EE = \text{duration per day} \times \text{BMR multiple} \times \text{BMR.}$$

For each individual, daily expenditure was the sum of all energy expenditures over the 24-hour period, and the energy expenditure for the total sample was the sum of all individuals' energy expenditure.

Development of the physical activity frequency questionnaire

The relative contribution of each activity to the daily energy expenditure was computed for the total sample and, separately, for males and females. The activity-specific energy expenditure was also determined as a proportion of the individuals' daily energy expenditure. The principal activities required to account for 95 percent of the energy expenditure for the total sample, and separately for 95 percent of men and women's energy expenditure, were selected for inclusion in the questionnaire. Individuals' activities which accounted for ≥10 percent of individuals' energy expenditure were also chosen.

For each activity, durations were summed over the 24-hour period if it had been performed several times by the same individual. For example, the duration spent in eating included all meals and snacks during the 24 hours.

Validation of the PAFQ

To validate the newly developed questionnaire, the energy expenditure assessed by PAFQ in 41 volunteers was compared with that measured using a modified, minute-by-minute heart rate method (27). Volunteers were recruited by advertisements placed in newspapers. Calibration between energy expenditure and heart rate was performed using linear regression. An electrode-belt worn around the chest included a microprocessor and memory to store 36 hours of data (BHL-6000, Baumann and Haldi, Switzerland). Heart rate was measured for six increasing levels of physical activity: resting (supine), slow walk on a treadmill, slow walk with 10 percent grade, fast walk with 0 percent grade, fast walk with 10 percent grade, and fast walk with 15 percent grade. Energy expenditure during the calibration procedure was measured by indirect calorimetry, with expired air being collected with a mouthpiece (28). At each level, the subject exercised for 7 minutes to reach a steady state; average energy expenditure and heart rate were estimated during the following 3 minutes.

After calibration, minute-by-minute heart rate was measured in free-living conditions during 3 days, including 2 weekdays and a weekend day. Energy expenditure during sleep was assumed to be equivalent to the BMR (25). During the subject's waking hours, energy expenditure was derived from heart rate using the relation established during the calibration procedure (28). When the recorded heart rate fell below the resting rate, energy expenditure was estimated to be at the resting level. The different values were summed over the 24 hours to obtain the daily energy expenditure. Subjects answered the PAFQ the day following the end of the heart rate monitoring. In addition, their activity was assessed by a telephone 24-hour recall during one of the monitored 3 days.

For each volunteer, the energy assessed by 24-hour recall was compared with the energy measured over the same day by heart rate monitor and with the daily energy measured by PAFQ. The heart rate monitor was used 2 days out of the 5 days of the week and one out of the weekend days; weighted daily energy expenditure over the 3 days was calculated by

$$[2.5 \times (\text{EE of weekday 1} + \text{EE of weekday 2})$$
$$+ 2 \times (\text{EE of weekend day})]/7,$$

and compared with the energy expenditure measured by PAFQ divided by 7.

Data were analyzed using SAS 6.07 (Statistical Analysis System, Inc., Cary, North Carolina). A log transformation was performed to achieve normality of the individuals' daily energy expenditure distribution.

Geometric means with their 95 percent confidence intervals are presented in tables 1–3. The SAS procedure for analysis of variance (general linear model (29)) was used to compare energy expenditures between groups.

The Wilcoxon rank-sum test (29) was used to compare men and women's median durations for each of the 70 activities or groups of activities listed in the PAFQ.

The t test for paired values was used on log-transformed data to test the hypothesis of no difference between individuals' energy expenditure obtained by heart rate monitor and by PAFQ, and between the heart rate monitor and the 24-hour recall. Pearson correlation coefficients (r) were used to compare the log-transformed values obtained with the different methods of measurement (29).

RESULTS

The 24-hour recalls' sample characteristics

Trained interviewers required, on average, 20 minutes to perform the 24-hour recall. Response rate was 76 percent. The 425 men and the 494 women who answered the 24-hour recall had the same age distribution as the general population. The geometric means of individuals' energy expenditure decreased when age increased (table 1). The youngest men and women expended, respectively, 600 kcal and 150 kcal more per day than the oldest groups. Differences between employed and unemployed persons were not statistically significant.

The 24-hour recalls were uniformly distributed over the week, and there was no statistically significant difference in individuals' energy expenditure according-

ing to the day of the week nor according to the interviewer (data not shown).

Activities selected from the 24-hour recalls

Of the 189 activities described in the 24-hour recalls, 73 were necessary to account for 95 percent of the energy expenditure of the total sample. "Sleeping," which rated only 1 BMR but lasted approximately 8 hours, was the major contributor, accounting for approximately 21.8 percent of the energy expenditure. Sleeping duration needs to be recorded in the PAFQ. The second major contributor (12.5 percent) was "sitting quietly" at home or during leisure time, performed by 963 per 1,000 subjects for a median duration of 3 hours and 45 minutes. The next most important contributors to the energy expenditure were nonoccupational light intensity activities of long duration, such as eating (5.6 percent), walking slowly (5.6 percent) or normally (5.1 percent), and light housekeeping (5.0 percent). Office work was the most important work-related activity, explaining almost 8 percent of the energy expenditure (4.8 percent office work seating and 3.0 percent for office work standing). The most important blue collar occupations accounted for less than 1 percent of the total sample energy expenditure: light cleaning (0.6 percent), sweeping floors (0.5 percent), storekeeping (0.6 percent), handiwork (0.5 percent), and walking carrying a weight (0.4 percent). The contribution of sports was small: soccer, tennis singles, gymnastics without weights, and skiing downhill or water skiing ranked, respectively, in 37th, 40th, 41st, and 48th position, and each explained only 0.3 percent of the total sample energy expenditure.

TABLE 1. Individual daily energy expenditure assessed by 24-hour recall, by sample characteristics, Geneva, Switzerland, 1994

Characteristic	Individual daily energy expenditure in men (n = 425)			Individual daily energy expenditure in women (n = 494)		
	No.	Mean* (kcal/day)	95% CI†	No.	Mean* (kcal/day)	95% CI
Age (years)						
35–44	135	2,922	2,815–3,032	153	2,144	2,090–2,200
45–54	131	2,817	2,714–2,925	157	2,165	2,110–2,220
55–64	93	2,595	2,487–2,706	115	2,125	2,063–2,188
65–74	66	2,325	2,171–2,491	69	1,990	1,910–2,073
p value‡		0.0001			0.0001	
Work						
Employed	342	2,734	2,676–2,793	307	2,143	2,107–2,180
Unemployed	83	2,650	2,522–2,785	187	2,092	2,046–2,139
p value‡		0.3			0.1	

* Geometric mean, adjusted for work when given by age strata and adjusted for age and body mass index when given by work strata.
† CI, confidence interval.
‡ For analysis of variance on log-transformed values.

A total of 12 activities, including occupations (auto mechanic, loading sacks in a truck, pulling a loaded wagon) and sports (soccer and squash) were not part of the 95 percent of the whole sample's energy expenditure but were selected to obtain the 95 percent of the men's energy expenditure. Three others were needed, including "dancing, aerobics, or ballet," to obtain 95 percent of the women's energy expenditure.

All activities that contributed to ≥10 percent of the individuals' energy expenditure were identified. While most of them had already been selected by the first methods, 46 other activities were added to the list. That was true for several sports, e.g., golf, which represented less than 0.1 percent of the total sample's energy expenditure but 15 percent of the individuals' energy expenditure for eight subjects.

Overall, 134 (73 + 12 + 3 + 46) activities were selected for the PAFQ. Because the specific list of activities and their median duration will vary from population to population, they are not displayed here but may be obtained on request from the first author.

Typical durations

The median duration per day for people performing the given activity was considered as a typical duration. It was statistically different by sex for only eight activities (driving a car or a truck at work, personal grooming, eating, cooking, and washing dishes, house-keeping and cleaning, walking normally, driving a car or a motorcycle, and gymnastics). Therefore, for simplicity, the median duration calculated for men and women together was displayed in the PAFQ.

Grouping activities

Activities identified with the 24-hour recall were grouped if they were conceptually similar and had the same energy requirement within a range of 1 BMR. For instance, the category "walking quickly or uphill" in the PAFQ groups "walking fast" (4.5 BMR), "walking very fast" (4.7 BMR), and "walking uphill" (5.2 BMR). A weighted duration and a weighted intensity were computed for each group of activities; weights were the frequency of performance of each activity in the 24-hour recalls.

Administering the physical activity frequency questionnaire

The PAFQ lists 70 activities or grouped activities. Participants are requested to indicate how many days of the past 7 days they performed each of the listed activities. Possible frequencies range from 0 (never) to 7 (every day). For each activity performed, respondents mark an average duration on a corresponding time-scale where the typical duration is displayed. Possible durations range from 0 to 10 hours per day with a precision of 15-minute intervals. For stair climbing, they indicate the number of floors. (An English version of the PAFQ may be requested by writing to the first author.)

At the end of the questionnaire, an open-ended section allows the respondent to add activities not already listed or activities performed with very different durations during the week. This possibility is illustrated by an example on the first page of the questionnaire. Sleeping is not listed but participants are asked at what time they usually awoke in the morning and went to sleep at night during the previous week. Self-administration of the questionnaire takes approximately 20 minutes. Coding frequencies, number of hours (0 to 10 hours), and number of minutes (15 or 30 minutes) takes less than 5 minutes and requires no specific expertise.

Computing individuals' energy expenditures using the PAFQ

Once the PAFQ is completed, if the total amount of hours declared is different from 168 hours (7 × 24 hours), a two-step correction is made. First, if the total sleep time is less than 45:30 hours (average 6:30 hours per night), it is set to 45:30 hours; or if it is more than 70 hours (average 10 hours per night), it is set to 70 hours. Second, the total duration for non-sleep activity is computed and the duration for each non-sleep activity is proportionately adjusted so that the corrected sleep time plus non-sleep time sums to 168 hours (7 × 24 hours). The energy expended over the last 7 days by the person is then obtained by summing the energy expended by all performed activities.

Validation

Results were available for 41 volunteers, 18 men and 23 women, aged 35–69 years. The energy expenditures measured by heart rate monitor over one of 3 days were compared with those measured by the 24-hour recall for the same day (table 2). The energy expenditure calculated by 24-hour recall tended to be lower (2,392 kcal) than by heart rate monitor (2,535 kcal), but the difference was not statistically significant. The Pearson coefficients of correlation between the individuals' energy expenditure measured by heart rate monitor and the individuals' energy expenditure measured by 24-hour recall were higher in men (r = 0.71) than in women (r = 0.55). The energy expenditure measured by PAFQ was not statistically different compared with the weighted energy expenditure estimated by heart rate monitor (table 3). The Pearson

TABLE 2. Comparisons of individual daily energy expenditure measured by heart rate monitor and by 24-hour recall, Geneva, Switzerland, 1994

| | | Individual daily energy expenditure | | | | | | |
	No.	Heart monitor geometric mean	95% CI*	24-hour recall geometric mean	95% CI	*p* value†	*r*‡	*p* value§
Men	18	3,064	2,756–3,406	2,867	2,579–3,187	0.12	0.71	0.000
Women	23	2,185	1,977–2,415	2,075	1,949–2,210	0.24	0.55	0.006
All	41	2,535	2,321–2,769	2,392	2,216–2,582	0.06	0.76	0.000

* CI, confidence interval.
† For paired *t* test.
‡ *r*, Pearson correlation coefficient.
§ *p* value for Pearson correlation coefficient.

coefficients of correlation between the individuals' energy expenditure measured by heart rate monitor and the individuals' energy expenditure measured by PAFQ were 0.59 in men and 0.65 in women. Daily energy expenditures measured by 24-hour recall and by PAFQ were highly correlated ($r = 0.80$, $p = 0.001$).

DISCUSSION

The PAFQ lists 70 physical activities or groups of activities. It was developed on the basis of a population survey using an approach similar to that proposed by Block et al. (24) for food frequency questionnaires. The data obtained from 24-hour recalls in the target population were used to establish a list of the major contributors in order to explain 95 percent of the energy expended by the total sample and by the male and female subsamples.

The relative contribution of each activity to the energy expenditure for the total sample took into account the intensity, the frequency of performance, and the median duration of this activity in the population. This approach identified low intensity activities which otherwise may have been overlooked as important

contributors to energy output. Light and moderate intensity activities were selected when performed by many subjects and for a long duration, e.g., being seated quietly (performed by 963 per 1,000 subjects with a median duration of 3 hours and 45 minutes a day) or driving a car (performed by 542 out of 1,000 subjects for 45–50 minutes). The relative contribution of each activity to the men's energy expenditure and the women's energy expenditure permitted identification of important energy consumers for these subgroups. Some activities contribute to ≥ 10 percent of the energy expenditure for few individuals but not for the community. They were also incorporated in the PAFQ. Most activities were performed by both sexes and had similar median duration. The few differences seemed compatible with the development of a single questionnaire.

Recommendations previously made to improve the validity of physical activity questionnaires advised a better assessment of light and moderate intensity activities such as household chores and occupational activities (5, 30). Of particular interest here was the identification of very common, low-intensity activities to be included in the questionnaire. About 50 percent

TABLE 3. Comparisons of individual daily energy expenditure measured by heart rate monitor and by physical activity frequency questionnaire (PAFQ), Geneva, Switzerland, 1994

| | | Individual daily energy expenditure | | | | | | |
	No.	Heart monitor geometric mean	95% CI*	PAFQ geometric mean	95% CI	*p* value†	*r*‡	*p* value§
Men	18	3,001	2,780–3,239	2,887	2,685–3,105	0.28	0.59	0.01
Women	23	2,261	2,070–2,469	2,265	2,119–2,421	0.96	0.65	0.000
All	41	2,560	2,381–2,753	2,520	2,371–2,678	0.52	0.76	0.000

* CI, confidence interval.
† For paired *t* test.
‡ *r*, Pearson correlation coefficient.
§ *p* value for Pearson correlation coefficient.

of the total energy expenditure was spent sleeping, sitting quietly, eating, walking slowly, or walking normally, and office work was the most important work-related activity. High-intensity activities such as sports (soccer, skiing, bicycling) ranked beyond the 37th position. The present results confirm the great importance of light and moderate activities in the energy expenditure of urban sedentary adults.

Validity

Distributions of the individuals' energy expenditure by sex and age obtained in the referent 24-hour recall data followed the expected decrease in older groups. The energy expenditures were consistent with energy intakes measured in the same general population, performed using 24-hour recall interviews (21).

Correlation coefficients between the heart rate monitor and the 24-hour recall ($r = 0.76$) and between the heart rate monitor and the PAFQ ($r = 0.76$), and between the 24-hour recall and the PAFQ ($r = 0.80$) were quite satisfactory.

Limitations

In men only, the energy expenditure estimated by 24-hour recalls and by PAFQ tended to be lower than the energy expenditure estimated by heart rate monitor method. Some activities may be underestimated by the PAFQ but the number of volunteers was insufficient to compare each of the 70 activities with the corresponding ones reported by 24-hour recall.

Although the heart rate monitor values are an acceptable method of questionnaire validation, they are not perfect either. Individuals may not use the electrode-belt during all waking hours, emotions can artificially increase heart rate, and the 3 days of measurement may not be representative of the whole week. Using heart rate monitors also prohibits absolute comparisons with previous questionnaires validated by means of the Caltrac monitor (5).

A single questionnaire may blur differences across subgroups of the target population (e.g., sex, age, occupation), and seasonal variations or week/weekend differences. These limitations were taken into account by allowing for large choice of possible frequencies and durations (reflecting the fact that the 24-hour recall data had been collected over a full year) and by the open-ended section, where participants can report atypical practices.

The activity collected by the PAFQ may not reflect a typical week for the person who completes the questionnaire. This may become a concern if we are interested in individual assessment. We therefore

added a question on whether the week described was typical in the final version of the PAFQ.

Because initial 24-hour recalls were conducted over the whole year, the questionnaire could be converted for assessment of activity over a longer period (a month, a year). Specific studies are, however, warranted to assess the validity of the PAFQ for recall periods longer than 7 days.

Conclusion

The PAFQ is a simple, self-administered physical activity questionnaire that is designed to assess energy expenditure and its major contributors in an urban, adult, general population. The data-based approach applied for its development was a crucial step to select an exhaustive list of physical activities and their typical duration. The same methodology, based on representative population surveys, may be used in other countries to design improved physical activity questionnaires. This frequency questionnaire permits the evaluation of total energy expenditure and of the energy expended by performing specific, including low and moderate intensity, activities. It may be used to evaluate future public campaigns aimed at shifting the population distribution of energy expenditure towards higher values.

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