INVITED COMMENTARY

Heart-rate monitoring: the answer for assessing energy expenditure and physical activity in population studies?

The benefits of physical activity are well-documented and exercise is now included in most health promotion recommendations. However, before adopting a population strategy it is important to establish baseline patterns of physical activity on which properly informed recommendations can be made and behaviour change measured. At present few would argue that it is difficult to draw meaningful conclusions and detect trends from studies that measure physical activity using different measurement instruments.

As pointed out by Wareham *et al.* (1997) in this issue, physical activity is a highly complex and variable behaviour and it is naive to assume that 'a single instrument could adequately assess the various dimensions of activity, which include total energy expenditure, frequency and aerobic intensity, weight-bearing, flexibility and muscular strength'.

However, while the optimum epidemiological tool for assessing both total energy expenditure (TEE) and associated patterns of physical activity does not exist, those who work in the area have drawn up an ambitiously long 'wish' list of criteria for the 'ideal' method. Thus it should be accurate, precise, objective, simple to use, robust, cause minimal intrusion into habitual activity patterns, socially acceptable, time-efficient and, finally, it should allow continuous and detailed recording of usual activity patterns.

The physical activity questionnaire remains the most practical and widely-used instrument in population studies. However, questionnaires and the other available alternatives such as activity diaries, observation, electronic motion sensors, indirect calorimetry, heart-rate (HR) recording and the doubly-labelled water (DLW) method can fulfil one or more, but rarely all, of the needs for epidemiological studies of physical activity. Not surprisingly, the need for improvements in methodology for assessing TEE and/or physical activity patterns is a recurring theme in the numerous literature reviews of the subject area.

Of all the techniques currently in use perhaps the most promising developments have been in the area of HR methodology. The use of HR monitoring as a proxy measure for TEE is not new and stems from the work of Berggren & Christensen (1950). It is based on the principle that for each person, HR and oxygen consumption (VO_2) tend to be linearly related throughout a large portion of the aerobic work range. When this relationship is known, the exercise HR can be used to estimate VO_2 (and then compute energy expenditure) during free-living activities. Unfortunately, early attempts at estimating TEE from HR were subject to uncertain error since TEE had to be derived by fitting various linear relationships to a single averaged HR accumulated over 24 hours. Thus it could not circumvent one of the major shortcomings in the method, that HR is not a good predictor of energy expenditure at low levels of activity. The more recent developments in minute-by-minute HR recorders have been vital for exploiting the potential of the methodology for two reasons. First, they now negate the need to rely on HR as an index of sedentary energy expenditure through identification of an individually pre-determined threshold HR

(FLEX HR) that is used to discriminate between resting and exercise HR. Second, the methodology provides not only an estimate of day-to-day variability in TEE but also provides objective indices of associated patterns of physical activity in terms of its duration, frequency and intensity.

However, it needs to be remembered that HR provides only a proxy measure of TEE and physical activity. Therefore, despite the obvious appeal and increasing popularity of the method in epidemiological studies, potential converts to the method should acquaint themselves fully with the uncertainties and likely sources of error in its use.

Probably the two key factors which impact on the validity and precision of the FLEX HR method are the representativeness of the derived HR *v.* VO_2 regression equation to free-living activity patterns and the definition of a reproducible FLEX HR. The individual nature of the HR *v.* VO_2 relationship makes it necessary to establish a regression equation for HR *v.* VO_2 for each subject at several levels and intensity of activity while recognizing that factors other than VO_2 consumption can influence HR. These include ambient temperature, emotions, food intake, body position, the muscle groups exercised, whether the exercise is continuous or stop-and-go, or whether the muscles are contracting isometrically or in a more rhythmic manner. Consequently opinions vary as to the type of activities necessary to calibrate HR *v.* VO_2. However, even if these opinions could be reconciled and calibration protocols are performed meticulously it is most unlikely that HR *v.* VO_2 relationships established in necessarily contrived situations could capture the cardio-respiratory dynamics associated with spontaneous and complex free-living energy expenditure patterns.

In addition, calibration should only be determined close to the time that HR will be monitored under free-living conditions as a previous calibration curve for the same individual cannot be relied on, particularly if nutritional, physiological, physical, medical or environmental conditions are changing. Although between-subject variation in the slopes of the regression lines is well-documented, within-subject variability merits further attention. This within-subject variability has obvious implications for planning and executing longitudinal studies of behavioural change in patterns of physical activity.

The definition of a reproducible FLEX HR to distinguish between resting and activity HR is also problematic because it is based on the tenuous assumption that one discrete pulse point can provide a clear-cut physiological distinction between rest and exercise. Again there is a lack of consensus about how to compute FLEX HR, probably because little is known about the extent of its variation between- and within-subjects, the nature of factors influencing its range in adults and children, and the reproducibility of a measured value for a given individual over time. This reproducibility will be critical when assessing the TEE of largely sedentary subjects, simply because in these individuals a substantial amount of daily HR will be spent in and around the FLEX HR where the predictive power of the method is known to be poorest. Given that the majority of subjects in affluent populations follow sedentary lifestyles, the potential for error in estimating the TEE of individuals is obvious and this has been verified in validation studies against DLW TEE.

The continuous monitoring of HR under free-living conditions should, in theory, present few problems. HR monitors are robust and designed to function well under many different field conditions. In practice, things do not always go to plan. Undoubtedly more experienced users of the technique will have encountered their own particular problems in monitoring the HR of free-living subjects. It is regrettable that these are not always reported in more detail, because it could save a lot of time and frustration for the novice and their subjects. For example, those intending to monitor the HR of children should be aware that this group probably represents the greatest challenge to the ingenuity and

patience of the research worker. Problems include: allergic reactions to electrodes; children who fiddle with the receiver console resulting in lost transmissions; loss of contact from ill-fitting transmitter belts because of small ribcages, and transmitter belts where the transmitter cannot be detached and used alone with electrodes. The final frustration may come when transmitters literally disappear under field conditions. However, it should be emphasized that most of these problems can be overcome. The best advice to potential users is to contact more experienced users and do not hesitate to ask about the finer practical details of using HR instrumentation. It will save time, money and frustration in the short and long run.

In conclusion, refinements in HR instrumentation and methodology will, no doubt, be forthcoming. In any case it is unreasonable to expect that a single method of measuring TEE and/or physical activity patterns such as HR monitoring could address all the issues raised in evaluating free-living energy requirements. Inevitably the choice of the most appropriate method to use (aside from considerations of validity and reliability) will probably be a compromise within the context of available resources, the numbers to be surveyed and the focus of concern of the study. Undoubtedly HR monitoring does meet many of the criteria for evaluating free-living patterns of TEE and physical activity. It provides, at least at a group level, an acceptable estimate of TEE and objective assessment of associated patterns of physical activity. It should always be remembered, however, that HR can only measure an individual's response to activity, and not the activity per se. Given the highly complex and variable nature of physical activity it would be naive to use HR monitoring in situations where accuracy in estimating TEE at the individual level is a paramount consideration.

Provided that the limitations of the method are recognized and errors in estimating TEE can be tolerated, HR monitoring is probably one of the best available techniques for simultaneous assessment of TEE and associated patterns of physical activity. The versatility of the technique has been confirmed through its successful application in small groups of well-nourished and marginally malnourished children, lactating women, normal adults, athletes such as cross-country skiers and distance runners, and in remote indigenous populations. Wareham *et al.* (1997) have now confirmed its feasibility for assessing the pattern and total level of energy expenditure in the epidemiological context. These examples demonstrate that judicious application of HR monitoring to many controversial public health issues concerned with the functional significance of physical activity patterns in childhood and adulthood in both developed and developing countries is merited.

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