Heart Rate Monitoring of Physical Activity Among Village, School, and Homeless Nepali Boys

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ABSTRACT: Continuous HR monitoring, in conjunction with self-reports and direct observation of physical activity, was undertaken in three samples of 10-12-year-old Nepali boys living in different physical and socioeconomic environments. A total of 134 daytime HR profiles were recorded from 67 boys (76 from 31 villages, 39 from 20 urban middle-class schools, and 19 from 18 homeless street boys). Habitual levels of physical activity were compared using mean daytime HR (bpm) and the following indicators: percentage time during which boys are active (HR> flex), defined as an individual's average between resting and exercising HR, moderately active (HR> flex + 20, also HR> 119 bpm), and vigorously active (HR> 119 bpm) over 10 hours of daylight. Mean daytime HR (102 bpm) and percentage time spent vigorously active (4%) did not differ between samples, despite obvious differences in lifestyles; thus better indicators are needed to characterize levels of physical activity. Percentage time spent active (HR> flex) was significantly higher (P<0.0001) for villagers participating in subsistence activities, as a result of low flex HR values, indicating a higher level of physical fitness. Evaluation of moderate physical activity was sensitive to the choice of indicator, either an individual calibrated (above flex) or an absolute threshold of HR elevation. The former may be more appropriate than the latter to compare physical activity levels in populations with different lifestyles and levels of physical fitness. 

Heart rate (HR) monitoring is a popular method of assessing levels of physical activity and energy expenditure (Sparr and Reina, 1986; Ceesay et al., 1990; Armstrong et al., 1990; Janz et al., 1992; Livingstone et al., 1992; Dasham and Prentice, 1993). The necessary equipment is simple to use, robust, and highly portable, and involves minimal restriction on habitual movement while enabling continuous and detailed recording. The method has been extensively calibrated against other procedures for assessing physical activity and energy expenditure, such as doubly labelled water or indirect calorimetry, which require relatively expensive or complex equipment (Ceesay et al., 1990; Kailward et al., 1989; Emonts et al., 1992). HR monitoring is, therefore, suited to long-term or large-scale studies of free-living populations, particularly in remote areas. It is a method that is well-accepted and even enjoyed by children (Spady, 1989; Livingstone et al., 1992). HR can be used as a proxy measure of physical activity and energy expenditure given the close relationship between HR and oxygen uptake during exercise, which must be calibrated for each individual (Sillan et al., 1993). Because HR is influenced by a variety of other factors (such as emotion, posture, and ambient temperature) (Freedson, 1992; Li et al., 1993), it is only a valuable indicator of energy expenditure during physical activity. Its use in energy expenditure studies requires the calculation of a flex HR.

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defined as "an individually predetermined HR that can be used to discriminate between resting and exercise HR" (Livingstone et al., 1992, p. 343).

Recent studies of British children have raised the concern that sedentary Western lifestyles do not involve sufficient high intensity exercise and periods of sustained HR elevations, believed necessary to promote physical fitness (Armstrong et al., 1990). Surprisingly, however, recent HR monitoring of children from the developing world have confirmed that a traditional lifestyle, based upon agricultural subsistence, results in even fewer periods of vigorous activity (Benfield, 1993; Diamant and Prentice, 1993). These studies relied upon an absolute threshold to define vigorous activity (HR 139 bpm), which does not take into account the role of habitual physical activity in promoting physical fitness and thereby lowering HR for any given level of exertion (Duineveld et al., 1990; Freedson, 1992; Shuteen et al., 1994). Indices of physical activity based on individually calibrated values, such as percentages of an individual's peak oxygen consumption (Spurr and Reina, 1989; Livingstone et al., 1993), or time spent above a flex HR, provide an alternative means of estimating differences between and within populations.

This report describes the use of HR monitoring data to evaluate physical activity in three sample of Nepali boys, a part of a larger study of their health and lifestyles (Panter-Brick et al., 1990; Baker et al., 1997). Heart rate monitoring was confined to boys because of the populations involved, namely, homeless street children, is almost exclusively male. The principal aim was to compare levels of physical activity of villagers, middle-class schoolboys, and homeless boys and their contrasting lifestyles. A related aim was to determine whether indicators of physical activity were best derived from individually calibrated values (flex HR), or more simply, from absolute cut-off points as previously done by other investigators. No attempt was made to determine total energy expenditure from HR data; only mean daytime HR and the percentage time spent above given values of HR elevation were used as indicators of physical activity.

MATERIALS AND METHODS

Study population

Heart rate monitoring was undertaken in Nepal in August/September (monsoon) and November/December (winter) 1993. Homeless boys live on the streets of Kathmandu independently of parents and other relatives. Some, especially the younger children, beg from locals and tourists; others rag-pick from rubbish piles any recyclable material (items of plastic, metal, and other waste) that can be sold to junkyards. Some boys were recent arrivals from rural areas; others had been living on the streets for up to 10 years. They were contacted via a non-governmental organization, Child Workers in Nepal (CWIN), which provides a common room facility where underprivileged children can sleep, play, eat, and receive medical attention and informal schooling.

Schoolboys attended a fee-paying school in a suburb of Kathmandu, either as day pupils or as boarders from rural areas. Most came from middle-class socioeconomic backgrounds.

Village boys were drawn from a remote population in central Nepal, situated in the foothills of the Himalayas, 2 days journey by bus and foot from Kathmandu. This population has participated in anthropological fieldwork for the last 13 years (Panter-Brick, 1989, 1990). It depends on agrarian activities for subsistence, and exploits a large land area (altitude 1,350-2,800 m) for planting five cereal crops, tubers, and vegetables, and for grazing cattle. Although poor, the village community is self-sufficient in home-produced foods over the year.

Sample

All available 10-15-year-old boys were targeted in the school and village samples. Among the homeless neither a total nor a random sample could be drawn for HR monitoring. Sampling had to be limited to those who, according to CWIN staff, could be trusted with the equipment. These boys were economically active, deriving their income outside of CWIN, mostly from rag-picking. They would spend 2-4 days a week down the city, then rested and played both in CWIN and on the streets. During HR monitoring, days were fairly representative of their habitual activity, as boys would rag-pick in relatively safe areas of the city. At night, however, homeless boys slept at CWIN rather than on the streets to prevent the equipment being stolen or damaged, or the boys being harmed in a fight. The total sample comprised 31 village boys, 20 urban schoolboys, and 18 urban homeless boys (Table 1). The purposes of measurements were explained by local assist-
TABLE 1  Individual characteristics and heart rate values in three populations of normal boys

<table>
<thead>
<tr>
<th></th>
<th>All boys (n = 67)</th>
<th>Village boys (n = 25)</th>
<th>School boys (n = 20)</th>
<th>Homeless boys (n = 20)</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (yr)</strong></td>
<td>11.9 ± 0.7</td>
<td>11.5 ± 0.6</td>
<td>11.6 ± 0.8</td>
<td>11.6 ± 0.8</td>
<td>12.2 ± 0.9</td>
<td>12.1 ± 0.9</td>
<td>12.1 ± 0.9</td>
<td>12.1 ± 0.9</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>149.7 ± 5.6</td>
<td>147.5 ± 4.3</td>
<td>150.1 ± 3.6</td>
<td>150.0 ± 3.4</td>
<td>149.7 ± 5.6</td>
<td>149.6 ± 4.4</td>
<td>149.8 ± 3.5</td>
<td>149.7 ± 3.4</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>37.3 ± 4.0</td>
<td>35.3 ± 3.2</td>
<td>38.5 ± 2.8</td>
<td>38.4 ± 2.6</td>
<td>37.3 ± 4.0</td>
<td>37.0 ± 3.2</td>
<td>37.4 ± 2.9</td>
<td>37.3 ± 2.8</td>
<td>0.09*</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>14.3 ± 0.6</td>
<td>13.3 ± 0.5</td>
<td>14.1 ± 0.5</td>
<td>14.1 ± 0.5</td>
<td>14.3 ± 0.6</td>
<td>14.1 ± 0.5</td>
<td>14.2 ± 0.5</td>
<td>14.3 ± 0.5</td>
<td>0.02**</td>
</tr>
<tr>
<td><strong>HR (rest)</strong></td>
<td>70.1 ± 7.0</td>
<td>70.2 ± 6.9</td>
<td>69.9 ± 7.0</td>
<td>69.7 ± 6.8</td>
<td>70.1 ± 7.0</td>
<td>70.1 ± 6.9</td>
<td>70.2 ± 7.0</td>
<td>70.1 ± 6.9</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>HR (peak)</strong></td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>183.0 ± 20.8</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Note: *P ≤ 0.05, **P ≤ 0.01. Significantly different between groups.

Heart rate monitoring

The equipment includes 12 Sports Tester PE3000 HR monitors (Polar Electro OY Finland), 4 Sports Tester PE4000 (Polar Electro OY Finland), and 4 Vantage XL monitors (Polar Electro USA) for simultaneous use in the three samples. The equipment consists of a transmitter, secured to the chest by means of a belt or electrodes, which transmits HR values to a small receiver, resembling a wristwatch, carried by the subject. In this study, the transmitter was attached with adhesive electrodes and further secured with elastoplast tape to prevent the possibility of accidental disconnection. Slight skin irritations was validated by a few boys, but otherwise the HR monitors were well tolerated. The wristwatch receiver was also covered with elastoplast tape to prevent boys from intentionally or accidentally activating its timer. It was then placed outside a cloth pouch and fastened to the inside of the boys' clothing to conceal it from view.

The PE4000 and Vantage XL HR monitors store over 83 hours of HR data recorded on a minute-by-minute basis, while the PE3000s have a limited capacity of 17 hours. The former two were fitted to homeless boys and schoolboys (at CWK and school) at 8 am, and the latter at 10 am. The team of data collection, to them, for a period of ~24 hours. Schoolboys were monitored only during the school week. Homeless boys attended CWK classes only occasionally, and in the main their HR recordings were on days that did not involve class attendance. Village boys were fitted with PE3000s for a period of about 12 hours and daytime and nighttime profiles monitored separately. On only two occasions did village boys wearing the HR equipment attend the local school. Each boy were the HR monitor for one night and 1–3 daytime periods. Boys were asked to proceed with their normal activities, but to avoid immersion in the equipment in water.

The procedure for determining flex HR has been described in Painter-Brick et al. (1996). Briefly, flex HR was calculated as the mean between resting and exercise HR during a graded activity protocol involving lying, sitting, and standing rest, as well as step-tread and jogging exercise.

Behavior

At the end of each recording period, boys were asked to recall their activities, location and approximate duration, health complaints, and events that had either excited or distressed them during the period of HR monitoring. Schoolboys and some of the homeless and villagers were given wristwatches 'to keep track of time or annotate a simple diary during the day.'
as a means of obtaining more detailed information than that provided by self-reports on behavior patterns. However, it became clear from trial observations of homeless boys that such an approach was overly intrusive and that boys tended to modify or cease their activity in the observer's presence, or sought to approach the observer. Spat-check observations of homeless boys at randomly chosen intervals were undertaken instead. Continuous minute-by-minute observation was confined to village boys who were already familiar with such a procedure (Pantel-Brick, 1989, 1995). Two village assistants, trained in time-allocation observation since 1982, followed individual boys at a distance and recorded, on a minute-by-minute basis, over a randomly chosen 1-hour period, the boy's activities, location, posture, load carried, and the social context of his behavior.

Anthropometry and hemoglobin

Height and weight were measured by the same researcher, using portable equipment (a Harpenden anthropometer and a Salter electronic scale with 0.2 kg precision), according to standard field procedures (Weiner and Laurs, 1951). The NCHS z-score values were used to indicate stature (height-for-age), HAZ, wasting (weight-for-height), WAZ, and underweight (weight-for-age). Red cell hemoglobin values, obtained from a finger-prick blood sample, were determined at Rosary University using a modified procedure for whole blood hemoglobin (Sigma Diagnostica Cyanmethemoglobin procedure no. 553-A).

Heart rate recordings were downloaded from the receiver onto a portable computer using the Polar Heart Rate Analyst Software package (Polar Electro OY Finland). A total of 76 daytime (12 in the monsoon, 24 in the winter) and 23 nighttime (all in the monsoon) HR profiles were obtained for the village boys. A total of 19 24-hour HR recordings for school boys and 19 24-hour recordings for homeless boys were obtained (in triplicate). Any HR values < 40 bpm and > 210 bpm were attributed to transmission problems and stored as missing values. The upper limit was derived from an estimation of maximum HR (220 bpm—age in years) and from the observation that sustained elevations in HR associated with vigorous activity (as determined from behavioral data) did not exceed 200 bpm. Matching the HR and behavioral data indicated that transmission problems, resulting in zeros or spikes, occurred during both rest and exercise and were not specific to given activities. Their exclusion from analysis is, therefore, unlikely to have biased results.

Since the nighttime profiles of homeless boys had, by necessity, been monitored under conditions other than their habitual nocturnal environment, the comparative analysis of these three populations was confined to daytime activity.

The first step of HR analysis was to select equivalent observation times for the three samples whose recordings started or ended at various times. In the case of villagers, daytime profiles averaged a start time of 0732 hours and a stop time of 1731 hours. Accordingly, only data within the window of time 0731-1720 hours were considered for the other samples.

Possible misrepresentation of levels of physical activity due to the timing of daily tasks was investigated. Homeless and village boys may sometimes work early in the morning, whereas schoolboys follow a structured timetable. Levels of physical activity could be underestimated if one group of boys was more active outside the chosen time period. Twenty-four-hour activity profiles were computed for windows of nine over two consecutive hours (0001-0020, 0201-0400, 0401-0600 hr, etc.), averaging minute-by-minute data to derive an average IR value for each 3-hour window. Average 24-hour activity profiles for each sample were depicted graphically and the profiles compared.

Another difficulty arose due to the variable number of daytime profiles (one to three) recorded for each individual boy. Analyses were repeated once for single days of HR recording and once for numbers of actual participants (averaging any multiple recording for each boy). Both methods yielded similar results, and those of the first are reported (Table 2), because it is based upon actual rather than composite days.

Levels of physical activity were evaluated using mean daytime HR (0731-1730 hr) and pentad time during which boys were physically active, moderately active, and vigorously active as defined by the following thresholds: 0 HR = individual fits HR (an individually calibrated threshold defining
TABLE 2: Diastolic HR and percentage of the day during which HR exceeded four indicators of physical activity.

<table>
<thead>
<tr>
<th>Indicator of activity</th>
<th>All boys</th>
<th>Village boys</th>
<th>School boys</th>
<th>Homestead boys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n (m = 38)</td>
<td>10 (7)</td>
<td>10 (7)</td>
<td>10 (7)</td>
</tr>
<tr>
<td>Active</td>
<td>65 (26)</td>
<td>73 (24)</td>
<td>46 (24)</td>
<td>57 (23)</td>
</tr>
<tr>
<td>Moderate</td>
<td>26 (20)</td>
<td>32 (20)</td>
<td>21 (15)</td>
<td>29 (19)</td>
</tr>
<tr>
<td>Vigorous</td>
<td>5 (5)</td>
<td>6 (4)</td>
<td>3 (3)</td>
<td>5 (4)</td>
</tr>
</tbody>
</table>

| Overall             |          |              |             |                |
|                     | n (m = 38) | 10 (7)      | 10 (7)      | 10 (7)         |
| Active              | 65 (26)  | 73 (24)      | 46 (24)     | 57 (23)        |
| Moderate            | 26 (20)  | 32 (20)      | 21 (15)     | 29 (19)        |
| Vigorous            | 5 (5)    | 6 (4)        | 3 (3)       | 5 (4)          |

The table shows the mean (SD) values for diastolic HR and the percentage of the day during which HR exceeded four indicators of physical activity for all boys, village boys, school boys, and homestead boys. The data is presented in a tabular format with columns for the indicator of activity, mean (SD) values, and the percentage of the day. The table includes overall and specific data for each category, highlighting the differences in HR based on the type of activity performed.

Results

Sample characteristics and HR indicators of physical activity are shown in Tables 1 and 2, respectively. Schoolboys are taller and heavier than either village or homestead boys, who by reference to NCHS percentiles are stunted but not wasted (Table 1). All boys show some hemoglobin values within the normal range. There are no differences between samples in age, BMI, average daytime HR, and percentage time very active. There are, however, significant differences for flex HR, percentage time active and moderately active. Thus villagers spent a greater portion of the day active (P < 0.001), Table 2) and also average lower flex HR (P < 0.0001, Table 2) than either schoolboys or homestead boys.

The two indicators of moderate activity give very different results for the village boys, namely 33% of the day above flex = 20%, and 17% of the day above 110 bpm (Table 2). In contrast, they give consistent results for the school (28%) and the homestead (11-13%) boys.

The 24-hour profiles, characterized by HR values recorded over consecutive 2-hour periods, are shown in Figure 1. The similarity of profiles for the three samples (mean HR range 401-1008 br, peaking at 111-1008 br, and falling after 1601-1600 br in schoolboys and 1601-2000 br in village and homestead boys) indicates that the compensatory analysis of activity patterns is not biased by differences in the timing of habitual activity. No significant seasonal differences are apparent for villagers as mean daytime HR

Physical activity: (1) HR > flex = 20%; (2) HR > 110 bpm (an individually calibrated value defining moderate activity, which averages 110 bpm for the whole group); (3) HR > 110 bpm (an absolute threshold defining moderate activity), and (4) HR > 120 bpm (an absolute threshold defining vigorous activity, roughly equivalent to 70% of maximum HR).

Behavioral data were collected on HR profiles. They are here evaluated graphically rather than by quantitative analysis. These data include self-reports for urban samples and direct observation for villagers totaling 26 one-hour periods of minute-by-minute observation.

Statistical analyses

Population differences in age, hemoglobin values, anthropometric characteristics, daytime HR, and percentage time spent above given values of HR - elevation were tested by means of parametric and non-parametric analyses of variance (ANOVA and Wilcoxon tests). Agreement between the two indicators of moderate activity, individually calibrated (flex > 20%), and absolute (110 bpm) threshold, was evaluated by means of a Wilcoxon matched-pairs test. The influence of seasonality on levels of physical activity was examined for the village sample (Wilcoxon matched-pairs test), but not for the other samples, because only low hemoglobin boys participated in both seasons and because schoolboys spent most of their day at school. Analyses were conducted using MINITAB and SAS statistical packages and P < 0.05 was the accepted level of significance.
and other indicators (Table 3), due to considerable intra-individual variability in HR values.

**DISCUSSION**

Despite the increasing popularity of HR monitoring, relatively few studies have used this method to assess levels of physical activity among children. This study was designed to compare the habitual levels of physical activity of groups of 10-13-year-old boys living in the same country, but in very different physical and socioeconomic environments. Some brief remarks about methodology are appropriate in the context of developing field techniques appropriate to remote areas, rather than laboratory, and to children (even homeless children), rather than adults.

Overall, continuous HR monitoring was quite successful, being both technically feasible and acceptable to the children. The methodology was indeed simple, non-invasive, and appropriate for use in free-living populations; it imposed minimal restriction on children’s habitual activity. Downloading of HR recordings only required a portable computer, which was powered by batteries rechargeable with a solar panel, and therefore, feasible even in the village areas which have neither roads nor electricity. The technique was also effective. Although a few recordings were lost, due to transmission problems (e.g., noise affecting Fig. 3), or perhaps due to boys playing with the equipment (despite concealment of the transmitter within a sealed pouch), the majority were of a sufficient quality for analysis. Most importantly, the procedure was popular with the boys. There was no shortage of volunteers wanting to wear the equipment in the village and school populations, although reliable participants were much harder to find among the homeless group.

However technically appropriate, the
### Table 3. Seasonal values for HR and physical activity indicators for village boys

<table>
<thead>
<tr>
<th></th>
<th>Mean HR</th>
<th>SD</th>
<th>Mean HR</th>
<th>SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>101</td>
<td>11</td>
<td>106</td>
<td>9</td>
<td>NS</td>
</tr>
<tr>
<td>Active</td>
<td>12</td>
<td>10</td>
<td>13.5</td>
<td>12</td>
<td>NS</td>
</tr>
<tr>
<td>Moderate</td>
<td>22</td>
<td>14</td>
<td>40</td>
<td>21</td>
<td>NS</td>
</tr>
<tr>
<td>Vigorous</td>
<td>14</td>
<td>15</td>
<td>5</td>
<td>5</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Note:** HR = heart rate, NS = not significant.

method was not implemented without notable challenges. The village and school participants evidently continued their daily routine activities that included being head-buttered by a goat and falling off a bicycle, but HR monitoring proved more problematical in the homeless population. The equipment was a very marketable commodity on the streets of Kathmandu. The receiver resembles a digital wristwatch and the equipment is both novel and Western in origin. Two Specterstents disappeared, having been sold by their bearers. Therefore, participating homeless boys were hard-picked by CWIN staff. Some homeless boys curtailed part of their daytime activities, because they were afraid of having the monitor stolen from them by older street gangs, who physically intimidate younger boys to extort money from them. One boy was assaulted while wearing the equipment and reported that his teenage attacker tried, but failed, to pull the equipment from him. Most homeless boys, however, continued to work and play on the streets, and confined their activities to relatively safe areas. But, because they slept at CWIN rather than on the streets at nights, the present analysis is restricted to daytime HR recordings.

This comparative study of Nepali boys yields one general finding with important methodological implications. Results show that the adoption of very different lifestyles has little impact on the mean daytime HR of 10-13-year-old boys. Heart rate averaged 100-104 bpm across the three samples, even though schoolboys spent a large portion of the recording period in the classroom, whereas villagers and street boys engaged in subsistence activities. Very similar values have been reported for youngsters in other developing countries. Thus boys aged 11-16 years living in a traditional rural village in

Soglao, who were monitored during the farming season, averaged a daytime HR of 99 bpm (Dihlham and Prentice, 1983). In the city of Cali, Colombia, groups of inadequately nourished and malnourished 10-12-year-old boys had a mean daytime HR of 130 bpm and 98 bpm, respectively (Sparre et al., 1986). Lower values for mean HR (80-94 bpm) were reported for 10-12-year-old Bolivian boys, but these referred to a 24-hour period and included HR during sleep (Stolz et al., 1994). In the Bolivian study, boys of low socioeconomic status (SES) had lower mean HR than high SES counterparts. This effect was thought to be mediated through the greater participation of poorer boys in household chores, such as carrying water to homes without running water. In contrast, SES had little impact on mean HR in this study. Despite inclusion of both village boys, who fetched water, firewood, and carried other loads, and middle-class schoolboys, who reported no involvement in household chores. twig effects, considered in the Bolivian study, are unlikely to have influenced the present results, as differences between the rural and Kathmandu areas are only 70 m, and villagers travel up and down the mountainside during their daily activities. Furthermore, the HR values reported for boys in developing countries are very similar to the mean value of 104 bpm obtained in a sample of 12-13-year-old boys in Northern Ireland, monitored over two school days and one weekend day (Livingstone et al., 1992). The present study thus confirms the remarkable similarities in mean daytime HRs of populations of largely pre- and early adolescent boys, regardless of country of origin, rural or urban background, even nutritional status. The question, therefore, arises as to whether the similarities in mean daytime HRs reflect similarities in levels of physical
activity and fitness, or whether comparisons of activity patterns across populations need to be based on more sensitive indicators. The assessment of habitual levels of physical activity has recently assumed increasing importance in Western populations, as an active lifestyle in adulthood predisposes physical fitness and reduces the risk of coronary heart disease, diabetes, and osteoporosis. In fact, recent studies have elevated physical inactivity to a major risk factor for coronary heart disease, in par with high blood pressure, high blood cholesterol, and cigarette smoking (Saul, 1994). Although the relationship between physical activity and health is less clear-cut in children than in adults (Dain et al., 1992; Skalli et al., 1990; Saul, 1984; Malina, 1995; exercise habits, or a lack of them, are frequently laid down in the early years, much that activity levels in childhood are a good predictor of future activity levels in adult life (Strong, 1990). In particular, Armstrong et al. (1990) expressed the concern that many British schoolchildren are failing to reach the levels of activity recommended to promote physical fitness (see Malina (1995) for a review of similar concerns in the U.S.). These levels consist of physical activity sufficient to raise the HR above 130 bpm for 20 minutes or longer at least three times a week (Simons-Morton et al., 1988). The British 11-16-year-old schoolboys spent 6.2% of a 12-hour period in vigorous physical activity above the threshold of 180 bpm (Armstrong et al., 1990). However, all three Nepali populations spent only 3.5% of their time above this threshold. Whereas Nepali schoolboys may have adopted a sedentary lifestyle, the homeless boys have to earn their living from the streets, and the village boys are part of a traditional subsistence economy. Similarly, Segoulese village boys spent 2.5% of their day at a HR exceeding 130 bpm according to Benfatto (1985), but only 1.7% according to Daham and Pratice (1986). These low levels of vigorous physical activity reflect a tendency to spend relatively more time working at a moderate pace to avoid physical exhaustion and to be able to sustain agricultural activities throughout the working day. Thus both Nepali and Segoulese villagers spent a smaller percentage of their day at HRs exceeding 130 bpm than the British schoolboys studied by Armstrong et al. (1990). Those findings, therefore, call into question the applicability of a hitherto com-

Two indicators of moderate physical activity were selected in this study for the purposes of comparing the values of an individually calibrated threshold and an absolute threshold of HR elevation. Values above individual flex + 20%, averaging 118 bpm for all children, were comparable at the outset with the absolute threshold of 110 bpm. The two indicators gave consistent results for the homeless and school populations, but discrepant results for the village boys. According to HR flex + 20%, villagers spent 33% of their time in moderate physical activity, much more than the other two groups, but according to the threshold of 110 bpm, they spent only 17% of time moderately active comparatively less than the homeless boys. This suggests that the two indicators are measuring different things or are confounded by other variables, such as an individual's level of physical fitness. Indeed, these two indicators of HR elevation are a measure of an individual's response to physical activity, rather than a measure of the activity per se (Freedson, 1992). The analysis of physical activity using absolute thresholds as indicators of activity fails to take into account possible differences in physical fitness, brought about by differing levels of habitual physical activity, which may influence the HR achieved in response to any given level of activity. The use of individually calibrated flex HR and derivations from this value does take into account individual and population differences in physical fitness, if it can be assumed that physical fitness is the major determinant of flex HR. The validity of such an assumption has been discussed in Panten-Brick et al. (1990). The indicators are discrepant for villagers because of their significantly lower mean flex HR (91 bpm), and hence lower flex HR + 20% (mean of 109 bpm). They are consistent for the schoolboys and the homeless boys who average similar flex HR values (100–103 bpm) and thus flex HR + 20% values close to 110 bpm. Thus, group comparisons of physical activity should take into account possible differences in the initial physical fitness of participants. One approach is to measure VO2max and calculate HR at a percentage of peak oxygen consumption (Spurr, 1990). Another is to calculate the percentage
time above individual flex HR as an indicator of being physically active, as was done in the present study. This showed that village boys were the most active, spending nearly three-quarters of the day at HRs above flex HR (Table 2). As expected, schoolboys were the least active, spending only about half the day at HRs exceeding flex HR, thereby exhibiting very similar levels of physical activity to schoolboys in Northern Ireland (Livingstone et al., 1992). The homeless were in an intermediate position, active for two-thirds of the day. Direct measures of physical fitness (VO2 max) were not attempted, but as discussed below, the behavioral data give some corroboration of the likely levels of physical fitness of individual participants.

Matching HR profiles with given activity patterns provided useful information, although the behavioral data were of differing quality in the three populations. Most schoolboys had watches and were able to give detailed information about the nature and timing of bouts of physical activity, which corresponded well with their HR recordings (Fig. 2). Few homeless boys had watches, so their self-reports were less precise, but it was still possible in most cases to match the sequence of activities to the HR profile (Fig. 3). Self-reports for villagers were the least informative, as boys were frequently unaware of the time and speed they were in the same activity (e.g., herding or cutting grass). However, direct observation over 1-hour periods provided extremely fine detail on the relationship between physical activity and HR for individual boys (Fig. 4). A variety of activities were identified as raising HR above the threshold of 125 bpm. For village boys, vigorous physical activity included cutting grass, carrying loads of maize, grass, or clay, walking uphill, and playing. For the schoolboys, cycling, physical education classes, and martial arts, and for the homeless, carrying water, playing, and running on the streets were all examples of vigorous activity. However, activities that involved little physical exertion, such as resting in the village boys, playing marbles and studying in the schoolboys, and playing board games in the homeless boys, also raised HR values above 125 bpm. Such HR elevations without corresponding physical exertion may reflect inaccuracies in the time-allocation data, or the influence of factors other than physical activity on HR, such as emotion, and in children in particular, changes in posture (Livingstone et al., 1992). Nevertheless, such agents frequently have only a moderate or transient impact on HR (Salins et al., 1993), and in the present study, sustained elevations in HR generally corresponded to reported or observed bouts of physical activity. By contrast, in village boys, observed physical activity such as load carrying of ~10 kg or walking uphill did not cause a marked elevation in HR. The examination of matched HR and behavioral data permits an evaluation of the actual relationship between HR and physical activity.
Fig. 3. Example of a matched 24-hour continuous heart rate recording and a 24-hour activity self-report for a typical day. Data begins at 0830 h. A, sleep; B, drink tea at a small hotel; C, wash and rag-pick; D, eat meal at a hotel; E, draw and play board games at CWR Ulster House; F, sell plants at market; G, walk and rag-pick. The determined activity reflects transcription preferences and were counted as missing values in subsequent analyses.

Fig. 4. Example of a 1-hour heart rate recording matched with the direct observation of activities for a typical day (profile begins at 0800 h). A, eat meal in field; B, resting; C, weed in field standing; D, carry load of grass weighing 10 kg back home; E, sitting rest.

Both activity reports and HR indicators show, as expected, that school boys were the least active of all groups. School lasted from 0940 h to 1540 h, during which time boys engaged in physical activity only during their 40-minute lunch break and also in one 40-minute period of martial arts and one 40-minute period of physical education per week. At home, cycling and playing outside were reported, but long periods were spent studying or watching television. Some underestimation of habitual activity may have occurred because sporting activities tended to occur at weekends and because one-third of the HR recordings were obtained in the week prior to the school examinations. Behavioral data showed that the homeless, in contrast, engaged in rag-picking, walked considerable distances while carrying their sack of recyclable waste, and frequently engaged in rowdy and physical play. Although some street-based activity may have been curtailing by boys wearing the HR monitors, direct observation of the homeless over an extended period of fieldwork indicates that they are less active than village boys.

Both the behavioral and HR data suggest that rural boys led a more physically active
lifestyle than the two urban populations. Elsewhere in Nepal villagers face escalating shortages of arable land (O'Lea, 1993; Sat
taur, 1990), but in the remote area the main shortage is the availability of household la
ter to operate a mixed agro-pastoral econ
cy (Pantzer-Brick, 1985, 1988). The local ethnic group (Tamang) has small families, and the labor of children is therefore fre
quently essential to subsistence. Village boys infrequently attend school and work instead in agricultural activities, carry heavy loads (> 30 kg) up and down slopes of up to 45% incline, herd animals on the mountainside, search for and carry firewood, and fetch water.

The level of energy expenditure sustained by village boys may well contribute to their moderately poor growth status. As well as being the most active, and possibly also the most physically fit of the three populations, village boys were also the most stunted, as indicated by height-for-age z-score values (Table 1; Pantzer-Brick et al., 1986). The re
lationship between physical activity levels and nutritional status, as reported in other studies, has been found to be both complex and variable. In preschool children, chronic energy deficit has been linked to reduced levels of spontaneous physical activity (Chavez and Martinez, 1981). Senegalese 10-11-year-old boys from a rural farming community who exhibited mild stunting, but a reduced cardiovascular performance, as assessed by forced vital capacity, and performed poorly in tests of running, throwing, and long jump, when compared to American boys of the same age (Benfice, 1980). Whereas mean daytime HR values were almost identical for groups of mildly stunted boys and adequately nourished Co

Colombian school boys monitored over 5 hours of schooling and 5 hours of free time, under
nourished boys were unable to keep up with their adequately nourished counterparts who were typically organized in various sport
ning activities, except for a short period after a high energy meal (Sputt and Retha, 1988).

In adults, stunting has been associated with a reduced ability to perform physically demanding activities such as sugar cane cut
ing (Sputt, 1990), but by contrast, Diz et al. (1991) found that neither nutritional status nor dietary supplementation influenced the productivity of Gambian laborers during a road-building program, or the pattern of their HR recordings during and after work. However, participants received a substantial financial reward for their efforts, which might have accounted for maintenance of productivity at the expense of a low in body weight. The above studies indicate both an association between poor nutritional status and physical activity, and the possibility of sustained activity in the presence of strong incentives, whether financial reward or survival.

In conclusion, this study has shown that the three samples of Nepali boys have similar
mean daytime HRs and percentage of the day sustained in vigorous physical activity as defined by the absolute threshold of HR elevation previously adopted in the litera
ture. They do differ with respect to per
centage those physically active and moderately active, where comparisons are based on an
individually calibrated threshold of HR ele
vation. Different results may be obtained us
ing an individually calibrated or an absolute threshold of physical activity, due to under
lying differences in flex HR values. Our find
ings suggest that comparison of activity lev
els between populations living in differing environments is best performed using indi
vidually calibrated indicators of physical ac
tivity that attempt to take into consideration underlying variation in levels of physical fit
ness. Although HR monitoring has been shown to be a very valuable tool for study of physical activity, it should always be re
membered that it measures the individual’s response to the activity, and not the activity per se.

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LITERATURE CITED


