Comparative Study of Flex Heart Rate in Three Samples of Nepali Boys

C. PANTER-Brack, A. TROPP, B. BAKER, and C. WORTHYMAN
Department of Anthropology, Dartmouth College, Hanover, NH 03755, USA.
United Kingdom: Department of Anthropology, Emory University, Atlanta, GA 30322.

ABSTRACT. Flex heart rate (HR, beats per minute) has assumed increasing importance in studies of energy expenditure and physical activity. Flex HR is defined as the mean of maximum resting and minimum exercise HR recorded during a standard test. This report examines methodological and substantive issues regarding the measurement and interpretation of population variation in flex HR values. Flex HR was determined for 80 Nepali 10-14-year-old boys living in contrasting physical and socioeconomic environments (2) village boys, 24 urban middle-class schoolboys, and 28 homeless street boys. The three populations exhibited significant differences in flex HR, with villagers averaging lower values than school boys or homeless boys (91, 100, and 103 bpm, respectively, P < 0.001). They also differed in mean resting HR (P < 0.0002), but not in the percentage increase of flex over resting HR. To evaluate reliability, flex HR measurements were repeated on 14 school boys after a 6-month interval. Mean initial and repeat values were not significantly different, but discrepancies were large for individual subjects (~15 to ~24 bpm). This suggests that flex HR is reliable at the population level, but not necessarily stable for individuals over time. The range of factors contributing to variation in flex HR between and within populations has implications for the use of HR monitoring to estimate levels of physical activity.

Heart rate (HR) monitoring has been advocated as an inexpensive and non-invasive method of assessing levels of energy expenditure in free-living populations (Sparr, 1980; Sparr and Resto, 1980; Enoos et al., 1982; Livingstone et al., 1992; Bisgrove, 1987; KatsEventz et al., 1994). HR recordings are valuable indicators of levels of physical activity only during exercise, because at rest, the influence of other factors such as emotion and posture predominate. The application of HR monitoring to energy expenditure studies, therefore, requires the prior identification of each individual’s flex HR, defined as an “individually predetermined” HR that can be used to discriminate between resting and exercise HR (Livingstone et al., 1992). Flex HR has been measured for populations of adults and children in both Western and developing countries (Sparr et al., 1980; Cressy et al., 1980; Diaz et al., 1991; Livingstone et al., 1992; KatsEventz et al., 1994; Stephen, 1994). As well as its use in energy expenditure studies, flex HR has been applied to studies of continuous HR monitoring in order to determine the percentage of total observation time during which subjects are physiologically active (Livingstone et al., 1992).

Flex HR values have played an important role in the estimation of energy expenditure and physical activity, but little attention has been paid to flex HR per se. Little is known about the extent of its variation between and within populations, the nature of factors influencing its range in adults or children, and the reliability of measured values for given individuals over time. The present investigation of flex HR has...
three objectives. First, it compares flex HR in three populations of Nepalese children living in contrasting physical and socioeconomic environments. Second, it investigates the relationship between flex HR and individual characteristics such as age, height, and weight. Third, it tests the reliability of flex HR measures by repeating determinations in a subsample.

HR monitoring was undertaken as part of a wider multidisciplinary study of the health and lifestyles of Nepalese street children, rural villagers, and urban middle-class school boys (Pankert-Brick et al., 1996; Baker et al., 1991). Estimates of homeless street children in Nepal are almost exclusively males. HR monitoring was confined to boys in all populations. The HR study was designed both to determine individual flex HR values and to obtain 24-hour HR recordings of habitual activity. Flex HR is discussed in the present work, whereas the results of continuous HR monitoring are presented elsewhere (Pankert-Brick et al., 1996).

POPULATIONS AND SAMPLES

HR monitoring was undertaken between August and December 1993 in two urban populations, known to Baker since 1990, and one rural population, known to Pankert-Brick since 1992.

Groups of children

Homeless boys in Kathmandu (altitude 1,200 m), the capital of Nepal, live and work in the streets independently of their families. Most boys or rag pickers (sell-waste products for recycling) and sleep in small groups by temples, bus stations, or junkyards. Some are recent migrants from rural areas; others have lived on the streets for several years. They were contacted via a nongovernmental organization, Child Workers in Nepal (CNW), which has a drop-in center for underprivileged children. The 1990-93 CNW census, updated every week by staff who walk the streets and check the background of homeless children, counted 499 homeless boys, ages 6-15 years.

Urban middle-class boys were drawn from a fee-paying school in a suburb of Kathmandu, which caters to day pupils or, less frequently, boarders from rural areas. These boys are financed by their own families, although about one-quarter receive sponsorship or free education.

Village boys lived in a remote area in central Nepal (population 1,540 in the foothills of the Himalayas, altitude 1,970 m), a 2-day journey by bus and foot from Kathmandu. Their families depend on agricultural activities for subsistence and almost all are self-sufficient in home-produced foods.

Samples

All available 10-15-year-old boys in the school and village populations were recruited for the study. It proved more difficult to recruit homeless boys, because of their highly mobile lifestyle. CWIN helped to identify participants within the target age range, but owing to slow recruitment, two 14-year-old volunteers were also included. In total, samples comprised 31 village, 24 school, and 25 homeless boys. The purpose of the study was explained and consent obtained from the children and local authorities. All boys declared themselves to be healthy at the time of testing.

MATERIALS AND METHODS

HR measures

HR was recorded using Sports Tester PE3000 HR monitors (Polar Electro OY Finland) and Vantage XL monitors (Polar Electro USA) in the urban samples. The equipment consists of a transmitter attached to the chest by means of adhesive electrodes or an adjustable belt and a small receiver worn on the wrist like a watch or fastened to clothing.

The protocol to determine flex HR (Table 1) was modified from the procedure described by Cesarey et al. (1989). Heart rate values were recorded at 1-second intervals while boys engaged in the following five activities: lying supine, sitting on the ground, standing still, stepping on and off a 15 cm wooden block at a rate of 30 steps/min, and jogging at a rate of 138 steps/min after 1 minute of recovery. The rates for stepping and jogging were recorded from a metronome or a cassette tape, which was then played to the boy during the test. The boys practiced the exercise activities in advance of measurement, and for some, the presence of an adult stepping or jogging alongside assisted in maintaining the required rhythm. Each activity lasted 2 minutes to allow a period of 3 minutes for habituation and 1 minute for data recording.

A subsample of schoolboys, 14 in total, repeated the protocol 3 months after original
testing to assess the reliability of flex HR.
The protocol was performed in the same time of day on both occasions.
The work output of the steepest exercise was calculated from the following formula (Panter-Brick et al., 1992):

\[
\text{Workload (watt) = W \cdot h \cdot 9.8 \cdot \text{N} \cdot \text{sec}^{-1}}
\]

where \( W \) = body weight (kg), \( h \) = bench height (m), \( 9.8 \) = gravitational constant (m sec\(^{-2}\)) and \( N \) = ascents/minute.

Anthropometry
Weights (with minimal clothing) and heights were measured by the same researcher in all three populations, following standard procedures (Winter and Lunn, 1981) and using portable equipment (Salter electronic scale with 0.2 kg precision and a Stadiometric anthropometer). Growth status was indicated by reference to NCHS reference values for stature (height for age, - HAZ), weight-for-height, (WHZ), and underweight (weight-for-age, - WAZ) (Hamill et al., 1977, 1979).

Hemoglobin
Blood spot samples were obtained from a finger prick, air dried at ambient temperature, and shipped to the laboratory at Emory University, to determine hemoglobin concentrations for each participant.

ANALYSES
Heart rate recordings were downloaded from the receivers onto a portable computer using the Polar Heart Rate Analysis Software package (Polar Electro OY Finland).

An example of the resultant traces is shown in Figure 1.

Flex HR was defined as the mean of the maximum rest and minimum exercise values (Livingstone et al., 1999). Maximum rest HR was taken as the average of the three maximum values achieved during lying, sitting, and standing. Minimum exercise HR equaled the single minimum value recorded during light exercise i.e., stepping/jogging is included (with consideration of fire HR, but serves as a calibration point in studies that seek to establish the relationship between HR and energy expenditure). The mean resting HR was calculated as the average of mean values recorded during lying, sitting, and standing. HR elevation, or the
percentage by which flex HR exceeded mean resting HR, was also calculated (Table 3). Differences between samples were tested by means of one-way analyses of variance (ANOVA) when appropriate; where appropriate, relationships between individual flex HR and other variables were examined by means of multiple regressions and correlations. The reliability of flex HR was ascertained by means of a Wilcoxon matched-pairs test for the 14 school boys who completed initial and repeat measurements at a 3-month interval. Analysis were conducted using Minitab and SAS statistical packages and P < 0.05 accepted as the level of significance.

RESULTS

All variables were normally distributed; summary statistics are given in Table 5. The three samples differ in weight (P < 0.01), height (P < 0.0001), and hemoglobin values (P < 0.05), but not the body mass index or age. The village and homeless boys are stunted, but not wasted (HAZ and WAZ values, Table 2). Village boys average lower HR while sitting (P < 0.0002), standing (P < 0.0001), and stepping (P < 0.0001), and hence average both lower mean resting HR (P < 0.0001) and mean flex HR (P < 0.0001). The percentage increase of flex over resting HR is the same across populations.

There are significant differences in work output between samples (school vs. village boys: 13 (SD 3) vs. 13 (SD 1) watts, P = 0.002; NS between street boys 14 (SD 2) and other samples), due to the height and weight differences between boys. There is no significant within-sample association between flex HR and work output, between flex HR and age (over the 3-year span), or between flex HR, hemoglobin values, and anthropometric variables: results of correlation and multiple regression analyses not shown.

Differences between initial and repeat flex HR values across school boys are not significant, averaging only 3 (SD 11) bpm, but for individual boys, the magnitude of such differences is large, ranging from -15 to +24 bpm and averaging 9 (SD 7) bpm (Table 4).

DISCUSSION

Two issues centering on the methodological and substantive aspects of flex HR measurement are considered. The first involves some clarification of the procedures for measurement and computation. Calculations of flex HR have been made following a number of differing protocols, including the measurement of light exercise on a treadmill and a bicycle ergometer. In this study, under field and not laboratory conditions, the decision was made to keep equipment at a minimum and to select an exercise suitable to the local children. The protocol described by Cessna et al. (1989), which requires only a step-test protocol for light exercise, was deemed most suitable. Some amendments were, however, necessary in light of trial measurements conducted among British and Nepali children. The total duration of the protocol, originally devised for adults to last a total of 20 minutes, was shortened to 21 minutes, as homeless children, in particular, had limited attention spans. A recovery period of 1 minute before two spells of exercise was also instituted. A stepping block height of 15 cm was chosen, sufficient to induce an elevation of HR corresponding to light exercise, a higher step was difficult for some Nepali children, who are relatively short in height. Work output (a function of individual weight, bench height, and the rate of ascent/minute) was only 14 watts (SD 2) for boys in this study. An explicit calculation of work output is rarely made in the literature. Of course, the determination of flex HR, the value serving to discriminate between resting and exercise HR, is sensitive to the choice of workload corresponding to light exercise—a very light effort will yield a very low flex HR value.

Different approaches for computing flex HR also have been favored. Some studies have derived flex HR from a single maximum rest HR value achieved during either lying, sitting, or standing (Spragg et al. 1988; Cessna et al., 1989; Kalvins-aryk et al., 1994), others from the mean of HR values recorded during lying, sitting and standing (Livingstone et al., 1992), in a study of 15-year-old Norwegian children, found that the former method may overestimate flex HR, as some children recorded a higher HR during standing rest than during light stepping exercise, and standing HR was the single value determining maximum rest HR. The elevation of standing HR was attributed in part to a psychologica lly driven elevation of HR in anticipation of exercise, and in part to a physiologically mediated change in stroke volume with changes in posture. To avoid this problem,
FLEX HEART RATE OF NEPAI BOYS

Table 2. Sample characteristics mean and SD of all samples of Nepali boys

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, HR, and anthropometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>12.6 (4.2)</td>
<td>11.8 (4.6)</td>
<td>12.1 (4.1)</td>
<td>.05</td>
</tr>
<tr>
<td>EN (%)</td>
<td>15.3 (4.2)</td>
<td>13.9 (4.6)</td>
<td>15.4 (4.4)</td>
<td>.036</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>57.9 (9.3)</td>
<td>59.6 (9.6)</td>
<td>59.2 (9.2)</td>
<td>.00007</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.2 (8.6)</td>
<td>157.8 (8.9)</td>
<td>158.0 (8.7)</td>
<td>.00007</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.3 (4.7)</td>
<td>16.2 (4.8)</td>
<td>16.2 (4.8)</td>
<td>.955</td>
</tr>
<tr>
<td>WA</td>
<td>0.41 (0.3)</td>
<td>0.41 (0.3)</td>
<td>0.45 (0.3)</td>
<td>.00007</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>35.9 (5.5)</td>
<td>35.8 (5.5)</td>
<td>35.8 (5.5)</td>
<td>.955</td>
</tr>
<tr>
<td>Observed heart rate values</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (beats/min)</td>
<td>76 (9)</td>
<td>80 (9)</td>
<td>80 (9)</td>
<td>.85</td>
</tr>
<tr>
<td>Mean resting (beats/min)</td>
<td>68 (9)</td>
<td>68 (9)</td>
<td>68 (9)</td>
<td>.92</td>
</tr>
<tr>
<td>Mean standing (beats/min)</td>
<td>94 (9)</td>
<td>95 (9)</td>
<td>97 (9)</td>
<td>.99</td>
</tr>
<tr>
<td>Mean supine (beats/min)</td>
<td>117 (11)</td>
<td>117 (11)</td>
<td>117 (11)</td>
<td>.99</td>
</tr>
<tr>
<td>HR oscillations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean resting (beats/min)</td>
<td>66 (9)</td>
<td>70 (9)</td>
<td>70 (9)</td>
<td>.92</td>
</tr>
<tr>
<td>Flex HR (beats/min)</td>
<td>92 (9)</td>
<td>100 (9)</td>
<td>100 (9)</td>
<td>.00007</td>
</tr>
<tr>
<td>HR elevation (%)</td>
<td>15 (5)</td>
<td>15 (5)</td>
<td>15 (5)</td>
<td>.92</td>
</tr>
</tbody>
</table>

N = 177; mean values in brackets; HR = heart rate; BMI = body mass index; EN = height for age; WA, weight for height; WA, weight for age; NCBR measures.

The flex HR was defined as "the mean of the highest HR for all resting activities and the lowest HR of the exercise activities" (p. 344). Because maximum standing HR was also elevated for some Nepali boys, this study followed Livingstone et al. (1992) and utilized the three values (lying, sitting, and standing) in the calculation of maximum rest HR. But Livingstone et al. (1992) proceeded to use the mean of three mean rest values, whereas this study used the mean of three maximum rest values to derive maximum rest HR.

The second issue considers the significance of absolute flex HR values and their variability across populations. This study reports significant differences in flex HR between the two groups of Nepali children. Flex HR was lower for poor rural boys (91 bpm) than for urban school and homeless (boys 100 and 103 bpm, P < .0001). By comparison, the mean flex HR of 13-year-old Northern Irish boys was 94 bpm (Livingstone et al., 1992) and that reported for urban Colombian 10-12-year-old school boys was 95 bpm (Spurr et al., 1986). The percentage increase of mean flex HR above mean resting HR (12-18%), which was the same procedure to the value of 11% reported by Livingstone et al. (1992). At face value, this indicates that comparable levels of light exercise

Table 3. Total and repeat flex heart rates (beats/min) for children of 24 school boys

<table>
<thead>
<tr>
<th>Participant</th>
<th>Initial</th>
<th>Repeat</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95</td>
<td>100</td>
<td>-5</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>102</td>
<td>-10</td>
</tr>
<tr>
<td>3</td>
<td>97</td>
<td>96</td>
<td>-1</td>
</tr>
<tr>
<td>4</td>
<td>96</td>
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<tr>
<td>5</td>
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<td>7</td>
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<td>92</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>98</td>
<td>98</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>102</td>
<td>102</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
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<td>98</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>99</td>
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<tr>
<td>12</td>
<td>100</td>
<td>100</td>
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</tr>
<tr>
<td>13</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

N = 10; mean values in brackets; HR = heart rate; Diff = difference; Initial = first measure; Repeat = second measure; Mean = mean of initial and repeat measures.

Nepali and Indian people have lower resting and exercise HRs compared to people in developed countries. The Nepali boys' lower mean values than the comparable age-group children's 14-12 years old (Agrawal, 1992) and the difference in the mean values for the 14 boys average 9.5 ± 1.0 bpm.
were chosen for the HR flex protocol and that flex HR values similarly demarcated between rest and light exercise.

Katzmarzyk et al. (1994) also have reported significant differences in flex HR between two populations of Sibarian adults, namely, village residents and participants of work parties known as "brigades." The flex point was a mean 7 bpm higher in "brigade" relative to village men (104 vs. 97, P < 0.05), and 22 bpm higher in "brigade" relative to village women (124 vs. 102, P < 0.01). The between-population differences were attributed to elevated resting HR in the "brigade" sample, and the sex difference to the poorer fitness levels of females as determined from measurements of VO2 during sub-maximal fitness testing (Katzmarzyk et al., 1994).

Differences in physical fitness may explain the sample differences in flex HR in the present study. Village boys averaged lower mean resting HR (P < 0.0002), and consistently lower HR during the sitting (P < 0.0002), standing (P < 0.0001), and stepping (P < 0.0001) part of the protocol. They showed lower jogging values than urban schoolboys, but higher values than homeless streetboys, although caution must be exercised in the interpretation of jogging HR values. Although all boys performed the sitting, standing, stepping, and jogging parts of the protocol adequately, many homeless boys failed to jog at the required rate, even when adults jogged alongside them. These homeless boys did not appear to find the jogging phase demanding, and in fact, found it very amusing. In contrast, many middle-class schoolboys showed signs of difficulty while performing the 4-minute jogging exercise, and their high mean jogging HR values may reflect a lack of physical fitness.

Indeed, the analysis of 24-hour HR monitoring and direct observation of activity patterns (Pante & Brick et al., 1996) indicates that the village lifestyle is physically the most demanding, and is therefore strongly involved in water and firewood collection, herding animals, and carrying loads on the mountainside, some of which are 130% of their own body weight. A lifestyle involving sustained levels of physical exercise should promote physical fitness and a lower HR for any given level of physical activity. However, no evaluation of physical fitness was done in this study.

Another factor considered in accounting for the differences in flex HR values is variation in actual workload. As the urban boys are taller than villagers (Table 2) (Pante-Brick et al., 1999), they might have found stepping easier. Stephens (1984) also considered whether short stature in the case of Sibarian adult women (relative to men) would affect the ability to perform a step-test. The recommendation was made that step-tests be standardized for workload by modifying bench height according to the height and weight of participants. Such adjustment of step height in direct proportion to individual body weight was done, e.g., by Pante-Brick et al. (1999) in order to compare the performance of anaemic and control individuals during a standard work output (results on adults, but not preadolescent boys working at 40 watts, were presented). The fact that a "standard" step-test would involve differences in actual workload for taller/shorter participants or anaemic/controlled boys was anticipated at the outset, but not specifically addressed in this study by modifying the protocol. Work output was significantly lower for school boys relative to villagers (15 vs. 15 watts, P < 0.003), but despite this, the latter managed to achieve lower stepping HR values than urban counterparts. Furthermore, the HR values were neither significantly correlated with work output nor with individual height. The shorter height of villagers is not, therefore, a confounding factor in this study.

Other variables potentially contributing to variation in flex HR must be considered, namely, individual age, health and nutritional status, environmental temperature, and altitude. However, no significant associations of flex HR with age, haemoglobin, weight, or height, were found for these Nepali 10-17-year-olds. In Columbia also the mean flex HR values of undernourished and inadequately nourished boys were identical (Spurr et al., 1985). The Nepali boys who participated in the flex HR protocol if they reported feeling well and thus great ill health and cachexia as a cause of variation in HR elevation. Indeed, although values are lower for villagers in this sample, all blood spot haemoglobin are within the normal range (Table 2).

The possible effect of altitude on HR was discussed by Slotten et al. (1981) in a study of Bolivian boys living at low (400 m) and high altitude (4,000 m). Lower mean resting, maximum, and mean HR was found at high altitude, which was attributed to changes in autonomic regulation of HR resulting in a
reduced sensitivity of the heart to sympathetic drive and to a possible increase in parasympathetic activity. In the present study, the altitude difference between the Nepali rural and urban locations (570 m) is unlikely to explain the lower flex HR of village boys.

A final comment can be made with respect to the reliability of flex HR measurements and the extent of within-population variation. Flex HR measurement was repeated on 14 schoolboys 3 months after initial testing. Mean values did not differ over time, but there were considerable discrepancies for individual subjects: the likely range of error was only 3 bpm for the sample, but averaged 9 bpm for individual boys. The results suggest that flex HR is reliable at a population level, if not individual level. Intraclass variation in flex HR, and consequently in the relationship between HR and energy expenditure, may partially account for the fact that HR monitoring has been found a valuable procedure for the estimation of energy expenditure among groups, but not for single individuals (Kalberer et al., 1989).

Licht et al. (1983) report considerable intrasubject variation in the relationship between energy expenditure and HR, assessed by means of regressions calibrated for individual flex, having repeated a graded activity protocol. They concluded that the use of HR monitoring as a proxy measure for energy expenditure requires the calibration of HR with energy expenditure just prior to HR monitoring, as a previous calibration curve for the same individual cannot be relied upon. The intrasubject variation in flex HR exhibited by the Nepali schoolboys also suggests that flex HR should be determined just prior to 24-hour HR monitoring as variations in its value will influence the discrimination of training and exercise intensity and the evaluation of physical activity levels in any one individual. Although between-subject variation in calibration measures are well known (Livingstone et al., 1992), within-subject variation deserves further attention.

In conclusion, both methodological and substantive issues regarding the measurement of HR flex should be carefully examined prior to the application of HR monitoring to estimate levels of physical activity and energy expenditure. First, the workload involved in light exercise should be quantified and variation in individual work output during measurement of HR flex explicitly recognized. The possibility of within-subject variation should be recognized, as repeat measures of flex HR, although reliable at a population level, may differ considerably for an individual over time. Second, greater attention should be paid to possible differences in flex HR values and levels of physical fitness across populations. This has implications for between-population comparisons, which rely on the use of absolute cutoff points to compare levels of physical activity (Paxton-Brock et al., 1990). With these caveats, the use of HR monitoring is a useful and appropriate method for estimating levels of physical activity.

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