PHYSIOLOGICAL MEASUREMENT DURING VARIABLE PHYSICAL WORK DEMAND ACTIVITY

I. The Validity of the 10 Beat Measure for Calculation of Heart Rate Minute⁻¹

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Introduction

It has been proposed by Brooke, Hamley and Thomason (1970) "that exercise heart rate should be defined as the time taken for 10 beats of the heart measured from the stable wave pattern of the normal electrocardiogram and converted into beats/minute". They report that the 10 beat measure is the most acceptable for both within trial and between trial reliability during work to exhaustion on the Müller cycle ergometer when using a continuously increasing load.

In many physical activities the load consists of short bursts of high energy expenditure interspersed in a lower rate of sustained effort. This pattern of physical work characterizes the activity of players in most high energy cost games, both the major invasive team games such as soccer and rugby and court games such as tennis and squash. This type of activity contrasts sharply with the continuously and linearly increasing load test used in establishing the validity of the 10 beat measure for determination of heart rate min⁻¹.

Telemetry or the use of a transitory electrode device, T.E.D., Brooke and Knowles (1971), provide the facility for monitoring heart rate during activities with variation in physical work demand. Telemetry can be used to provide a continuous record of heart rate but clearly there is considerable advantage to be gained if the 10 beat measure is valid as a method for determining heart rate min⁻¹ in this type of activity. The analysis of ECG traces obtained during the entire performance can be very costly in research time and materials when minute by minute heart rates are required for say, the full 90 minutes of a soccer match. At the same time, heart rate measurement via telemeters or T.E.D.'s is increasingly used in studies of energy expenditure, Brooke and Knowles (1974), Wilmore and Haskell (1971), Bradfield (1971), McArdle et al (1971) and Andrews (1971).

The Problem

The problem was to investigate the relationship between the exercise heart rate obtained from the time for 10 beats measured at the end of each work minute and the heart rate obtained from the sum of all heart beats for each work minute in active young men performing a treadmill task containing increasing numbers of 5 second speed bursts min⁻¹.

Method

Continuous direct wire ECG recordings were made at a paper speed of 150 cms min⁻¹ (25 mm sec⁻¹) from 12 trained male soccer players (Age $\bar{x}$ = 24 years). All subjects performed an identical pre-test treadmill run followed by a horizontal treadmill work test to exhaustion which required increasing numbers of 5 second bursts of speed per minute as shown in Table I.

Table I

The physical work regime on the Treadmill with jog speed 10 km hr⁻¹ and 'Burst' speed 20 km hr⁻¹

Min.	No. of 5 Sec. Bursts	Jog Duration per Min.
1	1	55 sec
2	1	55 sec
3	2	50 sec
4	2	50 sec
5	3	45 sec
6	3	45 sec
7	4	40 sec
8	4	40 sec
9	5	35 sec
10	5	35 sec
11	6	30 sec
12	6	30 sec

The variations in speed were obtained by using the fast response electronic speed control system of the Jaeger "Laufertotest" Treadmill.

The ECG trace for each subject was analysed using the following two procedures:-

1. The number of beats/min⁻¹ was obtained by marking off the recording paper in 150 cm portions, corresponding to each minute of exercise, and counting the number of R-R wave intervals with the aid of a mechanical counter. This provided a direct measure of the total number of beats in each exercise minute.
2. The heart rate in beats/min⁻¹ was estimated also by calculation from the last 10 beats recorded in each

minute after the manner of Brooke et al (op. cit).

The paired data, total beats recorded per minute versus beats/min⁻¹ calculated from the 10 beat measure (number of data pairs $n = 94$), was subjected to the analysis of variance procedures employed by Brooke et al (op. cit) and described by Hoyt (1941), Jackson (1941) and Liba (1962) to obtain a reliability coefficient (r_{11}) by the formula,

$$r_{11} = \frac{V_I - V_I \times T}{V_I + (k - 1)V_I \times T}$$

The standard error of measurement relating to the reliability coefficient obtained was established using the formula given by Thorndike (1951),

$$Se = S\sqrt{1 - r_{11}}$$

Results

Table II gives the descriptive statistics (mean heart rate and standard deviation) from the paired data at each point and over all data pairs.

Table II

Means and standard deviations for the two techniques of heart rate measurement at each minute of the variable load, increasing intensity work task

Time	No. of Subjects (data pair)	$\bar{x}$ Total No. of beats min ⁻¹	S.D.	$\bar{x}$ '10 beat' Heart rate (beat min ⁻¹)	S.D.
0-1	11	161.36	13.86	169.64	11.32
1-2	12	172.33	12.99	173.33	14.28
2-3	11	175.73	12.74	179.27	11.50
3-4	11	180.55	12.14	182.27	11.82
4-5	10	185.10	14.49	186.20	10.72
5-6	7	184.43	13.40	186.71	13.47
6-7	8	186.62	12.26	187.75	11.71
7-8	8	187.87	11.38	190.25	9.94
8-9	6	187.19	9.70	189.33	9.56
9-10	5	181.00	23.92	182.00	23.65
10-11	5	188.00	8.92	190.44	8.91
Overall	94	179.98	14.73	182.60	13.19

Table III shows the results from analysis of the replicability of the paired data at each work intensity and overall, together with the standard errors of measurement and the 95% confidence limits to describe the bounds of variability of any single subject, given by the formula $\pm tSe$ for samples of this size.

Table III

Replicability coefficients, standard error of measurement and 95% confidence limits overall and minute for the two types of heart rate measurement in the variable load, increasing intensity work task.

Time (min)	No. of Subjects	r_{11}	S	Se	$\pm t Se$ (p = .05) for error of measurement $\pm$ beats min ⁻¹
0-1	11	0.889	13.05	4.347	9.685
1-2	12	0.921	13.36	3.75	8.254
2-3	11	0.958	11.98	2.45	5.459
3-4	11	0.946	11.72	2.72	6.060
4-5	10	0.904	12.42	3.89	8.799
5-6	7	0.962	12.97	2.53	6.191
6-7	8	0.937	11.59	2.91	6.882
7-8	8	0.917	10.40	3.00	7.095
8-9	6	0.891	9.26	3.05	7.842
9-10	5	0.985	21.43	2.75	7.634
10-11	5	0.963	8.50	1.63	4.525
Overall	94	0.939	14.01	2.69	5.326

Discussion

Comparison of the results of this study with those obtained by Brooke et al (op. cit) for linearly and continuously increasing power load reveal some reduction in reliability and slight increase in the 95% confidence limits. Table IV shows some of the more important values for comparison.

Table IV

Comparison of results from variable (present study) and continuously increasing work demand (Brooke et al).

	Brooke et al	Present Study
Lowest r_{11}	0.950	0.889
Highest r_{11}	0.999	0.985
Overall r_{11}	—	0.939
95% level at lowest work point	± 5.70 beats/min	± 9.68 beats/min
95% level at highest work point	± 1.39 beats/min	± 4.52 beats/min

The reduction in accuracy from use of the '10 beat' measure to estimate heart rate/min for 'unsteady state' work is apparent. It is not considered so great as to invalidate the technique for energy expenditure studies since alternative methods of estimating the energy cost of field activities are also dependent upon techniques which involve approximations. Traditional indirect

calorimetry, Durnin and Passmore (1967) and Åstrand and Rodahl (1970), use expired air samples collected during only a limited period of the whole activity and have the added disadvantage of encumbered performers. Manual pulse palpation is notoriously prone to measurement error at the higher exercise heart rates and this is the only alternative to the use of telemetry and T.E.D. techniques. Even with complete measurement of all heart beats, the tedium resulting pre-disposes to error. If greater precision than the present technique is required the solution is electronic digitalisation of the ECG trace.

It should be noted that reliability tends to increase with increased work intensity. This agrees with the findings reported by Brooke et al, op. cit, and adds weight to the case for accepting the validity of the '10 beat measure' for determination of heart rates min^{-1} during or immediately post exercise.

Conclusion

The '10 beat measure' is a valid technique for use in the measurement of exercise heart rates in activities where the physical work demand is variable and the objective is assessment of energy expenditure.

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