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Communications

RECOVERY CARDIAC COST FOLLOWING SHORT DURATION HIGH INTENSITY EXERCISE IN PREPUBERTAL, JUST PUBERTAL, AND POSTPUBERTAL GIRLS AND ITS RELATIONSHIP WITH PHYSICAL AND PHYSIOLOGICAL PARAMETERS

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Recovery cardiac cost (RCC) after short duration high intensity exercise and its relationship with physical and physiological parameters were assessed for 45 sedentary girls aged 10-25. RCC of postpubertal girls were significantly lower than those of prepubertal and just pubertal girls, when expressed in terms of cost in beats above rest. No significant differences were found among the three groups regarding RCC values in terms of % cost above rest. Age and diastolic blood pressure were negatively correlated with RCC both in terms of cost in beats above rest and % cost above rest only in postpubertal group. Pre-exercise heart rate in postpubertal group was negatively correlated with RCC only in terms of % cost above rest. No positive or negative correlation was found between RCC and other parameters under study, in prepubertal and just pubertal groups.
Keywords: sedentary; maturity; cardiac activity

INTRODUCTION

Heart rate has been used to demonstrate the effect of work on cardiac performance since early 1900's (Bowen,1904). It has been shown later by various investigators (Brouha et al., 1961; Brouha and Maxfield, 1962; Maxfield, 1964) that the rate of oxygen consumption is not necessarily a reliable indicator of the physiological strain induced by work, whereas heart rate reflects the degree of strain. When continuous measurement of heart beats during performance is not possible, as often in the case of less availability of laboratory equipments, pertinent evidence of the degree of the physiological strain induced by work can be easily obtained from the recovery cardiac cost (RCC) when the experiment is over (Gemmill et al., 1930). In the following years, studies on cardiovascular performance, fitness, strain etc., were conducted by using heart rate during recovery period after exercise and the rapidity of return of the same to the pre-exercise level was the area of interest (Oida et al., 1997).

Measurement of recovery cardiac activity following various intensities of exercise using heart rate were conducted in different categories of sports persons (Oida et al., 1997; Solberg et al., 2000) as well as among sedentary men and women of higher age group (Maxfield, 1964; Brouha and Maxfield, 1962; Maxfield and Brouha, 1963).

Whereas previous research has made comparisons among various sports categories as well as between aged men and women, the influence of maturation before, during, and following pubertal period on RCC remains unknown, especially in cases of Indian girls. Keeping this lacuna in mind, the present investigation has the following objectives:

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1. To determine whether any significant difference exists among prepubertal, just pubertal and postpubertal girls, regarding the value of RCC expressed both in terms of cost in beats above rest and % cost above rest.

2. To determine whether there is any relationship between RCC expressed in terms of cost in beats above rest and % cost above rest with age and other physical as well as physiological parameters.

MATERIALS AND METHODS

Forty five normal healthy sedentary female subjects aged 10 to 25 participated in the present investigation. No individual was accepted as subject if she had a history of any cardiovascular or pulmonary disorder or displayed an irregular electrocardiogram or abnormal blood pressure in the pre-exercise resting state. The subjects were divided into three groups according to maturity status; prepubertal (Pre) group (n=15), just pubertal (Pub) group (n=15), and postpubertal (Post) group (n=15). Maturity status was assessed by trained research nurses by using Tanner's Indices for pubic hair development (Tanner, 1962). Written consent was obtained from both the participants and their parents and/or guardians. Subjects were not tested during menses.

All the subjects were requested to refrain from eating and engaging in any strenuous physical work for at least 1 hour before the experiment. The purpose of the experiment was explained to them to stimulate their interest and to encourage them to perform the task to their utmost ability. After an initial half-hour rest, the subject's physical and physiological characteristics, including age, height, weight, pre-exercise (baseline) heart rate, peak heart rate, respiratory rate, blood pressure (pre-exercise), $\dot{V}O_2$max (ml/min/kg), $\dot{V}O_2$max (l/min), previous case history were noted. The body surface area (BSA-m^2) was estimated for each individual using the DuBois formula:

$$BSA=0.007184\ W^{0.425}\ H^{0.725}$$

for the weight (W) in kilograms and height (H) in centimeters (DuBois and DuBois, 1916).

Regarding recovery cardiac cost assessment in all age groups, exercise consisted of running on a motor driven treadmill (Venky Treadmill, D.IG.Model No.1460 RE) at a speed of 8 km/h for 5 minutes at a 3.0 uphill inclination. The treadmill was calibrated before the actual test and all subsequent warm-ups. Warm up consisted of walking on the treadmill at a speed of 4 km/h at 4.5 inclination for 5 minutes (Slonim et al.,1957). Peak heart rate was recorded from palpation of carotid artery using an electronic stop watch, immediately after exercise by 10 beats method, afterwards converted to beats/min. After performance, post exercise heart rate was measured for each minute up to 20 mins (Maxfield,1964), while the subject lying supine on a comfortable base. Recovery cardiac cost was calculated according to Maxfield and Brouha (1963), which is the following:

RCC (beats) = Sum of recovery heart beats.

RCC above rest in beats was calculated from cardiac rest cost and RCC in the following way:

Cardiac rest cost (beats) = Average resting heart rate (beats/min) x Recovery time (min)

RCC above rest (beats) = RCC (beats) - Cardiac rest cost (beats)

RCC in % above rest was calculated by general % calculation procedure used in the mathematics. The $\dot{V}O_2$max was assessed from the results of an incremental work test (30W increase in exercise intensity per 2 min) performed on a cycle ergometer for all age groups (Kondo et al., 1996). Both recovery cardiac cost and $\dot{V}O_2$max were measured on the same day, RCC followed by $\dot{V}O_2$max, providing sufficient recovery time between the two tests, so that the elevated heart rate could return to the baseline level. The whole experiment was performed in a laboratory of Calcutta, eastern region of India, the temperature of which was 28±1°C and the relative humidity 64%.

All data were reported as group means ±SD. To test the significance of the difference between the means of 3 test samples, Student's t test was applied. Pearson's product-moment correlation was used to measure the probable correlation coefficient between recovery cardiac cost and other physical as well as physiological parameters. Significance was set at $P<0.05$.

RESULTS

The physical and physiological characteristics of three groups are shown in Table 1. The Pub group and Post group were significantly older, taller and heavier, than Pre group. Post group was significantly older ($p<0.001$) and significantly less in pre-exercise heart rate ($p<0.05$), peak heart rate ($p<0.01$) and pre-exercise respiratory rate ($p<0.001$) than Pub group. No statistically significant difference was observed in blood pressure value among all three groups. $\dot{V}O_2max$ expressed in ml/min/kg unit was found to be not significantly different among age groups. But $\dot{V}O_2max$ value in absolute unit ,i.e. l/min was found to be significantly higher in Post group than in both Pre ($p<0.05$) and Pub ($p<0.05$) groups.

Between-group difference in RCC value, when expressed in terms of % cost above rest, was found to be statistically nonsignificant. But when expressed in terms of cost in beats above rest, RCC was found to be significantly lower in Post group than in Pre ($p<0.01$) and Pub ($p<0.01$) groups.

Table 1. Physical parameters and physiological characteristics of prepubertal, just pubertal and postpubertal subjects.

	Pre (n=15)	Pub (n=15)	Post (n=15)	
Age (years)	13.1 ± 0.7	16 ± 1.1 ***	22.8 ± 2.2 ***	###
Body height (cm)	141.3 ± 5.7	156.4 ± 6.7 ***	156.8 ± 4.1 ***	
Body weight (kg)	36.2 ± 7.1	49.1 ± 9.4 ***	51.7 ± 7.6 ***	
BSA (m^2)	1.2 ± 0.1	1.45 ± 0.1 ***	1.49 ± 0.1 ***	
HRb (beats/min)	83.4 ± 6.5	85.8 ± 6.0	78.7 ± 8.0	#
HRp (beats/min)	206.9 ± 11.1	210.4 ± 11.0	197.1 ± 13.9 *	##
Rr (per min)	21.3 ± 2.7	23.8 ± 4.2	18.1 ± 3.6 *	###
BPs (mmHg)	110.9 ± 7.7	116 ± 8.5	114.6 ± 10.6	
BPd (mmHg)	69.8 ± 8.9	75.8 ± 8.2	71.4 ± 11.0	
$\dot{V}O_2max$ (ml/min/kg)	32.8 ± 2.0	31.4 ± 2.3	34.5 ± 3.5	
$\dot{V}O_2max$ (l/min)	1.48 ± 0.3	1.54 ± 0.3	1.78 ± 0.3 *	#
RCC_b (beats)	815.8 ± 192.7	846.9 ± 136.2	579.6 ± 243.5 **	##
$RCC_{\%}$ (%)	49.1 ± 12.7	49.4 ± 8.0	50.5 ± 19.4	

Values are mean ±SD. Pre, prepubertal; Pub, just pubertal; Post, postpubertal; BSA, body surface area; HRb, pre-exercise (baseline) heart rate; HRp, peak heart rate; Rr, pre-exercise respiratory rate; BPs, systolic blood pressure; BPd, diastolic blood pressure; $\dot{V}O_2max$, maximal aerobic capacity; RCCb, recovery cardiac cost in beats above rest; RCC%, recovery cardiac cost in percentage above rest. * $p<0.05$ (Pre vs Post), ** $p<0.01$ (Pre vs Post), *** $p<0.001$ (Pre vs Pub, Pre vs Post), # $p<0.05$ (Pub vs Post), ## $p<0.01$ (Pub vs Post), ### $p<0.001$ (Pub vs Post).

Table 2. Correlation coefficients between RCC and physical or physiological parameters in postpubertal subjects (n=15).

Parameters	RCC_b	$RCC_{\%}$
Age (years)	-0.64 **	-0.56 *
Body height (cm)	-0.23	-0.17
Body weight (kg)	-0.42	-0.45
Body surface area (m^2)	-0.41	-0.43
Pre-exercise heart rate (beats/min)	-0.29	-0.56 *
Peak heart rate (beats/min)	-0.07	-0.06
Pre-exercise respiratory rate (rate/min)	0.36	0.22
Systolic blood pressure (mmHg)	-0.42	-0.44
Diastolic blood pressure (mmHg)	-0.55 *	-0.6 **
$\dot{V}O_2max$ (ml/min/kg)	0.08	0.07
$\dot{V}O_2max$ (l/min)	-0.31	-0.33

* $p<0.05$, ** $p<0.01$

No significant correlation coefficient was observed between RCC and other physical and physiological parameters in cases of Pre and Pub groups. But in Post group (Table 2), significant negative correlations were observed between RCC in terms of beats cost (r=-0.64, $p<0.01$) as well as RCC in terms of % cost above rest (r=-0.56, $p<0.05$) and age. Significant negative correlations again observed between RCC in terms of % cost and pre-exercise heart rate (r=-0.56, $p<0.05$), RCC in terms of cost in beats and diastolic blood pressure (r=-0.55, $p<0.05$), and RCC in terms of % cost above rest and diastolic blood pressure (r=-0.60, $p<0.01$).

DISCUSSION

According to pediatric literature, physical maturity and anaerobic metabolism are interrelated to each other. Anaerobic metabolism is found to be limited in children, relative to adults. The contention that maturation influences anaerobic metabolism is highly supported by lower peak blood lactate concentration (Atomi et al., 1986) and lower anaerobic power in children, compared with adults (Falk and Bar-Or, 1993). There are a number of explanations for the low blood lactate concentration, often reported in the literature, including motivation of the subjects, measurement techniques, muscle size etc. (Petersen et al., 1999). It has been frequently suggested that at similar relative exercise intensities, prepubescent children rely more on oxidative metabolism than do their pubertal and more adult counterparts (Berg et al., 1986).

Energy coefficient of the heart is being met in the form of ATP, either by glycolysis or by oxidation of carbohydrates and non-carbohydrates. Metabolism of cardiac muscle is similar to that of skeletal muscles. During cardiac contractions, ATP and creatine phosphate breakdown and supply energy. The energy is resynthesised by the oxidation of pyruvic acid or lactic acid. In the absence of O_2, lactic acid is produced by glycolysis which supplies energy. Cardiac muscle uses lactic acid completely. Probably it indicates that heart muscle uses glucose for synthesis of glycogen, while it derives energy by burning lactic acid (Chatterjee, 1987a). However, anaerobic metabolism can generate high energy phosphate bonds at a rate even 100 times that of oxidative phosphorylation (Das, 1993). This explanation may support the lower recovery cardiac cost value in the case of Post group. In our study, the Post subjects may have relied more on glycolysis, and the Pre and Pub subjects may have relied more on oxidative metabolism, an explanation also put forward by Taylor et al. (1997).

From magnetic resonance images of the leg, it was determined by Petersen et al. (1999) that the mean gastrocnemius muscle thickness in pubertal girls was up to 44% greater than that of prepubertal counterparts (13 mm vs 9 mm). It was also demonstrated by various other investigators (Zhu et al., 1993) that gastrocnemius muscle is the primary contributor of muscle power during intense exercises. It favours rapid glycolysis under exercising conditions, which in turn causes generation of more energy than oxidative metabolism, and initiates a tendency toward lower ‘pHi’ (intracellular pH) as well as overall decreased cardiac strain, and accordingly lower RCC in Post group.

In the present study, in Post group, age and HRb showed a negative correlation with RCC. As it was explained in Chatterjee (1987b), cardiac activity is inversely proportional to age, but directly proportional to metabolic rate. It can be well adjusted according to the metabolic needs. Cardiac response (especially heart rate) to various stimuli like exercise, excitement etc also have an inverse relationship with size of animals; the greater the size, the smaller the heart rate (Chatterjee, 1987b). These findings may explain the relationship observed in our study, as the height, weight and BSA were all found to be significantly higher in Post group than in Pre and Pub groups.

Negative correlation was also found to exist between RCC and BPd or pre-exercise heart rate. Diastolic blood pressure is the measure of peripheral resistance. It indicates the constant load against which heart has to work (Chatterjee, 1987c).

In our findings, recovery cardiac cost value following short term high intensity exercise was found to be significantly lower in postpubertal subject than in pre pubertal and just pubertal subjects. Although just pubertal group showed higher RCC values than prepubertal group, the differences were found to be statistically nonsignificant. Cardiac activity in response to physical stress decreases gradually as the age and maturity increase .

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