Physical activity patterns defined by continuous heart rate monitoring

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Abstract

To investigate the physical activity patterns of British primary schoolchildren (mean (SD) 10·7 (0·3) years) the minute by minute heart rates of 67 boys and 65 girls were monitored continuously for three 12 hour periods during normal schooldays. In addition 39 children had their heart rates monitored during a 12 hour period on a Saturday. Few children experienced the volume (frequency, intensity, and duration) of physical activity associated with an improvement in cardiopulmonary fitness. Shorter (five minute) periods of the required intensity were, however, quite common. No difference between moderate amounts of activity was detected between boys and girls, but the boys had more five minute sessions of intense activity than the girls. These findings suggest that more research into the effects of short periods of intense physical activity on the cardiopulmonary systems of young children is required and that the determinants of habitual physical activity require further investigation especially in the context of sex differences at such an early age.

A recent review of the published physical activity recommendations for children concluded that appropriate physical activity for children should entail large muscle groups moving dynamically for periods of 20 minutes or longer, three or more times/week, at an intensity that elicits heart rates equal to or in excess of 140 beats/minute.[1] This recommendation correlates with the amount of physical activity suggested by Morris *et al* as being associated with a low incidence of coronary heart disease in adults.[2] Other reviewers, however, have indicated that more intense exercise—up to 80% of maximum heart rate (roughly 160 beats/minute)—is necessary for the improvement of children's cardiopulmonary fitness.[3] Whether British primary schoolchildren regularly undergo these amounts of physical activity is unknown.

Interpretation of published reports about children's physical activity patterns is beset with problems caused by the inherent difficulty of defining the quality and quantity of children's physical activity. Reliable data are limited and must be interpreted according to the methods used. The 'self report' (by retrospective questionnaire or daily diary) of the intensity and duration of periods of activity by children is difficult because children are less conscious of time than adults and tend to engage in physical activity that is sporadic, both in time and intensity. Ideally the relative intensity and duration of activities should be immediately and simultaneously assessed. The monitoring technique must be socially acceptable, it should not burden the child with cumbersome equipment, and it should have a minimal influence on the child's normal physical activity patterns. Bar-Or suggested that if a true picture of habitual physical activity is required, at least three days of monitoring are necessary.[4] No investigation of habitual physical activity among British primary schoolchildren that satisfies these criteria to our knowledge has been carried out. This study was therefore designed to examine the physical activity patterns of such children, aged 10 years.

Subjects and methods

SUBJECTS

Written informed consent to participate in the project was obtained from the parents and all the children in the sixth year at five primary schools in Devon. The children's age was computed from date of birth and date of physical activity assessment. Height was measured with an anthropometer (Cranlea Medical) calibrated against a Harpenden stadiometer (Holtain), and weight was determined on scales (Griffin and George) calibrated against a beam balance (Avery 3306 ABV).

ASSESSMENT OF PHYSICAL ACTIVITY

The volume (frequency, intensity, and duration) of physical activity of 67 boys and 65 girls was estimated from continuous heart rate monitoring over three normal schooldays. Physical activity is not directly measured in this way, but—perhaps more importantly—the relative stress being placed upon the cardiopulmonary system by the activity is monitored. For ease of exposition, however, it will be assumed that volume of heart rate response is indicative of volume of physical activity.

A self contained, computerised telemetry system (Sport Tester 3000) was used to record continuously heart rates minute by minute. The Sport Tester 3000 consists of a lightweight transmitter, which is fixed to the chest either by a belt or with electrodes, and a receiver/microcomputer, which is worn as a watch on the wrist. It is a reliable and valid way of recording heart rates in children,[5] and a recent survey of the most popular commercially available heart rate monitors concluded that the Sport Tester 3000 was first choice as 'in addition to having excellent validity and stability it permits almost

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total freedom of motion'.[6] The Sport Tester 3000 is capable of storing and replaying minute by minute heart rates for up to 16 hours and if it is interfaced with a microcomputer a simple programme permits sustained periods when heart rates are above selected thresholds to be readily identified and recorded. Each child was monitored from about 0900 until 2100 during a normal schoolday. The receivers were retrieved, replaced, and refitted the next morning and the process was repeated for three days. In addition 39 of the children (16 boys and 23 girls) were monitored from 0900 until 2100 on a Saturday.

Results

The data were stored and analysed using RS1 database (BBN Software Products Corporation) installed on an IBM-PC. Descriptive statistics were computed and the significance of differences assessed by the appropriate *t* test.

The physical characteristics of the children are shown in table 1. There were no significant differences ($p>0.05$) between the girls and boys in age, height or weight, or between girls and boys in the percentage of time they spent with heart rates above 139 beats/minute during either weekdays (boys 9·4%, girls 8·2%) or Saturdays (boys 5·2%, girls 6·0%). The boys, however, spent a significantly higher percentage of time ($p<0.05$) with heart rates above 159 beats/minute during weekdays (boys 4·5%, girls 3·5%) but not during Saturdays (boys 1·8%, girls 1·8%).

Table 1 Physical characteristics of the children. Values are expressed as mean (SD)

	Boys (n=67)	*Girls (n=65)*
Age (years)	10·7 (0·3)	10·7 (0·3)
Height (m)	1·4 (0·06)	1·4 (0·07)
Weight (kg)	35·3 (5·7)	36·2 (7·1)

Table 2 Number (%) of children and number of periods when they achieved heart rate of >139 beats/minute during three days of weekday monitoring

	Boys (n=67)	*Girls (n=65)*
5 Minute periods:		
0	1 (1)	0
1	2 (3)	6 (9)
2	4 (6)	4 (6)
≥3	60 (90)	55 (85)
10 Minute periods:		
0	13 (19)	16 (25)
1	10 (15)	18 (28)
2	13 (19)	11 (17)
≥3	31 (46)	20 (31)
20 Minute periods:		
0	41 (61)	43 (66)
1	12 (18)	14 (22)
2	7 (10)	7 (11)
≥3	7 (10)	1 (2)

Table 3 Number (%) of children and number of periods when they achieved heart rate >159 beats/minute during three days of weekday monitoring

	Boys (n=67)	*Girls (n=65)*
5 Minute periods:		
0	5 (7)	10 (15)
1	6 (9)	17 (26)
2	12 (18)	9 (14)
≥3	44 (66)	29 (45)
10 Minute periods:		
0	31 (46)	36 (55)
1	13 (19)	16 (25)
2	7 (10)	5 (8)
≥3	16 (24)	8 (12)
20 Minute periods:		
0	52 (78)	51 (78)
1	10 (15)	11 (17)
2	3 (4)	3 (5)
≥3	2 (3)	0

Table 4 Number (%) of children and number of periods when they achieved heart rate >139 beats/minute during one day of weekday monitoring

	Boys (n=16)	*Girls (n=23)*
5 Minute periods:		
0	7 (44)	10 (43)
1	5 (31)	5 (22)
2	2 (13)	1 (4)
≥3	2 (13)	7 (30)
10 Minute periods:		
0	12 (75)	15 (65)
1	4 (25)	4 (17)
2	0	0
≥3	0	4 (17)
20 Minute periods:		
0	13 (81)	22 (96)
1	3 (19)	1 (4)
2	0	0
≥3	0	0

Table 5 Number (%) of children and number of periods when they achieved heart rate >159 beats/minute during one day of weekday monitoring

	Boys (n=16)	*Girls (n=23)*
5 Minute periods:		
0	11 (69)	17 (74)
1	3 (19)	3 (13)
2	2 (13)	1 (4)
≥3	0	2 (9)
10 Minute periods:		
0	13 (81)	21 (91)
1	3 (19)	2 (9)
2	0	0
≥3	0	0
20 Minute periods:		
0	14 (88)	23 (100)
1	2 (13)	0
2	0	0
≥3	0	0

The interpretation of continuous heart rates is complex because not only is the metabolism of the child reflected, but also the transient emotional state, the prevailing climatic conditions, and the specific muscle groups that perform the activity. Therefore although the percentage of time spent in various heart rate ranges is of interest, we think that the primary consideration should be the number and length of sustained periods above selected thresholds. Accordingly we have analysed the number (%) of children who have sustained five minute, 10 minute, and 20 minute periods with heart rates above 139 beats/minute and 159 beats/minute during weekday and weekend monitoring (tables 2, 3, 4, and 5). The boys had significantly more 5 minute periods with their heart rate above 159 beats/minute during weekday monitoring ($p<0.05$) but there were no other significant differences between the sustained heart rate response of boys and girls ($p>0.05$).

Discussion

Few children spent daily periods of 20 minutes

or longer with their heart rates above the recommended thresholds, indicating that sustained periods of physical activity for this length of time are not features of children's habitual physical activity. A similar analysis of 10 minute periods also showed that only a minority of children spent a daily session with their heart rates above the recommended levels. When 5 minute periods were examined, however, it was shown that most of the children had daily sessions of this length when their heart rates exceeded 139 beats/minute and two thirds of the boys and almost half of the girls had a daily 5 minute period when their heart rates exceeded 159 beats/minute. Over half of the children had a five minute period on a Saturday with their heart rates over 139 beats/minute, although only a small minority elicited heart rates of over 159 beats/minute for this length of time. It is therefore obvious that the physical activity patterns of primary schoolchildren consist of relatively short periods of physical activity, perhaps as a result of their limited attention span.

To put these figures into perspective it is noteworthy that with children of this age we have found that brisk walking on the treadmill at 6 km/hour elicits steady state heart rates in excess of 140 beats/minute and jogging at 8 km/hour generates steady state heart rates of over 160 beats/minute. Our results therefore indicate that although there seems to be no difference in moderate activity (equivalent to brisk walking) of boys and girls, boys experience more short intense periods of physical activity than girls.

No previously published study that we know of has reported the unobtrusive heart rate monitoring of British primary schoolchildren for extended periods of time. Direct comparisons of our data with those from elsewhere are difficult because of the different methods used, and because of our emphasis on the importance of sustained periods of physical activity. In a study from the Netherlands Saris developed a heart rate integrator and used the instrument in a biannual, 24 hour, analysis of 217 boys and 189 girls over a six year period beginning when the children were 6 years old.[7] He concluded that, at all ages, boys had a higher total energy expenditure and spent more time above 50% of maximal aerobic power than girls. Atomi *et al* monitored the 12 hour heart rates of 11 Japanese boys aged 10·4 years during three 'rainless days in winter' with a heart rate memory recorder.[8] They reported that boys spent on average 4·7% of their time at heart rates equivalent to 60% of maximal aerobic power.

The most quoted studies of the physical activity of primary schoolchildren are, however, those carried out by Gilliam *et al* with 6 and 7 year old children in the United States.[9–11] In their initial study they monitored the heart rates of 22 boys and 18 girls from 0800 until 2000 during a summer day. Both boys and girls had heart rates of more than 160 beats/minute for 2·9% and 1·3% of the time, respectively. The boys had heart rates of more than 140 beats/minute for 7·8% of the time and the girls for 4·0% of the time. In an intervention study in which they used the same methods and probably studied some of the same children, they reported that on average 59 children aged 7 years old spent 6·9% of their time with heart rates above 140 beats/minute.[10 11] They concluded that young children seldom undergo physical activity of high enough intensity to promote cardiovascular health, and that boys are more active than girls.

The physical activity patterns reported here compare favourably with those of children from elsewhere. Our data confirm the finding that boys experience more sessions of intense activity than girls, but we have detected no difference in moderate activity between the two sexes. Primary schoolchildren rarely experience periods of physical activity of the duration recommended for the improvement of cardiopulmonary fitness. More research into the effects of relatively short periods of intense physical activity on the cardiopulmonary systems of young children is required. The determinants of children's habitual physical activity must be further investigated, especially in the context of sex differences at such an early age.

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