Heart rates during competitive orienteering

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This study investigated the heart rate profiles of 16 experienced, competitive orienteers (aged 15–62 years) during three competitive events. Each competitor was assessed over three different types of course which were classified as: fast run (FR), slow run (SR) and highly physical (HP). The results showed that all subjects recorded heart rates that were between 140 and 180 beats min^{-1} for the majority of each event (irrespective of age or course type). The heart rate data indicated that the activity was largely aerobic but varied in intensity, with phases of strenuous anaerobic work. The type of course was shown significantly (analysis of variance; $P < 0.001$) to affect the mean heart rate attained by each orienteer (FR = 160, HP = 158, SR = 150 beats min^{-1}), with courses that required more technical skill and hence slower running producing lower mean heart rates; although the general physical demands were similar for all courses. The older orienteers (>45 years) recorded heart rate profiles that were similar to those of the young orienteers with no correlation being found between age and mean heart rate while exercising.

Keywords: Orienteering, heart rates, cardiovascular fitness, ageing

Competitive orienteering is a form of foot race which requires both physical fitness and navigational skills. Using a map (scale 1:10 000 or 1:15 000) and compass, the participants must visit a number of specific control sites in a designated order; the winner being the person who completes the course in the quickest time. The ages of the participants in orienteering events range from under 10 to over 70 years and to cover this range there are a maximum of 15 competitive age categories (the exact number depending upon the type of event) with men and women also competing in separate classes. Events range in standard and are designated as being: (1) local; (2) colour coded; (3) badge; (4) national. At any orienteering event a number of courses of varying length and technical difficulty are available, and competitors participate in a course that is appropriate for their age, fitness and experience. To maximize the technical aspect of the sport, competitors on the same course start at intervals of at least 1 min.

The venues for orienteering events include local parks, woods, forests, heathland, open moorland

and mountain areas. The terrain over which the event is run influences the distance covered, the amount of climb incorporated into the course and the 'runability' of the ground (which can vary from paths and grassland to heather, bracken, brashings and dense undergrowth). The physical nature of the sport means that it is a continuous form of exercise that may last from less than 30 min to over 2 h. Within this time the intensity of the exercise will vary according to: (1) the terrain, which may be uphill, downhill or flat; (2) the conditions underfoot, which may be even or uneven with obstructions such as undergrowth and brashings; (3) the vegetation, which may be open or dense; (4) the technical aspects of the course, which may be easy, thereby permitting fast running, or difficult requiring intricate navigation and therefore a slower speed.

With the increased popularity of orienteering the aims of this study were to investigate the heart rate responses of participants in a number of age categories, as this would provide some indication of the physical demands of the sport. It would also provide an indication of the heart rate capacities of relatively active individuals in a number of age groups.

Materials and methods

A group of 16 orienteers (six female and ten male) from the Saxons Orienteering Club of Kent volunteered to participate in the study (age range 15–62 years). All had been orienteering competitively for at least 3 years with 12 of the seniors being ranked nationally. The heart rate of each participant was monitored throughout three 'British Orienteering Federation' competitive events, which ranged in standard from colour coded to national (a total of 38 different events) and incorporated a variety of terrains. Before participating in each event each orienteer declared themselves fit and free from any illness that could influence their performance. In all events the participants ran at their own self-selected competition intensity in accordance with the course's physical and technical demands. Heart rates were recorded every 15 s using a PE3000 heart rate monitor (Polar Electronics, Kempele, Finland) which was also used to record the participant's split time at each control. Previous research has found this system to be reliable, unobtrusive and not to interfere with the orienteers' running or concentration¹. The recording of split times required no additional commitment by the participants as it is common practice among

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orienteers who normally use a wrist stopwatch for this purpose. The recording of heart rate started as the competitors left the start box and stopped as they crossed the finish line. After the event the data was loaded into a BBC microcomputer (Acorn Computers, Cambridge, UK) for analysis and each subject produced a detailed description of their run which included: (1) a copy of their route marked on their map; (2) a written description of their strategy for each control and any distinct incidents that occurred. These could then be located accurately on the heart rate profile using the recorded split times and related to the recorded heart rates. A typical heart rate profile for an event is shown in Figure 1.

Each subject was assessed over three contrasting areas in order to investigate the influence of terrain and the technical difficulty of a course on the competitors' heart rates. While all courses included an element of fast running, physically demanding terrain and periods of lower intensity exercise due to the need for complex navigation, the courses could be classified as follows:

1. Fast running low technicality (FR). These courses required a high proportion of time to be spent on path running with many of the controls being sited in areas which required little complex navigation.
2. Slow run and/or high technicality (SR). These courses required the competitors to spend a high a proportion of their time navigating through relatively dense vegetation or across difficult terrain which required a high degree of complex navigation.

3. Highly physical (HP). These courses required the competitors to negotiate a relatively large amount of uphill running and often included physically demanding terrain such as heather or waterlogged ground. The control sites for these courses were a mixture of high and low technicality.

The mean heart rates attained for each type of course were then compared using an analysis of variance for correlated data².

Results and discussion

The data for each subject are summarized in Table 1 (events for each subject in chronological order). The proportion of time (mean of three events) each subject spent with heart rates of (1) less than 100 beats min^{-1} ; (2) 100–119 beats min^{-1} ; (3) 120–139 beats min^{-1} ; (4) 140–159 beats min^{-1} ; (5) 160–179 beats min^{-1} and (6) > 180 beats min^{-1} are illustrated graphically in Figure 2.

The results showed that during the orienteering competitions all subjects had heart rates which were between 140 and 180 beats min^{-1} for the majority of the time. However, within each event the competitor's heart rate varied in accordance with the intensity of the exercise and terrain. These results were supported by the comments made in the competitors' reports which referred to phases of hard running and fatigue that could be located on their heart rate profile. Indeed, strenuous phases of activity, such as ascents or periods of fast running, often caused significant brief rises in heart rate that exceeded 170

Figure 1. A typical heart rate profile for an event. Numbered vertical lines indicate the arrival at each control site (19 in total). 'A' indicates the point at which time was spent copying down the first half of the course at 'master maps' and 'B' indicates the drop in heart rate associated with copying down the second part of the course at 'second master maps'

Table 1. Mean and standard deviation of heart rates for each event and the percentage of time each competitor spent in each heart rate zone. Male and female subjects are listed as M and W respectively

Subject	Age	Type of event	Duration of event (min:secs)	Mean(s.d.) heart rate (beats min ⁻¹)	Percentage of time spent in each of the heart rate zones (beats min ⁻¹)					
					<100	100–119	120–139	140–159	160–179	>179
W1	15	HP	87:34	172(20.0)	0.0	1.9	4.6	16.3	38.1	39.1
		FR	87:29	168(19.5)	0.0	2.1	6.9	23.1	23.0	33.9
		SR	35:26	163(22.3)	0.0	1.9	11.9	41.6	41.7	2.9
		Mean			0.0	2.0	7.8	27.0	37.9	25.3
W2	30	FR	78:03	153(10.1)	0.0	0.4	5.9	29.9	61.0	2.8
		HP	101:16	150(8.4)	2.5	1.0	12.5	61.0	23.0	0.0
		SR	101:19	146(9.2)	4.5	2.4	21.0	50.2	21.9	0.0
		Mean			2.3	1.3	13.1	47.1	35.3	0.9
W3	37	HP	120:21	163(9.0)	0.0	0.0	6.3	34.8	57.9	1.0
		FR	92:43	148(7.6)	0.0	1.8	18.7	45.2	34.3	0.0
		SR	60:33	168(10.2)	4.5	1.6	2.9	20.4	49.8	20.8
		Mean			1.5	1.1	9.3	33.5	47.3	7.3
W4	37	FR	79:56	161(9.2)	0.0	0.5	5.8	35.1	55.9	2.7
		SR	53:20	139(17.8)	5.9	10.2	33.8	29.7	13.6	6.8
		HP	62:27	156(16.1)	1.6	2.3	9.7	36.4	48.3	1.7
		Mean			2.5	4.3	16.4	33.7	39.3	3.8
W5	47	FR	81:04	171(8.7)	0.0	1.5	1.8	16.9	74.9	4.9
		HP	60:47	167(9.1)	0.0	3.0	3.5	16.5	76.0	1.0
		SR	90:30	153(11.5)	0.0	3.1	16.0	64.5	16.4	0.0
		Mean			0.0	2.5	7.1	32.6	55.8	2.0
W6	62	HP	55:39	161(10.2)	2.2	4.8	3.2	20.0	69.4	0.4
		SR	54:57	155(15.2)	2.2	4.9	14.4	50.6	24.3	3.6
		FR	70:36	172(8.6)	3.2	3.9	0.4	9.7	79.6	3.2
		Mean			2.5	4.5	6.0	26.8	57.8	2.4
M1	14	HP	75:43	176(9.6)	1.7	0.9	2.6	6.3	36.8	51.7
		SR	90:09	172(9.2)	0.0	0.4	3.6	13.8	49.6	32.6
		FR	60:02	179(11.7)	1.3	1.3	2.1	8.5	35.7	51.6
		Mean			1.0	0.9	2.8	9.5	40.6	45.2
M2	29	HP	153:06	150(10.3)	2.9	1.9	20.3	40.2	34.3	0.4
		FR	99:05	143(8.8)	3.0	3.2	29.4	50.5	13.3	0.6
		SR	96:21	147(10.2)	2.1	5.8	28.0	38.4	25.7	0.0
		Mean			2.7	3.6	35.9	43.1	24.4	0.3
M3	32	FR	93:45	170(11.7)	8.6	5.8	0.0	6.8	72.2	6.6
		HP	100:59	165(12.4)	16.2	5.9	3.7	23.7	46.5	4.0
		SR	138:12	157(14.3)	0.0	0.6	16.2	59.9	21.8	1.5
		Mean			8.3	3.9	6.6	30.2	47.0	4.0
M4	36	FR	54:18	157(7.5)	8.4	2.3	4.9	57.3	27.1	0.0
		HP	95:49	162(8.3)	3.0	4.7	8.8	54.2	29.3	0.0
		SR	76:35	158(5.8)	1.4	0.9	7.9	49.7	40.4	0.0
		Mean			4.3	2.6	7.2	53.6	32.3	0.0
M5	37	HP	74:39	157(8.7)	0.0	0.0	16.3	34.4	49.3	0.0
		FR	71:47	159(9.4)	2.7	1.4	3.3	34.4	58.2	0.0
		SR	102:36	154(13.1)	1.8	0.9	8.0	49.4	39.9	0.0
		Mean			1.5	0.8	9.2	39.4	49.1	0.0
M6	39	FR	120:46	149(11.3)	0.0	2.2	25.5	53.7	18.6	0.0
		HP	115:41	141(15.2)	3.3	6.7	38.9	45.9	5.2	0.0
		SR	109:27	138(14.9)	1.9	13.6	48.9	35.3	0.3	0.0
		Mean			1.7	7.5	37.8	45.0	8.0	0.0
M7	42	HP	89:30	161(8.0)	0.0	0.0	2.5	15.9	81.6	0.0
		FR	88:25	148(11.9)	0.0	0.6	7.4	67.4	24.6	0.0
		SR	87:29	152(12.8)	0.0	1.3	10.3	56.1	32.3	0.0
		Mean			0.0	0.6	6.7	46.5	46.2	0.0
M8	44	HP	84:52	153(5.2)	0.4	0.0	9.3	69.3	21.0	0.0
		FR	62:30	157(4.8)	0.0	0.4	1.6	17.5	80.5	0.0
		SR	57:47	137(15.2)	0.0	3.0	7.3	33.2	56.5	0.0
		Mean			0.1	1.1	6.1	40.0	52.7	0.0
M9	49	SR	78:23	125(16.3)	12.1	27.0	32.8	25.9	2.2	0.0
		HP	90:03	144(11.7)	0.0	4.1	25.6	66.0	4.3	0.0
		FR	65:06	138(17.6)	4.8	7.9	39.0	44.7	2.7	0.0
		Mean			5.6	13.0	32.6	45.7	3.1	0.0
M10	55	FR	95:46	164(4.8)	0.0	0.5	2.1	13.0	83.4	1.0
		SR	87:29	156(9.9)	0.6	1.4	0.9	14.3	82.8	0.0
		HP	169:43	152(9.6)	0.0	0.2	5.6	57.6	36.6	0.0
		Mean			0.2	0.7	2.9	28.3	67.6	0.3

Figure 2. Percentage of time each participant spent with heart rates (beats min^{-1}) in each heart rate zone (mean of three events)

beats min^{-1} . Therefore, the overall findings of this study are similar to others which have reported the varied physical intensity of competitive orienteering³⁻⁵, and as a consequence have advocated that when training for orienteering the participant should include training methods such as fartlek and intervals into their fitness programme as well as steady-state running.

The effects of the terrain and type of undergrowth were variable, with elevations in heart rate commonly being associated with periods of fast running and uphill sections. A comparison of the heart rates recorded during events held on different terrains revealed a statistically significant difference ($P < 0.001$) between course types. Those requiring slower running (SR) and more technical navigation produced mean(s.d.) heart rates of 150(11.8) beats min^{-1} that were slower than those obtained during events held on terrains that were 'highly physical' (HP) (mean(s.d.) 158(9.6) beats min^{-1}) or permitted a lot of fast running (FR) (mean(s.d.) 160(11.6) beats min^{-1}). However, even during events that were classified as 'slow run' all subjects maintained heart rates that were above 140 beats min^{-1} for most of the time. It may therefore be concluded that while the physical and technical nature of the courses did influence the competitors' heart rates, all the courses placed sufficient physical demands upon the participants to elevate their heart rates above 140 beats min^{-1} for a substantial period.

Detailed analysis of the heart rate profiles, split times and the competitors' written description of their run revealed that the cause of the heart rate falling below the training zone during an event was usually the competitor pausing to copy down their course on their map immediately after the start of a colour-coded event, and in some cases on the longer courses a similar pause to copy down the second half of their course at a second set of 'master maps' at the

midway point (see Figure 1). This did not occur in badge and national events, since the maps were premarked with the competitor's course. Another common reason for a fall in heart rate was the need to slow down in order to relocate when lost. In addition to this, slight falls in heart rate were often observed when the competitors arrived at control sites (Figure 1). These were associated with the participant pausing to work out the route to the next control, and subjectively it was noted that these particular declines in heart rate were less frequent and less substantial in the heart rate profiles of the more experienced orienteers who would attempt to plan ahead and sort out their route to a number of controls in advance, thereby removing the necessity to pause at each control.

Occasionally a slight rise in heart rate was observed when subjects made errors and this could be associated with psychological stress, although in most situations an error resulted in a fall in heart rate as the subject slowed down to relocate his/her position.

An analysis of variance test revealed a statistically significant ($P < 0.001$) difference in the mean heart rates attained by the different competitors. This could be due to a number of factors, including: the differing levels of fitness of the individuals; differences in their technical skill; variations in the courses run; differences in the level of physical intensity at which the competitors run; and variations in tactical strategies.

A regression analysis of the competitors' ages and their mean heart rate while competing showed no significant trend in any of the three types of course, which was somewhat unexpected since if there is a general decline in maximum heart rate with age^{6,7} this is also likely to be reflected by a reduction in the submaximal exercise heart rates; with the older orienteers recording lower mean exercise heart rates during the events. However, this was not the case

and an examination of the data (Table 1) shows that some of the older orienteers were exercising with higher average heart rates than the younger orienteers. While this could reflect a difference in fitness it also indicates that the older participants had relatively high heart rate capacities and possessed the ability to exercise with relatively high heart rates for prolonged periods. Furthermore, the results of this investigation clearly demonstrated that the older participants had heart rate capacities which were in excess of those expected for their age^{6,7}. Whether this was due to their regular participation in the sport, natural ability, or a combination of the two it is not possible to say. However, regardless of the cause, the results of this study indicate that for relatively fit individuals over the age of 45 years the commonly used formula for calculating maximum heart rates ($220 - \text{age}$)^{6,7} is inappropriate and, as a consequence of this, heart rate training zones which are estimated from age-predicted values are likely to be too low in this group.

Alternatively, the findings of this study could be interpreted to suggest that orienteering is excessively strenuous for the older age groups; however, since all the older participants in the study had been competing for at least 8 years and competed at their own level of perceived exertion during the study this interpretation was not considered likely by the authors. These results therefore go some way to support the findings of other studies^{8,9} which have suggested that the regular participation in exercise can reduce the decline in maximum heart rate that is associated with the ageing process¹⁰⁻¹² and can help to maintain a person's cardiovascular capacity as they age.

The overall findings suggest that orienteering is an activity which places significant demands upon the participant's cardiovascular system. It is therefore of sufficient intensity and duration to fulfil the criteria for good 'aerobic' exercise for relatively fit individuals of a wide range of ages, as outlined by a number of authorities¹³⁻¹⁶.

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