Heart rate responses of women aged 23–67 years during competitive orienteering

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Objectives: To compare the heart rate responses of women orienteers of different standards and to assess any relation between heart rate responses and age.

Methods: Eighteen competitive women orienteers completed the study. They were divided into two groups: eight national standard orienteers (ages 23–67 years); 10 club standard orienteers (ages 24–67 years). Each participant had her heart rate monitored during a race recognised by the British Orienteering Federation. Peak heart rate ($HR_{\text{max}}$), mean heart rate ($HR_{\text{mean}}$), standard deviation of her heart rate during each orienteering race ($\Delta HR_{\text{CONTROL}}$), and mean change in heart rate at each control point were identified. The data were analysed using analysis of covariance with age as a covariate.

Results: National standard orienteers displayed a lower within orienteering race standard deviation in heart rate ($6 (2) v 12 (2) \text{ beats/min, } p<0.001$) and a lower $\Delta HR_{\text{CONTROL}}$. ($5 (1) v 17 (4) \text{ beats/min, } p<0.001$). The mean heart rate during competition was higher in the national standard group ($170 (11) v 158 (11) \text{ beats/min, } p = 0.025$). The $HR_{\text{mean}}$ for the national and club standard groups were 99 (8)% and 88 (9)% of their age-predicted maximum heart rate (220–age) respectively. All orienteers aged >55 years ($n = 4$) recorded $HR_{\text{mean}}$ greater than their age-predicted maximum.

Conclusions: The heart rate responses indicate that national and club standard women orienteers of all ages participate in the sport at a vigorous intensity. The higher $\Delta HR_{\text{CONTROL}}$ of club standard orienteers is probably due to failing to plan ahead before arriving at the controls and this, coupled with slowing down to navigate or relocate when lost, produced a higher $HR_{\text{max}}$.

Therefore the aims of this study were to compare the heart rate responses of competitive women orienteers of different standards across a broad spectrum of ages and to assess whether the heart rate responses were related to age.

METHODS

The University College ethics committee approved the study.

Subjects and recruitment

Subjects were recruited through advertisements in local orienteering club newsletters, a national orienteering magazine, and leaflets distributed at British Orienteering Federation orienteering races. All subjects were regularly involved in competitive orienteering and had a minimum of four years experience, which ensured that they were familiar with the procedures and techniques of orienteering, and consequently were capable of providing valid data.

All subjects were informed that they were able to withdraw from the study at any time without any obligation. Before collection of the heart rate data, all subjects completed the following:

- general health questionnaire;
- consent form;
- questionnaire on current activity levels and general history of participation in physical activities;
- personal orienteering information sheet providing details of their orienteering history, standard of participation, and any specific achievements.

To assess the effects of standard on the subsequent heart rate data, the subjects were divided into two groups according to their standard at the time of data collection:

1. National standard orienteers with more than 3500 national ranking points (pre-2001 British Orienteering Federation ranking system) and who had been ranked nationally...
in the top six for their age group within the previous year. All subjects in this group had also represented England or Scotland at Senior and/or Masters level and/or had finished in the top three for their age group at the British Orienteering Championships.

(2) Club standard orienteers with 2500–3500 national ranking points.

Collection of heart rate data
All the orienteering races used for data analysis in the study were recognised by the British Orienteering Federation and had a winning time in excess of 40 minutes. Orienteering races were therefore of a “classic” nature and did not include short or sprint orienteering races. Each participant was provided with a heart rate monitor (PE3000 or Sports Tester, Polar Electro Oy, Kempele, Finland) with which the participants were encouraged to familiarise themselves during training runs before using it during the orienteering race. Monitors were preset to record heart rate at 15 second intervals. During the orienteering races the subjects were requested to record their split times on arrival at each control (check point) by pressing the appropriate button on the monitor. After the race, the data were downloaded for analysis through the appropriate interface.

To assist with the analysis of heart rate data, each subject was requested to provide the following information after each orienteering race:

- copy of the race map with identified route and controls clearly marked;
- analysis sheet highlighting any important information about the race, such as any difficulties in locating particular controls or obstructive vegetation;
- time taken to complete the race (which was also available from published results lists).

This information was then used to identify any specific incidents that may have influenced the recorded heart rate data.

Analysis of the heart rate data
From the heart rate recordings, each of the following were identified and calculated. Using the criteria of Creagh et al.,

- Heart rate peak (HRpeak): the highest heart rate recorded during the orienteering race.
- Heart rate mean (HRmean): the mean heart rate during the orienteering race (excluding the aforementioned first four minutes).
- Heart rate standard deviation (HRSD): the standard deviation in heart rate within the orienteering race (excluding the aforementioned first four minutes).
- The mean change in heart rate at each control (ΔHRcontrol): the change in heart rate occurring at a control was calculated as the difference between the highest heart rate recorded 15–30 seconds before reaching the control (as indicated from the split time recorded on the heart rate monitor) and the lowest heart rate recorded 45–60 seconds after leaving the control. A mean change in heart rate at controls was calculated for each competitor’s race data.

A regression line was fitted to the heart rate profile of each race (time v heart rate recorded at 15 second intervals, excluding the aforementioned first four minutes) and assessed for positive or negative trends.

Heart rate data for an orienteering race were to be rejected if they displayed uncharacteristic spikes or flat plateaus suggesting that the receiver had failed to record a true heart rate profile during the orienteering race. A participant’s ΔHRcontrol was not calculated if they failed to record a split time for more than three of their controls.

Statistical analysis
Data were analysed using the Statistical Package for Social Sciences (SPSS version 10.0). Analysis of covariance was used to assess any differences in the responses of the groups (national standard v club standard), with age being the covariate. Regression analyses were used to determine any relations between each heart rate factor (HRpeak, HRmean and HRSD) and the age of the participants. The data were checked for normality using Kolmogorov-Smirnov tests, and none violated normality. Values for HRpeak and HRmean were compared with predicted maximal heart rate derived from the algorithm 220–age.

To investigate any trend in heart rate within a race, regression analyses were used (time v heart rate recorded at 15 second intervals). Regression lines were classified as either positive or negative if p<0.05, and neutral if p>0.05. The frequency of positive, negative, and neutral regression lines were analysed using log-linear and χ² analyses (SPSS 10).

RESULTS
Eighteen women orienteers (eight national standard and 10 club standard) completed the study (table 1). Analysis of covariance with age as a covariate showed that HRmean was

| Table 1 | Summary of participants’ ages, orienteering experience, and race duration |
|---------|-----------------|-----------------|-----------------|-----------------|
|         | Age (years)     | Age range (years) | Orienteering experience (years) | Orienteering race duration (min) |
| National group (n=8) | 47 (14)         | 23–67           | 15 (9)           | 60 (14)         |
| Club group (n=10)   | 40 (13)         | 24–67           | 11 (6)           | 77 (28)         |

Values are mean (SD).

| Table 2 | Summary of heart rate data |
|---------|-----------------|-----------------|-----------------|-----------------|
| Group   | Peak heart rate (beats/min) | Mean heart rate (beats/min) | Within-race heart rate standard deviation (beats/min) | Average change in heart rate at controls (beats/min) |
| National group (n=8) | 181 (11)         | 170 (11)         | 6 (2)           | 5 (1)           |
| Club group (n=10)   | 179 (9)          | 158 (11)         | 12 (2)          | 17 (4)          |

Values are mean (SD).
significantly higher in the national standard group ($F_{1,15} = 6.2$, $p = 0.025$) (table 2). Regression analyses for $HR_{MEAN}$ with age for the national, club, and combined groups data failed to find a significant relation (table 3). When $HR_{MEAN}$ was expressed as a percentage of 220–age, the women competed at 93 (10)% of their age predicted maximum heart rate. For the national standard group, this was 99 (8)% and for the club standard group 88 (9)% of their age predicted maximum heart rate. A $t$ test assuming unequal variances showed the groups to be statistically different ($t = 2.64$, $df = 16$, $p = 0.018$). When $HR_{MEAN}$ was expressed as a percentage of predicted maximum heart rate and regressed with age, it was shown to increase by 5%/decade (table 3). All orienteers aged >55 years regardless of standard (n = 4) recorded $HR_{MEAN}$ greater than their age predicted maximum heart rate of 220–age, with this $HR_{MEAN}$ being sustained for race durations of between 40 and 70 minutes.

Analysis of covariance with age as a covariate showed that $HR_{MEAN}$ was significantly lower in the national standard group ($F_{1,15} = 41.2$, $p < 0.001$) (table 2). Regression analyses found no significant relation between age and $HR_{MEAN}$ in either group or for their combined data (table 3). Likewise analysis of covariance with age as a covariate showed that $ΔHR_{CONTROL}$ was significantly lower in the national standard group ($F_{1,15} = 41.5$, $p < 0.001$) (table 2) but was not related to age. Figure 1 clearly illustrates the differences in the heart rate profiles ($HR_{MEAN}$ and $HR_{PEAK}$) of national and club standard women orienteers.

Analysis of covariance with age as a covariate showed that $HR_{PEAK}$ was not affected by the standard of the orienteer ($F_{1,15} = 1.3$, $p = 0.276$) (table 2). Regression analysis using the combined data for the national and club standard groups indicated that $HR_{PEAK}$ values showed a non-significant decline of 2.5 beats/min/decade with increasing age (table 3). When compared with their age predicted maximum of 220–age, the $HR_{PEAK}$ of national standard women orienteers was 102 (8)% of age predicted maximum heart rate. Of the 10 women orienteers over the age of 40 years (six of national standard and four of club standard), seven displayed peak heart rates above that predicted from 220–age. When the $HR_{PEAK}$ of all the subjects was expressed as a percentage of predicted heart rate maximum and regressed with their age, there was a significant increase with age of 5%/decade (table 3). This indicated a growing discrepancy with increasing age between the $HR_{PEAK}$ recorded during the orienteering race and that predicted from 220–age.

The linear regressions of heart rate profiles produced two positive ($p < 0.05$), one negative ($p < 0.05$), and five neutral ($p > 0.05$) slopes in the national standard group, and two positive and eight neutral slopes in the club standard group.

**DISCUSSION**

The $HR_{MEAN}$ calculated from the heart rate monitoring data suggests that experienced competitive women orienteers of all ages participate in the sport at what may be regarded as a strenuous intensity. They sustained relatively high heart rates for a prolonged duration. Indeed despite the inclusion of older orienteers (>40 years), the $HR_{MEAN}$ of national standard women orienteers was 102 (8)% of age predicted maximum heart rate. Of the 10 women orienteers over the age of 40 years (six of national standard and four of club standard), seven displayed peak heart rates above that predicted from 220–age.

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**Table 3** Regression analysis between heart rate responses (beats/min) and age (years) for national and club standard orienteers, and combined groups

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group</th>
<th>Heart rate correlation with age</th>
<th>$r^2$ Value</th>
<th>$p$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak heart rate</td>
<td>Combined</td>
<td>$HR_{PEAK} = -0.256$ age + 191</td>
<td>0.131</td>
<td>0.140</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>$HR_{PEAK} = -0.333$ age + 197</td>
<td>0.193</td>
<td>0.276</td>
</tr>
<tr>
<td></td>
<td>Club</td>
<td>$HR_{PEAK} = -0.281$ age + 190</td>
<td>0.166</td>
<td>0.243</td>
</tr>
<tr>
<td>Mean heart rate</td>
<td>Combined</td>
<td>$HR_{MEAN} = -0.079$ age + 166</td>
<td>0.008</td>
<td>0.732</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>$HR_{MEAN} = -0.412$ age + 190</td>
<td>0.274</td>
<td>0.183</td>
</tr>
<tr>
<td></td>
<td>Club</td>
<td>$HR_{MEAN} = -0.020$ age + 159</td>
<td>&lt;0.001</td>
<td>0.950</td>
</tr>
<tr>
<td>Within race heart</td>
<td>Combined</td>
<td>$HR_{SD} = -0.091$ age + 13</td>
<td>0.137</td>
<td>0.131</td>
</tr>
<tr>
<td>rate SD (HRSD)</td>
<td>National</td>
<td>$HR_{SD} = -0.015$ age + 7</td>
<td>0.014</td>
<td>0.777</td>
</tr>
<tr>
<td></td>
<td>Club</td>
<td>$HR_{SD} = -0.059$ age + 14</td>
<td>0.212</td>
<td>0.180</td>
</tr>
<tr>
<td>$HR_{PEAK}$ as %</td>
<td>Combined</td>
<td>% predicted $HR_{PEAK} = 0.468$ age + 82</td>
<td>0.593</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>of 220–age</td>
<td>National</td>
<td>% predicted $HR_{PEAK} = 0.517$ age + 71</td>
<td>0.492</td>
<td>&lt;0.002</td>
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</tr>
</tbody>
</table>

**Figure 1** Heart rate profiles of a national standard (aged 41 years) and club standard (aged 37 years) orienteer.
standard orienteers was partly due to navigational errors that caused them to slow down and/or stop to relocate their position. A further factor contributing to the higher \( \text{HR}_{\text{CONTROL}} \) of the club standard orienteers. Observations made at controls that were visible to the investigators suggested that the national standard orienteers had checked that the code of the control matched that on the list they carried while approaching the control and had planned their direction of exit from the control before reaching it. Consequently they minimised the amount of time spent at the control and resumed running immediately. Conversely, club standard orienteers were often observed to pause and check their control code after they had arrived at the control. They then exited from the control reading their map at a walking pace before starting to run again. This appeared to be due to their failure to plan their route to the next control, including their immediate exit from the one that they were at, before arriving at it. They may therefore be deemed to have wasted time at the control. The difference between the two groups is perhaps exemplified by paraphrasing a quote from a British Champion who said that “top orienteers pass through the controls which are on their route around the course, whereas club standard orienteers use the controls as beginning and end points to a navigational leg”.

For the club standard group, fluctuations in running intensity caused by navigational difficulties (which were reported on the analysis forms) and the greater mean decrease in heart rate at controls is likely to have contributed to their lower \( \text{HR}_{\text{MEAN}} \) of the club standard orienteers. Observations made at controls that were visible to the investigators suggested that the national standard orienteers had checked that the code of the control matched that on the list they carried while approaching the control and had planned their direction of exit from the control before reaching it. Consequently they minimised the amount of time spent at the control and resumed running immediately. Conversely, club standard orienteers were often observed to pause and check their control code after they had arrived at the control. They then exited from the control reading their map at a walking pace before starting to run again. This appeared to be due to their failure to plan their route to the next control, including their immediate exit from the one that they were at, before arriving at it. They may therefore be deemed to have wasted time at the control. The difference between the two groups is perhaps exemplified by paraphrasing a quote from a British Champion who said that “top orienteers pass through the controls which are on their route around the course, whereas club standard orienteers use the controls as beginning and end points to a navigational leg”.

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The findings of this study indicate orienteering to be a physically demanding activity for both club and national standard women across the age range 23–67 years. Competitors displayed relatively high heart rate responses (\( \text{HR}_{\text{MAX}} \) and \( \text{HR}_{\text{MEAN}} \)) during orienteering races. In older women orienteers of both national and club standard, heart rate algorithms such as 220–age appear to underestimate the heart rate responses of these “athletic” women and would therefore appear to be inappropriate for these groups. This is despite the fact that they were not specifically trying to attain an \( \text{HR}_{\text{PEAK}} \) and therefore their true maximum heart rate may be even greater.

The finding of \( \text{HR}_{\text{MEAN}} \) values greater than that predicted from the algorithm 220–age agrees with the results of Bird et al., who indicated that, unlike cross country running races in which a consistent rise in heart rate was observed within a race, heart rate responses during orienteering races were less consistent and were likely to reflect the technical difficulty of the course as well as its topography.

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**REFERENCES**


**Take home message**

Although many aspects of this paper are descriptive, they provide an original insight into the heart rate responses of older women athletes who are an under-researched group. During competitive orienteering, many of the women sustained heart rates that were above what may have been expected if age related heart rate algorithms were applied. The intensity of the exercise could be described as strenuous, with differences between national and club standard competitors being evident in the form of greater fluctuations in heart rate in the club standard group, probably caused by less competent navigation and failing to plan ahead.

Likewise, the mixture of neutral, positive, and negative heart rate profiles also agrees with the work of Creagh et al., who indicated that, unlike cross country running races in which a consistent rise in heart rate was observed within a race, heart rate responses during orienteering races were less consistent and were likely to reflect the technical difficulty of the course as well as its topography.