VETERAN ATHLETES EXERCISE AT HIGHER MAXIMUM HEART RATES THAN ARE ACHIEVED DURING STANDARD EXERCISE (STRESS) TESTING

A St Clair Gibson, J Perold, G A Watermeyer, S E Latouf, J A Hawley, M I Lambert, T D Noakes

Objective. The stress electrocardiogram (sECG) is routinely used to screen individuals for underlying cardiac pathology before an exercise programme is prescribed. The underlying assumption is that the cardiac responses elicited during the sECG test are similar to those achieved during participation in sporting activities. However, this premise may be incorrect since the physical demands of different modes of exercise vary substantially.

Design. Ten veteran league squash players (LSP), 10 social squash players (SSP), 10 league runners (LR), 10 social runners (SR) and 10 sedentary individuals (SED) were recruited for the study. All subjects completed a lifestyle questionnaire, a full medical examination and a routine sECG. Thereafter each subject's heart rate (HR) was monitored on two separate occasions while participating in sporting activity.

Results. No sECG exercise-induced abnormalities were observed, although five subjects showed resting abnormalities. Maximal HR during the sECG, and maximal and mean HR during the field tests, were not significantly different between groups. However, maximal HR was significantly higher in all groups during their sporting activities than during stress testing in the laboratory ($P < 0.01$).

Conclusions. Maximal HR in veteran athletes during specific sporting activities was significantly higher than that attained

Medical Research Council/University of Cape Town Bioenergetics of Exercise Research Unit, Department of Physiology, University of Cape Town

A St Clair Gibson, MB ChB, PhD

J Perold, MB ChB, FCP (SA)

J A Hawley, PhD

M I Lambert, PhD

T D Noakes, MB ChB, MD

Department of Medicine, Groote Schuur Hospital and University of Cape Town

G A Watermeyer, FCP (SA)

Cardiac Clinic, Department of Medicine, Groote Schuur Hospital and University of Cape Town

S E Latouf, MB ChB, FCP (SA)

during a routine sECG. This finding was not sport-specific, nor was it related to the level of competitiveness of the trial participants. These data show that a routine sECG is a submaximal test of exercise performance, and should be interpreted as such.

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High levels of physical activity reduce the risk of cardiovascular disease in the general population.[1,2] However, the possibility that sudden death may occur during exercise remains a concern to physicians promoting a higher level of physical activity to their patients.[3,4] This is particularly important in exercising veteran athletes, for whom there is an increased prevalence of coronary artery disease and associated sudden death.[5-11]

The stress electrocardiogram (sECG) is routinely employed to screen individuals for undiagnosed cardiac disease before a safe and effective exercise programme is prescribed.[12] Although false-positive results due to the athletic heart syndrome have been described,[13] it is accepted that a positive test is a risk factor for overt cardiac disease.[8,14,15] A normal sECG allows practitioners to prescribe exercise in the patient's chosen activity.[16] This is based on the assumption that the cardiac response during a typical sECG is similar to that which the individual experiences during sports activity. However, it seems unlikely that the cardiovascular responses during a sECG will be identical to those induced by all sporting activities[3,4] since the physical demands of different sporting activities are varied, ranging from steady state, high-intensity exercise in runners,[17] to intermittent, high-intensity activity with many postural changes, for example in squash.[18]

Accordingly, the aim of this study was to determine whether the maximum cardiovascular response elicited by a routine sECG performed by physicians is similar to that achieved during different sporting activities, in particular running and squash. Middle-aged runners and squash players were chosen to participate in this study because of the increased prevalence of cardiac risk factors and cardiovascular-related sudden death in this particular age group of athletes.[3,4,7,11]

METHODS

Subjects

Ten male veteran league squash players (LSP), 10 social squash players (SSP), 10 league runners (LR), 10 social runners (SR) and 10 sedentary subjects (SED) were recruited for the study. Veteran participants were defined as individuals aged between 45 and 60 years who participated in their respective sports two or more times per week. League participants were involved in competitive sporting events on a regular basis, whereas social participants were not. After the risks and procedures involved in the study were explained, all subjects signed an informed consent. The study was approved by the Ethics and Research Committee of the Faculty of Medicine of the University of Cape Town.

Study design

A comprehensive questionnaire of cardiovascular risk factors was completed by each participant. All subjects underwent a full medical examination performed by the same physician (JP). Each subject's body fat was estimated from the sum of four skinfold measurements.[19] The subjects then underwent a sECG according to the modified Bruce protocol.[16]

The LSP and SSP groups subsequently played two squash matches in their normal environment, while the LR and SR groups ran two 5 km time trials. During all field tests, the heart rate (HR) of each subject was recorded using portable telemetric HR devices (Polar Electro, Kempele, Finland). These devices have been shown to be reliable[20] and are used to study HR responses in different sporting disciplines.[21] All tests were performed in the early evening and completed within 6 weeks of the initial sECG.

sECG testing

A modification of the Bruce protocol[16] using a stationary cycle ergometer (Tunturi Pro, Finland) was used to perform the sECG. The cycle ergometer protocol was used to ensure that as far as possible the testing procedures followed those of routine sECGs performed by physicians, as described in the American College of Sports Medicine *Guidelines for Exercise Testing and Prescription*.[16] A twelve-channel sECG monitor (Hellige EK53, Germany) was used to perform the sECG.

Electrodes were placed over the subjects' praecordium after the skin had been shaved and cleaned with alcohol. Resting blood pressure (BP) and HR were measured from the right arm while the subjects were in a supine and standing position. Diastolic BP (DBP) was defined as the pressure at the fourth Korotkoff sound.

The test began after the subject had familiarised himself with the cycle ergometer. Thereafter, the subject started pedalling at 60 revolutions/minute (RPM) at a power output of 50 W. Power output was increased by 50 W every two minutes. The test was terminated when the subject was unable to maintain a cadence of 60 RPM. BP, HR and sECG were recorded every 2 minutes during the test and at the point coinciding with the termination of the test. BP, HR and sECG were also measured 3 and 6 minutes after termination of the test.

The sECG traces were assessed independently and retrospectively by two physicians (GAW, SEL), one of whom was a cardiologist (SEL). The physicians were unaware of the identity of the different patients' sECG traces. The sECG traces were assessed for baseline abnormalities and exercise-induced

ST-segment changes.[22] The exercise test was considered positive when ≥ 0.1 mV of new ST-segment depression occurred at 80 milliseconds after the J point.[23]

BP measurements

Resting BP and exercising BP were measured at every incremental stage increase during the sECG by means of audible sphygmomanometry using a calibrated mercury column sphygmomanometer with an appropriately sized cuff. Korotkoff phases I and IV were measured at all time periods representing systolic BP (SBP) and diastolic BP (DBP) readings. The BP recordings were all performed by the same physician (JP) using the same apparatus on the right arm of all subjects during all testing procedures. The measurement of DBP during exercise is sometimes difficult. However, when phase IV of the Korotkoff sounds is taken the results are reproducible.[24] Also, any possible residual error is the same under all conditions.

Field tests

HR was recorded at 5-second intervals during the field tests. Subjects were allowed to warm up on their own before the field tests in order to keep test conditions as normal as possible. HRs were recorded during league matches in the LSP group. Subjects had no control over the playing quality of their opposition. The SSP played against their regular partners. Both LR and SR ran the same 5 km time trial. The subjects were allowed to warm up on their own before the time trial. Subjects then ran at their own pace after being instructed to run the 5 km as fast as possible.

Statistics

All data are expressed as mean (standard deviation) (SD). An analysis of variance (ANOVA) was used to detect differences in the subjects' general characteristics, HR and BP for the laboratory and field tests. Statistical significance was accepted when $P < 0.05$. Where significant F-values occurred, a Scheffe's *post hoc* test was performed to determine where these differences occurred. Pearson's product moment correlation coefficient was used to determine relationships between the HR data obtained from the sECG and the field tests. A chi-square test was used to assess differences in the nominal and frequency data from the questionnaire.

Results

No significant differences were found in age or height between the LSP, SSP, LR, SR or the SED groups (Table I). The subjects in the SED group had a greater degree of body fat ($P < 0.01$) and weighed more ($P < 0.05$) than the subjects in the LR group (Table I).

Retrospective analysis of the resting sECG traces revealed that one sedentary subject and one social squash player had a right bundle-branch block at rest, one sedentary subject a bifascicular block at rest, one social squash player diffuse T-wave inversion at rest, and one sedentary subject anterolateral T-wave inversion with voltage criteria for left ventricular hypertrophy at rest. No further exercise-induced ST-segment changes occurred in any subject.

Table I. Descriptive characteristics of the 10 veteran league runners, 10 social runners, 10 league squash players, 10 social squash players, and 10 sedentary subjects

	Age (yrs)	Height (cm)	Mass (kg)	Body fat (%)
LR	49 (3)	179.1 (3.8)	76.0 (6.3)*	21.4 (3.7)†
SR	52 (6)	179.1 (6.3)	83.4 (9.0)	24.2 (3.2)
LSP	49 (5)	178.0 (4.3)	78.7 (11.4)	23.0 (3.7)
SSP	53 (5)	173.2 (7.1)	79.8 (13.1)	25.2 (3.3)
SED	53 (5)	175.9 (5.9)	91.4 (11.0)	28.1 (3.9)

All values are mean (SD).
* $P < 0.05$: mass: LR v. SED.
† $P < 0.01$: body fat (%): LR v. SED.
LR = league runners; SR = social runners; LSP = league squash players; SSP = social squash players; SED = sedentary subjects.

Table II shows the differences between pre-test resting HR, SBP and DBP for the different groups. The LR group had a significantly lower resting HR than the SSP ($P < 0.05$) and SED ($P < 0.01$) groups. The resting HR of the SR group was significantly lower than that of the SED group ($P < 0.01$). There was a significant difference in pre-test HR between a combined runners group ($N = 20$) and combined squash players group ($N = 20$) (56 (6) v. 62 (6) beats/min., $P < 0.05$). There were no differences in resting SBP or DBP between groups (Table II).

Table II. Pre-test standing HR (beats/min), SBP and DBP (mmHg) of the 10 veteran league runners, 10 social runners, 10 league squash players, 10 social squash players, and 10 sedentary subjects

	HR	SBP	DBP
LR	54 (10)*	148 (28)	90 (7)
SR	58 (6)*	130 (15)	84 (7)
LSP	59 (7)	127 (8)	81 (7)
SSP	66 (8)†	140 (16)	88 (10)
SED	72 (8)*	137 (15)	87 (9)

All values are mean (SD).
* $P < 0.01$: HR: LR v. SED; SR v. SED.
† $P < 0.05$: HR: LR v. SSP.
HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; LR = league runners; SR = social runners; LSP = league squash players; SSP = social squash players; SED = sedentary subjects.

Table III shows the maximal HR (HR_{ECG}), and maximal systolic (SBP_{max}) and diastolic (DBP_{max}) BP reached during the sECG test. No significant differences in HR_{ECG} were found between any of the groups. The SBP_{max} was significantly higher in the LR group compared with the SED group (210 (21) v. 185 (18) mmHg, $P < 0.05$, Table III). Exercise time to fatigue in the

Table III. HR_{ECG} (beats/min), SBP_{max} and DBP_{max} achieved during the sECG, and time taken for the sECG test (T_{ECG}) (min) by the 10 veteran league runners, 10 social runners, 10 league squash players, 10 social squash players and 10 sedentary subjects

	HR_{ECG}	SBP_{max}	DBP_{max}	T_{ECG}
LR	148 (16)	210 (21)*	91 (10)	9.2 (1.4)†
SR	154 (9)	201 (17)	84 (8)	8.8 (1.4)*
LSP	153 (8)	200 (16)	85 (8)	8.4 (1.3)
SSP	156 (12)	196 (13)	91 (8)	7.8 (1.5)
SED	151 (14)	185 (18)*	92 (8)	6.4 (1.7)†

All values are mean (SD).
* $P < 0.05$: SBP_{max}: LR v. SED; $P < 0.05$ T_{ECG}: SR v. SED.
† $P < 0.01$ T_{ECG}: LR v. SED.
HR_{ECG} = maximal heart rate; SBP_{max} = maximal systolic blood pressure; DBP_{max} = maximal diastolic blood pressure; LR = league runners; SR = social runners; LSP = league squash players; SSP = social squash players; SED = sedentary subjects.

sECG was shortest in the SED group (6.4 (1.7) min), and longest in the LR group (9.2 (1.4) min, $P < 0.01$, Table III).

No significant differences were found between the average HR attained during the first and second field test for all subjects (172 (10) v. 173 (12) beats / min). Therefore, the data from the second test were used for further evaluation, except in three subjects where 10 or more HR data points were lost as a result of a poor HR signal from the transmitter. In these subjects the first field test was used for analysis. In two squash players and one runner both tests showed excessive electrical interference and could not be interpreted; consequently these subjects were not used for subsequent analysis.

Table IV shows that there were no significant differences between the LR, SR, LSP or SSP groups for maximal HR attained (HR_{max}) and mean HR (HR_{mean}) attained during the field test, or for the time taken to complete the field test (TT).

Table IV. HR_{max} (beats/min) and HR_{mean} attained during the field test and time taken for the field test (TT) (min) by the 8 veteran league runners, 10 social runners, 10 league squash players, and 9 social squash players

	HR_{max}	HR_{mean}	TT
LR	167 (16)	156 (14)	21.8 (2.3)
SR	170 (9)	158 (9)	25.0 (3.9)
LSP	177 (8)	159 (10)	26.0 (4.8)
SSP	172 (15)	155 (12)	26.0 (5.0)

All values are mean (SD).
LR = league runners; SR = social runners; LSP = league squash players; SSP = social squash players.

Fig. 1 shows the relationship between the maximum HR attained during the sECG and field tests (HR_{ECG} and HR_{max} respectively). A significantly higher maximal HR was attained in the HR_{max} test than in the HR_{ECG} test for the LR (148 (16) v. 167 (16), $P < 0.01$), SR (154 (9) v. 170 (9), $P < 0.01$), LSP (153 (8) v. 177 (8), $P < 0.01$) and SSP (156 (12) v. 172 (15), $P < 0.01$) groups.

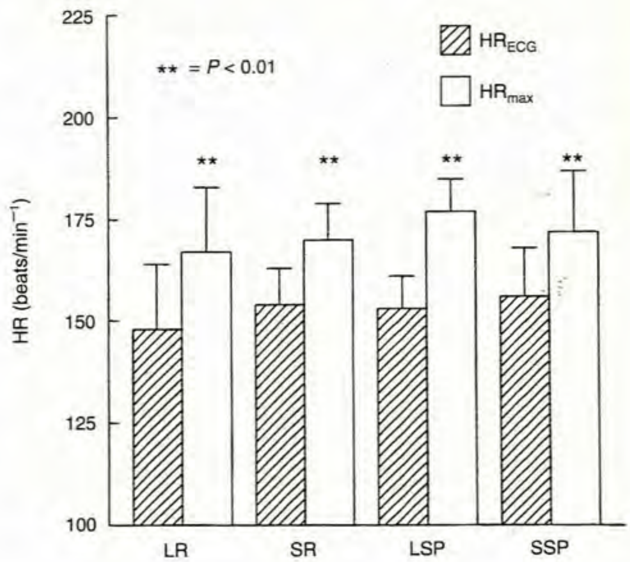

Fig. 1. The relationship between the maximum heart rate achieved during the sECG (HR_{ECG}) and field test (HR_{max}) for the league runners (LR), social runners (SR), league squash players (LSP) and social squash players (SSP). Values are expressed as mean (SD).

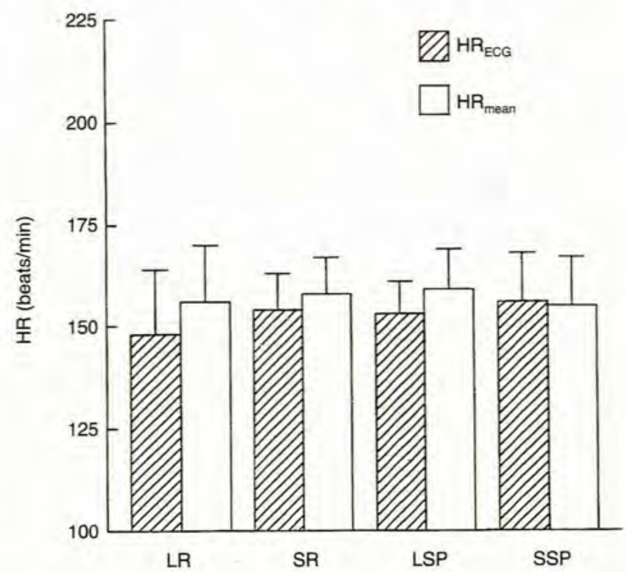

Fig. 2. The relationship between the maximum heart rate achieved during the sECG (HR_{ECG}) and the average heart rate of the field test (HR_{mean}) for the league runners (LR), social runners (SR), league squash players (LSP) and social squash players (SSP). Values are expressed as mean (SD).

Fig. 2 shows the relationship between the maximum HR in the sECG (HR_{ECG}) and the average HR in the field tests (HR_{mean}). No significant difference between HR_{ECG} and HR_{mean} were found for any of the groups.

The correlation coefficient between HR_{ECG} and HR_{max} for the LSP group was $r = 0.93$ ($P < 0.01$), for the SSP group $r = 0.60$,

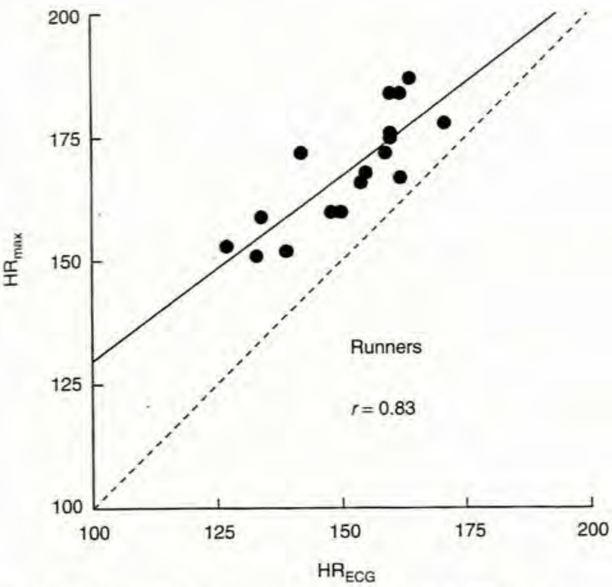

Fig. 3. The correlation between HR_{ECG} (beats/min) and HR_{max} (beats/min) for the combined runners group (N = 17). The dashed line is the line of unity.

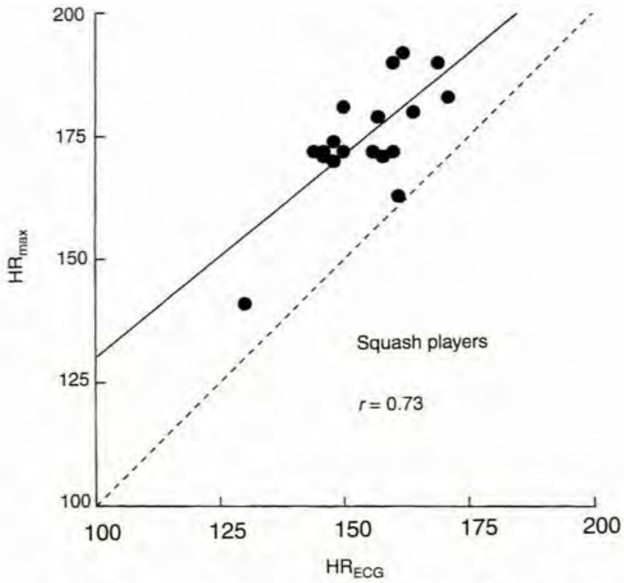

Fig. 4. The correlation between HR_{ECG} (beats/min) and HR_{max} (beats/min) for the combined squash players group (N = 17). The dashed line is the line of unity.

for the LP group $r = 0.69$ ($P < 0.05$) and for the SR group $r = 0.82$ ($P < 0.01$). The correlation coefficient for combined runners was $r = 0.83$ ($P < 0.01$) (Fig. 3), while for squash players it was $r = 0.73$ ($P < 0.01$) (Fig. 4).

Discussion

The important finding of this study was that the maximal HRs of the subjects while playing squash or running, either socially or competitively, were significant higher than the HRs attained by the subjects when undergoing a sECG to exhaustion. This HR response was neither sport- nor competition-specific. The finding that all subjects were able to exercise to a relatively high HR without symptoms during the stress test is a good prognostic indicator.[25] However the significant difference in maximal HR in the field compared with the laboratory sECG indicates that a maximal sECG, as described in exercise testing manuals,[16] is not indicative of the level of maximal HR achieved by individuals while exercising in either squash or running activities.

There was no significant difference between the mean HR attained during the field test and the maximal HR attained during the sECG. This suggests that the subjects were exercising at a similar intensity to the maximal HR achieved during sECG for the major part of the field test. The significantly higher maximal HRs described during the field tests must therefore have occurred during short periods of high-intensity activity during the exercise performance, a finding that has similarly been described by others.[26]

The sECG test procedures followed those of routine sECGs performed by physicians according to ACSM guidelines.[16] As such it cannot be argued that the reason for the differences between the HR_{ECG} and HR_{max} values was that the subjects were unfamiliar with the testing procedure. The HR_{ECG} data are valid because all subjects satisfied the criteria for an acceptable sECG. In addition, similar field values for HR_{max} have been described previously in veteran athletes.[3,25,27] Furthermore, the fact that moderately good correlations occurred between HR_{ECG} and HR_{max} in both runners ($r = 0.83$) ($P < 0.01$) and squash players ($r = 0.73$) ($P < 0.01$), indicates that performance in the two tests was related and not a spurious finding. Therefore, the difference between HR_{ECG} and HR_{max} in all groups in this study must be a real finding. It must be noted that the major reason for performing a sECG test would be to screen sedentary individuals before starting an exercise programme. However, this study showed that individuals who are already training are exercising at a HR significantly higher than that achieved during a sECG test. It remains to be seen at which HR level sedentary individuals perform when exercising for the first time in either rehabilitation or sporting activities.

It has been shown that with ageing the incidence of cardiac ECG abnormalities increases,[28,29] and that cardiac ECG abnormalities may indicate an increased risk of exercise-induced sudden death.[11] It must be noted that five subjects in this study had abnormal resting ECGs, although none showed signs of ischaemia during the sECG test.

The resting HR of the runners was significantly lower than that of the squash players. Whether the runners had an increased stroke volume, reduced sympathetic tone or increased parasympathetic tone compared with the squash players is beyond the scope of this study.

In conclusion, the maximal HR attained during squash and running is significantly higher than that attained during a sECG. This finding is not sport-specific, nor is it related to the level of competitiveness of the athletes. Although no subjects in the study had ischaemic symptoms or exercise-induced sECG changes, it must be noted that the maximal HR attained during the sECG was lower than the maximal HR during the squash or running field tests. These data show that the routine sECG using a cycle ergometer is a submaximal test of exercise performance, and should be interpreted as such. Physicians should therefore be aware that veteran athletes participating in squash or running activities are exercising intermittently at higher maximal HR than during routine sECG testing.

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