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Psychophysiological responses to the Stroop Task after a maximal cycle ergometry in elite sportsmen and physically active subjects

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Abstract

Physical fitness moderates the psychophysiological responses to stress. This study attempts to determine whether the degree of fitness could affect the response to physical and psychological stress after comparing two groups of men with good physical fitness. Saliva samples from 18 elite sportsmen, and 11 physically active subjects were collected to determine hormonal levels after carrying out a maximal cycle ergometry. Heart rate and skin conductance level were continuously recorded before, during, and after a modified version of the Stroop Color-Word Task. With similar scores in trait anxiety and mood, elite sportsmen had lower basal salivary testosterone, testosterone/cortisol ratio, and HR before an ergometric session than physically active subjects, but no differences were found in salivary cortisol and blood pressure. Salivary testosterone and cortisol responses were lower and testosterone/cortisol ratio responses higher in elite sportsmen. During the Stroop Task, elite subjects showed lower heart rate and skin conductance level over the entire measurement period, and greater heart rate recovery with respect to the baseline values than physically active subjects. The effects of two standardised laboratory stressors on a set of psychophysiological variables were different when elite sportsmen and physically active subjects were compared. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Steroids; Heart rate; Skin conductance level; Cycle ergometry; Stroop Task; Anxiety; Mood; Physical fitness

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1. Introduction

Habitual moderate physical activity has positive effects on physical and psychological health (Petruzzello and Tate, 1997), being usually considered to be a good preventive measure or even an element of treatment for illnesses such as cardiovascular disorders (Baum and Posluszny, 1999). Crews and Landers (1987), after a meta-analyses of 34 studies, concluded that fit subjects compared to control subjects had lower psychophysiological responses to psychological stressors, which has been confirmed in later studies (Boutcher and Landers, 1988; Steptoe et al., 1990; Van Boxtel et al., 1997). Most studies have compared trained and untrained subjects, using inactive men as a control group (Sinyor et al., 1983; Dorheim et al., 1984; Boutcher and Landers, 1988; Claytor et al., 1988; Van Doornen and De Geus, 1989; Tegelman et al., 1990; Tsai et al., 1991; Steptoe et al., 1993; Boutcher et al., 1998).

Nevertheless, it is worth noting that the effects of physical activity on health are dose-dependent (Suay et al., 1997). Thus, intense physical activity, without appropriate recuperation periods, can produce negative effects on health, as in the case of the overtraining syndrome which is found more and more frequently in professional/elite sports persons (Lehmann et al., 1997). The testosterone/cortisol ratio has been proposed as an indicator of adaptation to training in the measure that it reflects the anabolic/catabolic balance of the organism (Adlercreutz et al., 1986). Based on data about testosterone and cortisol responses to physical bouts (Vasankari et al., 1993; Nieman et al., 1994; Perna and McDowell, 1995), it has recently been suggested that their ratio could also be used as a marker of acute intense efforts (Suay et al., 1997).

Physical and mental stimuli have been employed separately in numerous studies on psychophysiological responses to stress in the laboratory, but very few have used both together. Some of these studies aimed to compare the psychophysiological responses to both types of stressors (Turner and Carroll, 1985; Carroll et al., 1987; Goldberg et al., 1996). The main purpose of the rest was to analyse the responsiveness to psychological stress after doing acute physical exercise. With this latter aim, non-significant differences in the psychophysiological reactivity to mental tasks have been found between physically active subjects in comparison to inactive subjects of both gender (Roth, 1989) and with low-active women (Duda et al., 1988). Nevertheless, Steptoe et al. (1993) compared 36 competitive sportsmen and 36 inactive men, finding lower heart rate reactivity to an arithmetic and to a public speaking task in the former group.

Heart rate (HR) and skin conductance level (SCL) are sensitive measures of the autonomic activation which increase in response to mental laboratory stressors. Both measures are highly correlated with well-established independent indices of mental load during computer tasks (Kohlisch and Schaefer, 1996). As has been mentioned above, this increased autonomic activation can be attenuated by acute physical activity, however, some factors such as duration and intensity of exercise, and individual differences also contribute to the reduction of responsiveness (Steptoe et al., 1993). Among the psychological dimensions, the more studied are probably trait-anxiety and mood states, evaluated by STAI-T and Profile of Mood States (POMS) at least in sports contests (Suay et al., 1998).

This study aimed to determine whether the differences in the practise of exercise could affect the response to physical and psychological stress comparing elite sportsmen and physically active subjects. Based on previous data, we hypothesised that elite sportsmen would show better adaptation to the maximal cycle ergometer test (measured by testosterone/cortisol ratio (Tsal/Csal ratio)) due to the fact that they are used to this type of effort, showing generally lower salivary cortisol (Csal) increases than other subjects. Concretely, our expectations were increases in salivary testosterone (Tsal) in response to the maximal cycle ergometer test for both groups, but a different response of Csal, with no changes in the elite sportsmen and increases in physically active subjects. Furthermore, we hypothesised a lower autonomic activation during the mental task together with a better recovery in elite sportsmen than in physically active subjects, which would be reflected in lower HR and SCL values. A second aim of our study was to investigate the relationship between both endocrine and electrophysiological responses to physical and psychological stressors in order to advance the understanding of the underlying mechanisms of the stress response. Following a recent finding (Girdler et al., 1997) we hypothesised an association between testosterone and HR responses to the stressors. To accomplish these purposes, hormones measured before and after a maximum physical stressor (cycle ergometer test) and also HR and SCL changes in response to an acute mental stressor (Stroop task) carried out after the cycle ergometry were compared in elite sportsmen and physically active subjects, controlling their anxiety and mood as two psychological aspects which may affect these responses. An integrative perspective which includes the responses of different psychophysiological variables such as endocrine, cardiovascular and emotional reactions to stress has been emphasised.

2. Method

2.1. Subjects

The sample was composed of 18 elite professional sportsmen and 11 young physically active men, whose characteristics are shown in Table 1. The sportsmen practised handball ($n = 10$) or judo ($n = 8$), trained between 15 and 20 h a week, and were recruited by means of their coaches. The other group was composed of subjects who had the highest estimated maximum oxygen uptake ($V\text{O}_2$ max), selected from a sample of healthy university students recruited by teachers. The estimated $V\text{O}_2$ max was calculated from the Physical Activity Index (PA-R), weight, height, gender and age, following the procedure indicated by Jackson et al. (1990); their level of physical activity was inside the range proposed by public health guidelines (USA and UK) for health benefits (moderate activity at least 5 days a week). Subjects did not use medication, woke between 07.00 and 07.30 h and did not train or practice exercise 36 h before arriving at the laboratory. All participants gave an informed consent approved by the local ethics committee.

Table 1
General characteristics (mean ± S.D.)

	Elite sportsmen	Physically active subjects
Age (years)	22.39 ± 2.61	22.64 ± 2.01
Fat (%)	9.68 ± 3.00	10.57 ± 6.02
BMI (kg/m^2)**	25.83 ± 1.43	23.06 ± 3.09

**$P < 0.01$.

2.2. Procedure

Each subject of both groups participated in one single session that was carried out at the Sports Medicine Centre (Cheste, Valencia, Spain) at the beginning of the sports season. The session lasted from 09.00 to 14.00 h. Firstly, the subject provided the first salivary sample and answered the POMS (09.00–09.30 h). Secondly, a medical interview, anthropometric measurements, resting HR (Kenz-ECG 302) and blood pressure (BP) (Speidel-Kellep) registers and administration of the Trait Anxiety Inventory (T-STAI) were carried out (09.30–11.00 h). Afterwards, between 11.00 and 12.30 h approximately, each subject performed a maximal ergometer test until voluntary exhaustion including measurements of several physiological parameters. After the test, the subject relaxed for 20 min, before the collection of a second salivary sample and the completion of the S-STAI. The subject was then conducted to another room, isolated from noise, with constant temperature (22 ± 2°C) and humidity (50 ± 10%) where he carried out the Stroop task while HR and SCL were simultaneously measured (between 12.00 and 14.00 h, approximately). The subject had to stay quietly and relaxed seated in front of the computer where the task was presented and afterwards perform a 3-min practice with the electrodes fixed. After 10 min of relaxation, HR and SCL were measured for baseline (5 min), the task (5–6 min), and post-task (3 min).

2.3. Cycle ergometer test

The test consisted of three steps: a warm-up (load-free cycling at 60 rev./min) lasting 4 min; an increase in the load every minute until voluntary exhaustion (8–15 min); and a 5-min recovery (load-free cycling). The exercise was performed on an electromagnetic cycle ergometer (Jaeger-Ergotest). The exercising subject was connected to a breath-by-breath analysis system (Sensor Medics MMC 4400 tc), to record the oxygen uptake ($V\text{O}_2$ max). HR was monitored by a Hellige Servomed SMS 182 device using a three-lead ECG (CM5) and recorded at 1-min intervals. Lactate was determined in deproteinised blood from an earlobe sample by a commercial kit (MPR2, Boehringer-Mannheim). Maximal lactate (LA max) was defined as the maximum concentration of three different samples taken at min 1, 3 and 5 post-exercise.

2.4. Stroop task

A modified version of the Stroop Color-Word Task composed of a practical didactic session and four assays with numeric and non-numeric stimuli (MacLeod, 1991) was used. The subject had to count the number of items included in each stimulus, ignoring distracters (numeric or not), as quickly as possible. Each response automatically elicited the next stimulus. Two performance parameters were computed: number of errors and reaction times.

2.5. Apparatus

Two silver–silver chloride electrodes for the skin conductance measure were fixed on tenar and hipotenar eminencies on the non-dominant hand by adhesive rings. A low density gel (358″) covered the sensitive part of both electrodes to enhance the conduction. Additionally, a sensor for the pressure detection was fixed to the ring finger of the same hand. The recording was performed by means of a Coulbourn Modular Recorder System (model S16-12, PA, USA) placed in another compartment of the room out of the subjects' view. The Optical Pulse Coupler (S71-40) and the Tachometer (S77-26) were used for the acquisition and processing of the heart signal, respectively. The transducer was an IR-LED Phototransistor with a frequency of response oscillating between 0.5 and 10 Hz. A third module, the Skin Conductance Coupler (S71-22) was used for the transduction and registration of SCL. This module applies a constant 0.5 V excitation signal to the subject with an accuracy of $\pm 0.1\%$ and produces an output signal that represents conductance in mV per mmho.

2.6. Hormonal determination

Saliva was directly collected from mouth to tube (Unitek R) 5 min after stimulation by water and lemon juice. Samples were centrifuged (5000 rev./min, 15 ± 2°C) and frozen at -20°C until determination by radioimmunoassay (RIA) at our laboratory (Central Research Unit, Faculty of Medicine, University of Valencia, Spain). Samples from each subject were run in duplicate in the same assay.

The Tsal assay required a previous extraction phase with ether. ^{125}I-testosterone tracer was added and decanted into a tube coated with a high specific antibody provided by a commercial kit (ICN Biomedicals, Costa Mesa, CA). Duplicate internal and external control tubes were routinely included in every assay. Tsal levels were expressed in pmol/l and sensitivity was below 6 pmol/l.

Csal was determined by a commercial kit adapted as was recommended in the protocol (Orion Diagnostica, Espoo, Finland). ^{125}I-cortisol tracer and a high specific antibody were used. Csal levels were expressed in nmol/l, the sensitivity was 1 nmol/l, and internal and external controls were included in the assays.

Good precision was obtained with intra and interassay variation coefficients below 5%. More details about hormonal determination have been previously described elsewhere (González-Bono et al., 1999).

The Tsal/Csal ratio was calculated expressing Tsal in pmol/l and Csal in nmol/l.

2.7. Self-report measures

A Spanish version (TEA, 1982) of the State-Trait Anxiety Inventory (Spielberger et al., 1983) was used. This inventory has an alpha reliability coefficient of 0.93 across studies.

Mood was measured with the Spanish version of the POMS conveniently validated (Balaguer et al., 1993). It contains 58 Likert-point items distributed into six scales: Tension, Depression, Anger, Vigor, Fatigue and Confusion. A total score was also computed by adding the scores for the subscales, subtracting the vigor score, and adding a constant of 100 to eliminate negative values (McNair et al., 1971). The higher the total score, the worse the mood.

By means of the Physical Activity Index (PA-R) the subject had to choose one of the following eight items which indicated the quantity of physical activity carried out habitually: 'avoid walking or get tired' (0); 'walking pleasurably and making normal use of stairs' (1); 'participate regularly in moderate physical activities for 10 to 60 min a week' (2); 'participate regularly in moderate physical activities for more than 1 h a week' (3); 'participate regularly in heavy physical activities less than 30 min a week or running less than 2 km' (4); 'participate regularly in heavy physical activities from 30 to 60 min a week or running from 1 to 5 km' (5); 'participate regularly in heavy physical activities from 1 to 3 h a week or running from 5 to 10 km' (6); and 'practice exercise more than 3 h per week or running more than 10 km' (7).

2.8. Data reduction and analyses

One-way ANOVAs were performed to compare both groups in anthropometric, psychological, and baseline physiological measures as well as task performance (number of errors and reaction times). Repeated measures ANOVAs with 'type of items' (numeric/non-numeric) as within-subjects factor was computed to verify the 'Stroop effect'.

For hormonal levels repeated measures ANOVAs with 'Time' (Basal/Post-ergometry) as within-subjects factor, and 'Group' (elite sportsmen/physically active subjects) as between-subjects factor were carried out, with Greenhouse–Geisser adjustments for degrees of freedom where appropriate. To measure the hormonal responses, the difference between post-ergometry and basal levels was calculated.

The recording system registered 10 data per second of HR and SCL. Mean values for each 30-s segment for baseline, task, and post-task were obtained averaging the last 3 min of baseline, the first 3 min of the task, and the 3 min of the post-task period, using Acqknowledge software. The correction of each artefact was displaced for its duration. With respect to electrophysiological measures repeated measures ANOVAs with 'Period' (Baseline/Task/Post-task) as within-subjects factor, and 'Group' as between-subjects factor, using Greenhouse–Geisser adjustments for degrees of freedom, were carried out. Reactivity was assessed via simple change scores (task minus baseline) while Recovery was considered as the difference between post-task and baseline measures following recent recommendations (Linden et al., 1997).

ANCOVAs including body mass index (BMI) as covariate were carried out for hormonal and electrophysiological parameters, as in other studies (Burke et al., 1996; Litschauer et al., 1998). ANCOVAs with trait-anxiety and mood scores as covariates were also calculated.

As post-hoc tests, one-way or repeated measures ANOVAs/ANCOVAs were used depending on the cases.

All the analyses were carried out by the SPSS 8.0 for Windows. Average values in the text are expressed as mean $\pm$ S.D. The alpha level was fixed at 0.05.

3. Results

3.1. Sample characteristics

Elite sportsmen and physically active subjects were similar in age and percentage of body fat, but BMI was significantly higher in the first group ($F_{1,28} = 10.83$, $P < 0.003$) (see Table 1).

3.2. Psychological profiles

No significant differences were found between elite sportsmen and physically active men in trait anxiety (16.94 ± 9.10 and 16.78 ± 5.14, respectively), and the total (131.78 ± 28.83 and 121.78 ± 17.15) or subscale mood scores. Lower scores in trait anxiety than those proposed in the norms for the general population were observed, whereas the total POMS score was within a normal range (Morgan et al., 1988).

3.3. Baseline physiological measures

Elite sportsmen showed lower resting HR and higher diastolic BP than physically active subjects ($F_{1,28} = 7.11$, $P < 0.01$, and $F_{1,28} = 4.15$, $P < 0.05$, respectively), but no differences between groups were found in systolic BP. In addition, basal Tsal and Tsal/Csal ratio were significantly lower in elite sportsmen than in physically active subjects ($F_{1,26} = 15.63$, $P < 0.001$ and $F_{1,26} = 24.11$, $P <$ 0.001), and no differences between groups in basal Csal were detected. In fact, Tsal levels in elite sportsmen were found to be in a normal-low range, whereas Csal levels were in a normal range according to other studies carried out at the same hours (Read and Walker, 1984; Kirschbaum and Hellhammer, 1992; González-Bono et al., 1999). For physically active subjects the Tsal and Csal concentrations were normal. The baseline physiological measures are presented in Table 2.

Table 2
Baseline physiological measures (mean ± S.D.)

	Elite sportsmen	Physically active subjects
HR (rev./min)**	51.00 ± 8.11	60.91 ± 11.94
Systolic BP (mmHg)	120.83 ± 8.95	120.73 ± 4.45
Diastolic BP (mmHg)*	68.05 ± 5.72	64.09 ± 3.75
Tsal (pmol/l)**	172.82 ± 57.72	290.70 ± 97.39
Csal (nmol/l)	11.89 ± 7.00	9.01 ± 4.39
Tsal/Csal ratio**	0.016 ± 0.007	0.037 ± 0.014

*$P < 0.05$.
**$P < 0.01$.

3.4. Response to the ergometry

3.4.1. Measures in the ergometry

In the ergometry (Table 3), the maximum HR was lower ($F_{1,28} = 4.54$, $P < 0.04$), and the duration ($F_{1,28} = 24.43$, $P < 0.001$), diastolic BP ($F_{1,28} = 23.46$, $P < 0.001$), and $V\text{O}_2$max ($F_{1,26} = 9.33$, $P < 0.005$) were higher in elite sportsmen than in physically active subjects. Systolic BP, maximal power output, and LA max were not significantly different between either group.

3.4.2. State anxiety and hormonal response

No significant differences in State anxiety were found when elite sportsmen and physically active subjects were compared (20.94 ± 6.91 and 17.45 ± 11.98, respectively).

The basal and post-ergometry hormonal levels are shown in Fig. 1. For Tsal, significant effects for 'Group' ($F_{1,24} = 38.62$, $P < 0.001$) and the interaction 'Group × Time' ($F_{1,24} = 6.63$, $P < 0.02$)

Table 3
Measures in the ergometric test (mean ± S.D.)

	Elite sportsmen	Physically active subjects
Maximum HR (rev./min)*	181.33 ± 8.54	187.73 ± 6.48
Systolic BP (mmHg)	179.44 ± 14.13	173.64 ± 15.01
Diastolic BP (mmHg)**	80.55 ± 10.83	63.64 ± 5.04
Duration (min)**	12.39 ± 1.72	9.54 ± 1.03
Maximal power (W)	307.78 ± 34.39	286.36 ± 31.07
$V\text{O}_2$ max (ml/min)**	3457.53 ± 431.96	2969.50 ± 338.83
$V\text{O}_2$ max (ml/min/kg)	40.90 ± 5.65	40.64 ± 4.44
LA max (nmol/l)	12.84 ± 1.99	12.15 ± 1.96

*$P < 0.05$.
**$P < 0.01$.

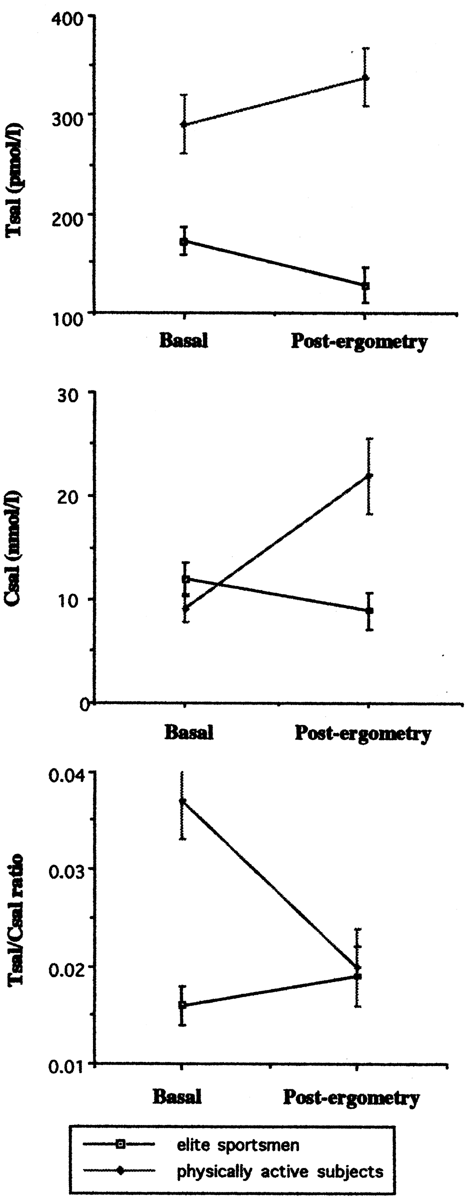

Fig. 1. Basal and post-ergometry levels of Tsal, Csal, and Tsal/Csal ratio for elite sportsmen and physically active subjects.

were found. Not only post-ergometry Tsal level ($F_{1,26} = 41.80$, $P < 0.001$) but also the response was significantly lower in elite sportsmen ($F_{1,25} = 6.63$, $P < 0.017$).

For Csal, 'Group' ($F_{1,27} = 5.33$, $P < 0.03$), 'Time' ($F_{1,27} = 5.60$, $P < 0.02$) and the interaction 'Group × Time' ($F_{1,27} = 14.45$, $P < 0.001$) showed significant effects. Post-ergometry level and the response of Csal were significantly lower in elite sportsmen ($F_{1,28} = 13.18$, $P < 0.001$ and $F_{1,28} = 14.45$, $P < 0.001$, respectively).

Also for Tsal/Csal ratio, a significant effect for 'Group' ($F_{1,24} = 6.71$, $P < 0.016$), 'Time' ($F_{1,24} = 6.50$, $P < 0.018$) and the interaction 'Group × Time' ($F_{1,24} = 12.88$, $P < 0.001$) were found. The response was greater in elite sportsmen than in physically active subjects ($F_{1,25} = 12.88$, $P < 0.001$). Thus, while Tsal and Csal levels showed a pattern of decrease in the former and an increase in the latter group, the results for the Tsal/Csal ratio were the opposite, with a slight increase in elite sportsmen and a striking diminution in physically active subjects.

When hormonal analyses were repeated with BMI, trait anxiety or mood as covariates no additional significant results were found.

3.5. Electrophysiological responses to the Stroop task

The Stroop task was effective to elicit electrophysiological responses since for both HR and SCL the factor 'Period' was significant ($F_{1.23,31.90} = 39.10$, $P < 0.001$, and $F_{1.89,47.35} = 8.75$, $P < 0.001$, respectively). When the stressor was introduced, HR and SCL rose significantly ($F_{1,26} = 37.42$, $P < 0.001$, and $F_{1,25} = 20.63$, $P < 0.001$, respectively) but showed a significant drop when it finished ($F_{1,26} = 44.39$, $P < 0.001$, and $F_{1,25} = 6.16$, $P < 0.02$, respectively), post-task levels being significantly lower than the baseline only in the case of HR ($F_{1,26} = 12.76$, $P < 0.001$).

The 'Stroop effect' proved to be significant as the number of errors ($F_{1,26} = 14.04$, $P < 0.001$) and the reaction times ($F_{1,26} = 18.77$, $P < 0.001$) were higher in numeric items in comparison to non-numeric ones.

'Group' did not show significant effects for HR (Fig. 2) and SCL (Fig. 3), but when the analyses were repeated using BMI as covariate, it presented significant effects on both parameters ($F_{1,24} = 4.19$, $P < 0.05$, and $F_{1,23} = 6.83$, $P < 0.02$ for HR and SCL, respectively), which reached

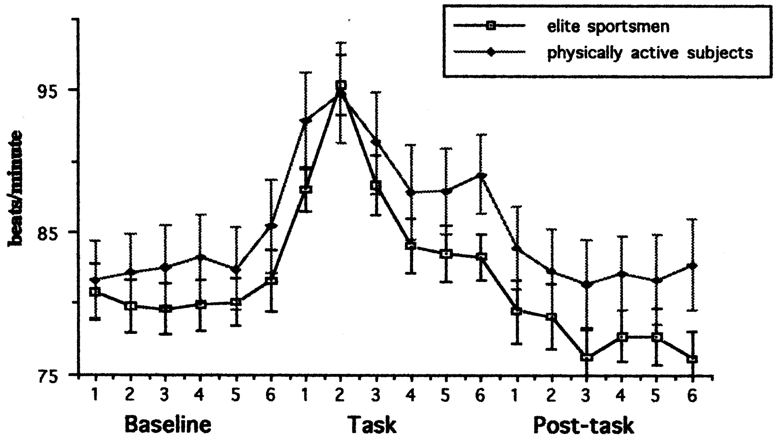

Fig. 2. Baseline, task, and post-task HR in the Stroop test each 30 s for elite sportsmen and physically active subjects.

lower values in elite sportsmen than in physically active subjects. No effects for 'Group' were found with trait anxiety and mood as covariate.

No significant differences between groups in their HR Reactivity were found, but the HR Recovery (post-task minus baseline) was significantly greater in elite sportsmen than in physically active subjects ($F_{1,26} = 4.21$, $P < 0.05$), that is, although both groups reached their baseline HR levels, elite sportsmen had lower post-task HR with respect to the baseline levels than physically active subjects. SCL Reactivity and Recovery did not differ between groups.

3.6. Relationship between hormonal and electrophysiological responses

In the total sample, the Tsal response correlated positively to HR Reactivity ($r = 0.39$, $P < 0.05$), whereas the response of the Tsal/Csal ratio correlated negatively to SCL Recovery ($r = -0.44$, $P < 0.03$). Furthermore, the basal ratio was positively related to SCL during baseline ($r = 0.45$, $P < 0.03$), task ($r = 0.51$, $P < 0.01$), and post-task ($r = 0.53$, $P < 0.01$) periods. No other significant correlations were found.

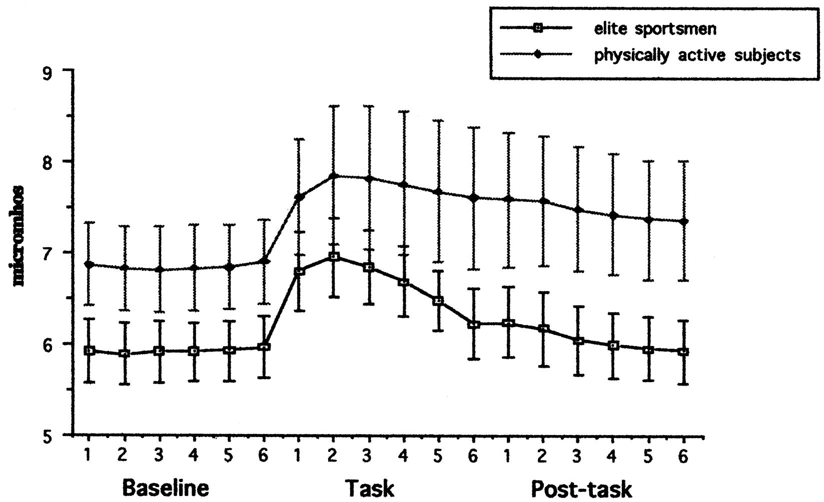

Fig. 3. Baseline, task, and post-task SCL in the Stroop test each 30 s for elite sportsmen and physically active subjects.

4. Discussion

This study confirms significant differences in several psychophysiological measures in baseline, reactivity, and recovery from different stressors between groups of men with different degrees of physical activity. At the baseline, the elite sportsmen had significantly lower Tsal and HR but did not differ in Csal and BP measures. Differences between groups in Tsal were amplified after a maximal physical effort, the mean rising somewhat for the physically active subjects, and falling for the elite group. Despite similar basal levels, Csal rose considerably in the physically active group but not in the elite sportsmen. Consequently, a derived measure (Tsal/Csal ratio) was significantly lower at baseline in elite sportsmen than in physically active subjects, increasing after the stressor in the former but decreasing in the later. On the other hand, the Stroop task elicited sharp HR and SCL increases which were followed by recovery. The HR profile was similar for both groups, but sportsmen showed a fall below initial baseline values in the recovery period. Both HR and SCL were generally higher for physically active subjects compared to elite sportsmen over the entire period measured, however, differences only reached statistical significance when BMI was employed as covariate. The importance of this index is not accepted sufficiently, it only being controlled in some studies; this lack of control may contribute to the contradictory results reported in psychophysiological responses.

The values obtained in the trait-anxiety for all subjects could be partially due to the fact that habitual practice of physical activity has positive psychological effects, such as a reduction of anxiety and negative mood or depression (Petruzzello and Tate, 1997). In addition, with respect to mood states both groups showed an 'iceberg profile' which is characteristic of physically active but non-overtrained subjects (Suay et al., 1998). This lack of differences between groups in trait anxiety and mood makes the comparison easier, since it reduces the importance of considering these psychological dimensions when studying the psychophysiolgical responses to stress.

The resting HR together with the longer duration and higher $V\text{O}_2$ max in the ergometer test in elite sportsmen than in physically active subjects confirm a better physical fitness. Nevertheless, the groups did not differ in their post-exercise maximal lactate values, which indicates that the glucolytic cost of the effort was equivalent in both groups. In addition, neither group differed in their state-anxiety after the test, showing scores similar to the mean of the general population in basal situations. Even if the evidence for the anxiolytic effects of maximal exercise is less convincing than moderate exercise, the cycloergometer test may have reduced state-anxiety as has been reported in studies employing similar intervals (Raglin and Wilson, 1996).

As has been mentioned above, not only the basal levels but also the hormonal responses to acute physical exercise were different in both groups. Although lower resting testosterone (hypoandrogenism), and higher resting cortisol (hypercortisolism) in trained than in sedentary men have been reported (McColl et al., 1989; Hackney et al., 1990; Vervoorn et al., 1991; Urhausen et al., 1995), however, no differences have also been found (Tegelman et al., 1990; Tsai et al., 1991; Vasankari et al., 1993). In a previous study, we found higher basal levels of Tsal and Csal in judo fighters than in sedentary control subjects (Salvador et al., 1995). In the present study, measurements were obtained before the sports season, and the results showed lower basal Tsal levels, but no differences in basal Csal, in elite sportsmen compared to physically active subjects. Testosterone levels increased in submaximal and maximal efforts, but in exercises carried out until exhaustion, the initial increase was followed by a considerable diminution but to a different degree depending on the characteristics of the sample and their fitness (Fernández-Pastor et al., 1992). In one study, testosterone levels decreased by 30% during a 4-h bicycle exercise in untrained but not in trained subjects (Vasankari et al., 1993). In our study, elite sportsmen showed a slight diminution in Tsal levels, even though a hypoandrogenism in their basal levels was detected, whereas physically active subjects showed an increase in this measure after the physical test. It is important to bear in mind that the glucolytic cost of the test was similar for both groups, which suggests that the differences in Tsal were not due to a different motivation to carry out the ergometer test until exhaustion. Furthermore, as in other studies, we have found a slight cortisol diminution in elite sportsmen (Perna and McDowell, 1995), and increases in control subjects (Nieman et al., 1994) after maximal acute exercise. No changes in the Tsal/Csal ratio have been found in elite sportsmen as has been previously reported (Tsai et al., 1991), whereas physically active subjects showed a decrease.

With regards to electrophysiological responses, an increment in HR and SCL when subjects were faced with the stressor followed by a post-task decrement was found in both groups. Moreover, elite sportsmen showed lower HR and SCL before, during and after the task, which coincides with the lower HR registered in trained versus untrained men during the exposition to different psychological stressors (Boutcher et al., 1998). Our results suggest that SCL is also a sensitive measure to detect the differences in autonomic responses depending on the physical fitness, although to our knowledge, no other studies have compared the SCL responses to a mental task after maximum physical exercise in groups differing in their physical activity.

Another point to take into account is cardiovascular reactivity, which could be defined as an acute and relatively quick change in a cardiovascular parameter produced by the presentation of a stressor (Hugdahl, 1995). As in other studies (Dorheim et al., 1984; Claytor et al., 1988), we have not found differences between the two groups compared. Nevertheless, a lower reactivity in trained subjects has also been described (Holmes and McGilley, 1987; Light et al., 1987; Turner et al., 1988), although in these studies trained subjects would be approximately equivalent in fitness and practice of exercise to our physically active subjects. Another index increasingly employed is cardiovascular recovery, which seems to be a good predictor of hypertension (Schuler and O'Brien, 1997). Our results show that although both groups recovered their basal HR levels 3 min after the Stroop task, the magnitude of the HR Recovery was greater in elite sportsmen than in physically active men, which follows the trend indicated in another study where trained men had faster cardiac recovery after the exposition to psychosocial stressors than untrained subjects (Sinyor et al., 1986).

Although in men, high androgen levels have been related to an increment of risk of cardiovascular alterations (Cohen and Hickman, 1987), other studies have not found any relationship (Cauley et al., 1987; Barrett-Connor and Khaw, 1988; Phillips et al., 1988). On the other hand, higher metabolic factors of cardiovascular risk in men with low plasmatic testosterone have recently been reported (Simon et al., 1992, 1997; Haffner et al., 1994a,b). In our study, no relationship between levels of Tsal and HR has been found, but there was a positive relationship between the Tsal response and HR Reactivity for the total sample. Moreover, basal Tsal/Csal ratio was positively correlated to baseline SCL, a point that, in our opinion, deserves further research. Hence, the responsiveness to both kinds of stressors appears to be related in healthy men with good fitness, a variable which could moderate this relationship.

On the whole, the present study demonstrates that the effects of two standardised laboratory stressors on a set of psychophysiological variables are different in men differing in their physical activity. Differences in other relevant moderating variables of the psychophysiological response such as trait and state anxiety, and mood were controlled. Moreover, the glucolytic cost derived from the physical effort carried out was also similar. However, differences appeared in some measures of physical fitness between elite sportsmen and physically active subjects which may justify the psychophysiological responses detected, demonstrating the impact of a different degree of physical activity. Hence, this study confirms that physical exercise practised by elite sportsmen or practised habitually but without controlled training or competitive situations induce different responses to laboratory stressors, and consequently moderate the psychophysiological responses to stress. Furthermore, our results suggest an association between hormonal and autonomic measures which deserve a closer analysis in order to understand the mechanisms underlying the response to stress.

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