Cardiac stress associated with display parachuting

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Abstract

Introduction: Acrobatic skydiving is considered a high risk activity. This risk and the difficulty of the maneuvers are stressors that modify the cardiac activity. Our aim is to analyze the electrocardiographic tracing and the evolution of the heart rate during this paratrooper activity, creating a figure of high difficulty.

Method: We put a Nuubo electrocardiographic monitor on two experienced paratroopers members of the Acrobatic Patroo-per Patrol of the Air Force (PAPEA) during the execution of an acrobatic exercise, called "diamond", in which four parachutists are attached during the flight. We analyzed the electrocardiogram (ECG) during the whole activity and we got the heart rate (HR) in the following phases: 1.- Up to the aircraft; 2.- Taking off; 3.- Before jumping; 4.- Preparing the figure; 5.- Formation flight and 6.- Landing. They jumped five times, obtaining the average of each jumper. Previously we made them an ECG at rest and maximal treadmill stress test (ST).

Results: Both jumpers get the largest HR while they fly preparing the formation (165 and 143 beats/min), it is 87% and 77% of the max HR reached in ST. Beats under 95 b/min are not registered in any stage or jump. Each jumper has a different response, depending on the effect that the take-off has on him. In one of them, HR increases gradually until it reaches the maximum peak when they are in formation, and on the other jumper it appears another peak, that is repeated in the five jumps, coinciding with the taking off. There is no other ECG alterations.

Conclusions: We conclude that cardiac stress caused by carrying out this type of exercises is manifested by significant increases in heart rate, around 80% of the maximum heart rate, without other electrocardiographic abnormalities.

Key words: Heart rate. Skydiving. Electrocardiogram.

Estrés cardiaco asociado a la realización de una formación acrobática paracaidista

Resumen

Introducción: El paracaidismo acrobático es una actividad de alto riesgo. Este riesgo y la dificultad de las maniobras son factores estresantes que modifican la respuesta cardiaca. Nuestro objetivo es analizar el trazado electrocardiográfico y la evolución de la frecuencia cardiaca (FC) durante esta actividad paracaidista creando una figura de alta dificultad.

Método: Colocamos un monitor electrocardiográfico Nuubo a dos paracaidistas experimentados de la Patrulla Acrobática Paracaidista del Ejército del Aire (PAPEA) durante la ejecución de un acrobatico ejercicio llamado "diamante" en el que cuatro paracaidistas estaban unidos durante el vuelo. Análizamos el electrocardiograma (ECG) durante la totalidad de la actividad y medimos la FC en las siguientes fases: 1.- Subiendo al avión; 2.- Tomando el vuelo; 3.- Antes de saltar; 4.- Preparando la figura; 5.- Vuelo durante la formación y 6.- Aterrizaje. Saltaron cinco veces, obteniendo el promedio de cada saltador. Antes de ello realizaron un ECG en reposo y una prueba de esfuerzo máximo en tapiz rodante.

Resultados: Los dos saltadores consiguieron las mayores FC cuando se preparaban para realizar la formación (165 y 143 lat/min), lo que supone el 87% y 77% de la FC más alta registrada en la prueba de esfuerzo máximo. No se registró ninguna FC inferior a 95 lat/min en ninguna de las fases o saltos. Cada saltador tenía una respuesta diferente, dependiendo del efecto que la toma de altura le causase. En uno de ellos, la FC aumentaba gradualmente hasta alcanzar su pico máximo durante la formación, mientras que en el otro saltador aparecía otro pico que se repetía en los cinco saltos, coincidiendo con el momento de la toma de altura. No se detectaron alteraciones electrocardiográficas.

Conclusiones: Concluimos que el estrés cardiaco producido por la realización de este tipo de ejercicios se manifiesta por aumentos importantes de la frecuencia cardiaca, en torno al 80% de la frecuencia cardiaca máxima, sin otras alteraciones electrocardiográficas.

Palabras clave: Frecuencia cardiaca. Paracaidismo. Electrocardiograma.

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Introduction

Stress is understood to be the body’s response to environmental demands which exceed its natural ability to cope. This response entails the nervous and endocrine systems regulating and modifying the sensation of pain, energy production, temperature changes, blood pressure and heart rate. The hormones involved include glucocorticoids and catecholamines.

Numerous situations or stressors have been described. These range from fear and new situations to the feeling of being watched or scrutinised and facing up to difficult tasks.

The physiological and emotional responses to these situations are regulated by the brain and do not necessarily suppose physical and mental health problems, but can be considered a way of preparing for an activity involving these factors. Typical physiological manifestations include an increased heart rate (HR), tremors and a dry mouth, which appear both when suffering from anxiety prior to examination and as an anticipatory response when about to enter into risky activities such as skydiving, other high-risk sports or unknown environments. Sometimes these responses are very intense, frequent or long-lasting and the stress suffered can lead to health complications by triggering the onset of a latent disorder, complicating the clinical signs or perpetuating the symptoms.

Parachuting in itself is considered a high-risk activity and, as such, calls for constant attention and concentration in order to minimise the possibility of having an accident. As a result, physiological reactions are sparked which help prepare the body for this situation as a consequence of the stress produced, as occurs in all athletes. This response is mediated by cortisol.

If to the innate risk of the activity we add the stress corresponding to carrying out an extremely difficult task, such as performing the manoeuvres involved in creating a display formation, then we arrive at a remarkably complicated situation which justifies the production of sufficient adrenaline, cortisol and ACTH, among other substances, to raise the heart rate.

These specific manoeuvres consist of controlling the parachute canopy in order to approach other teammates, joining parachutes in a specific formation and descending for a few minutes in a coordinated fashion, maintaining the figure formed, and then breaking free without getting tangled up with each other before landing.

The physiological and psychological responses associated with parachute jumping have been studied both in sport parachutists and military parachutists, in other circumstances such as tactical jumps, high-altitude jumps or tandem jumps, but never in display team jumps. Stress, together with physical exercise, is known to trigger episodes of arrhythmia, especially tachycardia which can cause sudden death, and we also know that psychosocial risk factors related to work lie in the background of many myocardial infarctions. Hence the importance of this study to discover the cardiac response to situations which are highly demanding, more mentally than they are physically. Therefore, our aim is to analyse the electrocardiogram pattern and evolution of the heart rate associated with the stress caused by very difficult precision parachuting.

Materials and method

Population

Two parachutists ("A" and "B") belonging to the Spanish Air Force’s Parachute Display Team (PAPEA) with three years’ experience in the group and aged between 27 and 26 took part. Both were informed of the objectives of and procedures involved in the study, and signed the corresponding informed consent document. Permission was received from the relevant military authorities and a favourable report was received from the Research Ethics Committee at the University of Murcia.

Procedure

A Nuubo® electrocardiographic monitor was fitted onto each of the parachutists during a "diamond with flag" formation in which four parachutists jump up during descent (Figure 1). Parachutist "A" occupied the middle right position and parachutist "B", the bottom position with the flag. After leaving the aircraft and freefalling for a few seconds, the parachutists open their parachutes and approach each other in order to perch on another jumper’s canopy and then continue to descend, all four together, until they reach the critical altitude at which the formation is broken. At that point, the figure breaks up, the parachutists separate and each one lands independently. The exercise was repeated on five separate occasions over two consecutive days in similar weather conditions.

In a session prior to the jumps, a cardiovascular examination was conducted on each parachutist which included auscultation, taking his blood pressure and an electrocardiogram at rest. They were then subjected to a maximum stress test (ST) on a treadmill (Runner® run 7411), measuring their respiratory response (Cortex®, Metalyzer 3B) and with electrocardiographic stress testing (CARDIOLINE®, Click ECG BT).

The Nuubo® device was fitted onto an elastic harness on each jumper’s chest (Figure 2). The harness bore five electrodes which, with the help of a conductive gel, tracked electrical activity to process and generate the three leads.

The Nuubo® monitor continuously recorded the three electrocardiographic leads from before embarking on the plane until their return to base after the last jump of the day. The electrocardiogram (ECG) was then analysed in search of alterations and the heart rate was determined in each of the stages into which the jumps were divided: 1.- Embarking; 2.- Taking off; 3.- Ready to jump; 4.- Flying to the formation, preparing the figure; 5.- In formation, and 6.- Landing. The jumps were videotaped from the ground with a camera synchronised to the second with the ECG device in order to relate every action with the corresponding heart rate.

To obtain the heart rates, the recording of each of the jumps was viewed, tracking the hour, minute and second, and selection was made of a segment of an ECG lead free of interference spanning five seconds.
before and after the moment chosen for each stage and the maximum HR was determined during this interval.

Statistical method

The mean (X) and standard deviation (SD) of the HR of each of the stages for each of the parachutists were obtained. The coefficient of variation (CV) was used to analyse the homogeneity of the measurements (CV=SD / X x 100), considering values of less than 20% homogeneous.

The mean values were compared using Student’s t-test after checking the normal distribution of the initial characteristics using the Shapiro-Wilk test and the equality of variances using the Levene test.

Table 1 shows the anthropometric descriptive data and the data of the initial assessment of each of the parachutists taking part, including heart rate at rest and maximum heart in the stress test (HRmax ST).

Table 2 shows the heart rates in each of the stages of each jump for parachutist “A” and “B”, respectively.

The coefficients of variation of the heart rates of each parachutist in each of the stages show that the values are very homogeneous and, therefore, the variability is minimal. Comparing the mean heart rates of each parachutist in each stage, significant differences can be observed (Table 3); these are more marked on take-off and during freefall before taking up formation (Figure 3).

By calculating the percentages of the mean heart rates in each stage with regard the heart rates at rest and the maximum in the stress test, we obtain the values shown in Table 4.

Table 1. Anthropometric characteristics and initial assessment.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Parachutist A</th>
<th>Parachutist B</th>
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</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27</td>
<td>26</td>
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<td>Years parachuting</td>
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</tr>
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<td>Years in PAPEA</td>
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<td>Height (cm)</td>
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<td>Weight (kg)</td>
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<td>21.8</td>
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<td>HR at rest (ppm)</td>
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<td>72</td>
</tr>
<tr>
<td>HRmax ST (ppm)</td>
<td>189</td>
<td>185</td>
</tr>
<tr>
<td>BP at rest (mmHg)</td>
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<td>120/65</td>
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<td>ECG at rest</td>
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<td>No alterations</td>
</tr>
<tr>
<td>ECG under stress</td>
<td>Compatible normality</td>
<td>Compatible normality</td>
</tr>
</tbody>
</table>

Table 2 shows the heart rates in each of the stages of each jump for parachutist “A” and “B”, respectively.
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Discussion

We considered precision parachuting to be a stressful practice with impact on cardiac activity. To investigate this, we monitored the electrocardiographic tracing and heart rate when completing a highly complex, high-precision parachute display formation.

Situations of anxiety or stress involve stressors which can be identified in each stage of the case we are focusing on.

In the first stage of the jumps, which we have called “Embarking” and consists of the parachutist carrying his equipment to the plane, we observed mean HRs of 115 and 105 beats per minute.

The second stage, “Taking off”, occurs within the plane, with the parachutist sitting or standing, but not doing anything else. The increase in HR responds to the stressful situation of preparing for what they are about to do and potential fear of what might happen. The values are similar to those reported at different stages in aircraft pilot training. We noted that the response was different in the two subjects. One maintained an average HR of 100 beats, while the other reached 130, which when compared with the HRs in the other stages suggests that each adapted differently to take-off, conditional on many factors, including different gene expression and the influence of aircraft noise on anxiety and health in general.

Certain factors related to risk activities may give rise to fear and anxiety because the participant is endangering his/her health. Some of these are factors external to the parachutist which can affect forming the figure, such as changes in the strength and direction of the wind or equipment failure, which, while not expected, are foreseeable, this being a planned activity in which uncertainty is limited and the environment monitored; these are, therefore, stressors which can be controlled. This is the situation we can observe in the third stage, “in the zone”, in which the parachutists are in the plane, flying over the jump zone, ready to exit. The subjects’ heart rates were higher than in the previous stage, but lower than those observed in stage 4, “in the air”, in which they freefall and open their parachutes to approach each other and take their positions in the formation.

In this fourth stage, the main stressor is the sensation of falling, together with those previously mentioned of fear of the parachute not opening and equipment failure. Another factor contributing to stress is the sensation of falling, together with those previously mentioned of fear of the parachute not opening and equipment failure.

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the other team members. They are concerned about being in the right place at the right time, occupying the predetermined position. The days on which this study was conducted, all the jumps were valid and were carried out in ‘privacy’, jumping in the vicinity of the air base without spectators. Had the exercise been performed at an exhibition or air show, the stressors mentioned above would be joined by the feeling of being watched and judged by a crowd expecting perfection, coupled with the responsibility of representing their institution (Air Force). Something similar happens at sports championships.

At this stage, fear of the parachute failing to open may have disappeared and experience in jumps of this nature exerts its influence. According to Mazureck et al’s study15,18, parachute training may lead to a reduced response to stress and improved autonomic control of the cardiovascular function in novice parachutists.

After achieving the figure, they must descend together without breaking the formation, each maintaining his position; this involves the new emotional burden of not contributing to the failure of the enterprise. After this, they need to separate and descend in order to land independently and safely. This creates a new stressful situation. If they cannot form the figure, they have failed and must try again, reorganising the team and the equipment, and taking off once again, with all the economic implications that would involve.

Other authors have used parachute jumps to assess immune, genetic22 and hormonal responses to stress, measuring, among other things, cortisol and salivary amylase6,13,32. The results of Meyer et al’s study33 suggest that experience may modulate the emotional response involving cortisol reactivity to parachuting, but does not cancel out its appearance altogether. This may be consistent with the data showing that, despite being highly experienced, the heart rates of our parachutists still rose during the different stages of the jump.

Other studies suggest that parachuting may result in reduced vagal activity associated with increased sympathetic tone during jumps. Experienced parachutists, however, are not exposed to high cardiovascular risk44. All the same, we agree on the need to study their cardiovascular function when subjected to stressors.

The cardiac response to episodes or situations of occupational stress has been studied in nurses34, members of the security forces24 and surgeons32, among other groups. These studies have focused on tachycardias as manifestations of the anxiety accumulated by the continued practice of the profession24 within the context of burnout syndromes and responses to specific situations which accentuate personal vulnerability in the professional task being performed. In the case of our parachutists, the pressure to which they are subjected is controlled by experience and planning execution of the exercise.

In order to avoid the consequences of stress36, each individual should employ coping strategies, i.e. make efforts to deal with the stressful situation40.

The main limitation of our study is the low number of participants, meaning we cannot arrive at categorical conclusions or make generalisations, but it can be used as a basis from which to guide the response to this activity and propose actions to promote health and conduct further research. It would be interesting to determine the influence of experience by comparing what occurs with novice and veteran parachutists when performing the same task.

Although we have not detected any anomalies, through this study we open the way to using the continuous study of electrocardiographic tracing for the physiological assessment of parachutists, compared with studies which only work with data from before and/or after jumping32 or ones which do not take tracings into account.

We can conclude that experienced parachutists who perform formation displays undergo cardiac stress, as manifested by significant increases in the heart rate of around 80% maximum heart rate. The electrocardiographic tracings only revealed continuous episodes of sinus tachycardia.

Acknowledgment

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Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

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