Cardiac stress associated with display parachuting

Ignacio Martínez González-Moro[1], María Carrasco-Poyatos[2], José L. Lomas-Albaladejo[1], Vicente Ferrer-López[1]

[1]Grupo de Investigación Ejercicio Físico y Rendimiento Humano. Universidad de Murcia. [2]Universidad de Almería.

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Summary

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 Patrooper 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 una formación acrobática en la que cuatro paracaidistas se unen durante el vuelo creando una figura denominada "diamante". Analizamos el electrocardiograma (ECG) durante todo el ejercicio y recogimos la FC en las siguientes fases: 1.- Subiendo al avión; 2.- Despegando; 3.- Antes de saltar; 4.- Preparando la figura; 5.- En formación y 6.- Tomando tierra. Se repitió cinco veces, obteniéndose la media de cada saltador. Previamente se realizó un ECG en reposo y una prueba de esfuerzo máxima (PE) en tapiz rodante.
Resultados: Ambos saltadores consiguen la mayor FC mientras vuelan preparando la formación (165 y 143 lat/min), supone el 87% y 77% de la FC máxima alcanzada en la PE. No se recogen FC inferiores a 95 pulsaciones en ninguna fase ni salto. Cada saltador tiene un tipo de respuesta, según le afecte el momento del despegue. En uno la FC aumenta paulatinamente hasta ella llega al pico máximo cuando están en formación y en el otro aparece otro pico, que se repite en los cinco saltos, coincidiendo con el despegue. En el ECG sólo se han observado episodios continuados de taquicardias sinusales.
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.

Correspondence: Ignacio Martínez González-Moro
E-mail: ignaciomgm@um.es

Introduction

Stress is understood to be the body's response to environmental demands which exceed its natural ability to cope[1]. This response entails the nervous and endocrine systems regulating and modifying the sensation of pain, energy production, temperature changes, blood pressure and heart rate[2]. The hormones involved include glucocorticoids and catecholamines[3].

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[4].

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[5]. Typical physiological manifestations include an increased heart rate (HR), tremors and a dry mouth, which appear both when suffering from anxiety prior to examination[6] and as an anticipatory response when about to enter into risky activities such as skydiving[7], other high-risk sports or unknown environments[8,9]. Sometimes these responses are very intense, frequent or long-lasting and the stress suffered can lead to health complications[10] by triggering the onset of a latent disorder, complicating the clinical signs or perpetuating the symptoms[11].

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[12]. As a result, physiological reactions are sparked which help prepare the body for this situation as a consequence of the stress produced[13], as occurs in all athletes. This response is mediated by cortisol[14,15].

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[16,17].

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[15,17-19] and military parachutists, in other circumstances such as tactical jumps[20,21], high-altitude jumps or tandem jumps[22], 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[23], and we also know that psychosocial risk factors related to work lie in the background of many myocardial infarctions[24]. 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 parachutists during a "diamond with flag" formation in which four parachutists join 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 the 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 timewise.

To obtain the heart rates, the recording of each of the jumps was viewed, tracking the hour:minute:second, and selection was made of a segment of an ECG lead free of interference spanning five seconds

Figure 1. "Diamond with flag" formation.

Figure 2. Nuubo® device with harness and electrodes.

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.

Results

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.

Variables	Parachutist A	Parachutist B
Age (years)	27	26
Years parachuting	4	4
Years in PAPEA	3	3
Height (cm)	182	175
Weight (kg)	70	67
BMI (weight/height2)	21.1	21.8
HR at rest (ppm)	64	72
HRmax ST (ppm)	189	185
BP at rest (mmHg)	120/60	120/65
ECG at rest	No alterations	No alterations
ECG under stress	Compatible normality	Compatible normality

Figure 3. Evolution of the mean heart rate (beats/min) of each parachutist in each stage of the jumps.

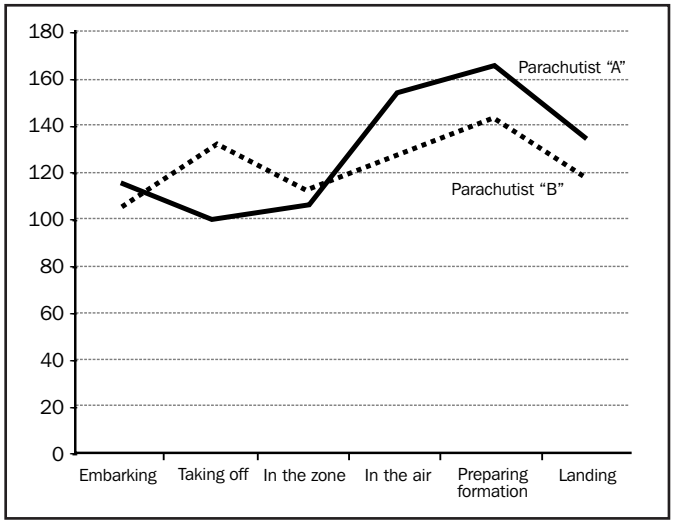

Table 2. Heart rates (beats/min) in each stage, jump and parachutist.

	Jump No. 1		Jump No. 2		Jump No. 3		Jump No. 4		Jump No. 5	
Paracaidista	**"A"**	**"B"**	**"A"**	**"B"**	**"A"**	**"B"**	**"A"**	**"B"**	**"A"**	**"B"**
Embarking	110	119	90	96	125	88	128	113	124	112
Taking off	101	138	99	144	97	125	95	123	110	128
In jump zone	105	122	103	120	100	117	116	111	104	93
In the air	153	130	156	142	166	122	150	121	150	131
Preparing formation	150	151	184	147	160	137	172	142	162	138
Landing	138	110	117	120	142	126	144	126	135	107

Table 3. Mean, standard deviation and CV of HR (beats/min) in each stage and parachutist.

	Parachutist "A"		Parachutist "B"		
	Mean ± sd	**CV**	**Mean ± sd**	**CV**	**Differences (p)**
Embarking	115.4 ± 15.8	13.7	105.6 ± 13	12.3	0.316
Taking off	100.4 ± 5.8	5.8	131.6 ± 9.0	6.9	0.000
In the zone	105.6 ± 6.1	5.8	112.6 ± 11.7	10.4	0.270
In the air	155.0 ± 6.6	4.3	129.0 ± 8.5	6.6	0.001
Preparing formation	165.6 ± 12.9	7.8	143.0 ± 6.0	4.2	0.007
Landing	135.2 ± 10.8	8	117.8 ±8.9	7.6	0.025

Table 4. Percentages of HR at rest and at maximum stress in each stage.

	% HR at rest		% HRmax ST	
Parachutist	**"A"**	**"B"**	**"A"**	**"B"**
Embarking	180.3	146.7	61.1	57.1
Taking off	156.9	182.8	53.1	71.1
In the zone	165.0	156.4	55.9	60.9
In the air	242.2	179.4	82.0	69.8
Preparing formation	258.8	198.6	87.6	77.3
Landing	211.3	163.6	71.5	63.7

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[25]. 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[26] and the influence of aircraft noise on anxiety and health in general[27].

Certain factors related to risk activities may give rise to fear and anxiety because the participant is endangering his/her health[7]. 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[28]; 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[26], together with those previously mentioned of fear of the parachute not opening and equipment failure.

Another factor contributing to stress is the fear of failure. In our case this would consist of not achieving the objective of the jump, creating the planned figure, due to poor personal handling or discoordination between the members of the team. We can consider this a professional factor and what differentiates these subjects and makes them unique for their mission[29], in a manner similar to that of first-class athletes[30]. The response to this factor lies in the high heart rates shown in stage 5, "preparing the formation". During these few minutes of their descent, the physical exercise the parachutists perform is focused on controlling their parachutes and their relative position in space and with regard

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[31].

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*[15,18], 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, genetic[26] and hormonal responses to stress, measuring, among other things, cortisol and salivary amylase[7,15,32]. The results of Meyer et al's study[33] 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 risk[34]. 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 nurses[35], members of the security forces[36] and surgeons[37], among other groups. These studies have focused on tachycardias as manifestations of the anxiety accumulated by the continued practice of the profession[38] 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 stress[39], each individual should employ coping strategies, i.e. make efforts to deal with the stressful situation[40].

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 jumping[22] 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.

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Conflict of interest

The authors do not declare a conflict of interest.

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