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Análisis de los factores de variabilidad de la frecuencia cardíaca afectados tras una prueba de tolerancia a la hipoxia en función del género.

An analysis of the factors of heart rate variability affected after a hypoxia tolerance test as a function of gender

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Resumen. La variabilidad de la frecuencia cardíaca (VFC) es la variación de los intervalos de tiempo entre latidos cardíacos y refleja el resultado de la interacción entre el sistema nervioso autónomo y el sistema cardiovascular. La hipoxia es un factor estresante que provoca cambios en la VFC y una disminución en la saturación arterial de oxígeno (SaO_2). El objetivo de nuestro estudio es analizar si los dominios de tiempo y frecuencia de la VFC se ven afectados tras una prueba de tolerancia a la hipoxia en participantes sanos en función del género. Material y métodos: 23 voluntarios sanos (11 mujeres y 12 hombres) con una edad media de 23.08±2.99 realizaron una prueba de tolerancia a la hipoxia (11%, 5050 m) con el simulador iAltitude. Se monitorizó la frecuencia cardíaca y la SaO_2 durante la prueba y se obtuvieron datos de la VFC en los dominios de frecuencia (DF) y tiempo (DT). Analizamos los cinco minutos antes y después de cada sesión. Resultados: La hipoxia inducida por la altitud simulada puede causar cambios en la VFC en un grupo de individuos sanos. También se encontraron diferencias estadísticamente significativas entre antes y después de la prueba de hipoxia normobárica en las variables de dominio de tiempo RRm, SDNN, HRm, HR STD, pNN50. Además, en las mujeres se encontraron diferencias estadísticamente significativas en RMSSD y en las variables de dominio de frecuencia HF y LF/HF. Mientras que en los hombres se encontraron diferencias estadísticamente significativas en SDNN. Tanto en hombres como en mujeres, se observaron diferencias significativas en RRm, HRm y pNN50. Conclusión: Las diferencias encontradas en la VFC después de la prueba de tolerancia a la hipoxia indican que las mujeres muestran una mayor activación del sistema nervioso parasimpático en comparación con los hombres. Mientras que los hombres mostraron una mayor activación simpática.
Palabras clave: Variabilidad de la frecuencia cardíaca, hipoxia normobárica, estrés, sistema nervioso autónomo. (Heart rate variability, normobaric hypoxia, stress, autonomic nervous system)

Abstract. Heart rate variability (HRV), the variation of time intervals between heartbeats, reflects the result of the interaction between the autonomic nervous system and the cardiovascular system. Hypoxia is a stressor that causes changes in HRV and a decrease in arterial oxygen saturation (SaO_2). The aim of our study is to analyse if the time and frequency domains of HRV are affected after a hypoxia tolerance test in healthy participants as a function of gender. Material and methods: 23 healthy volunteers (11 women and 12 men) with a mean age of 23.08±2.99 performed a hypoxia tolerance test (11%, 5050 m) with the iAltitude simulator. Heart rate and SaO_2 were monitored during the test and HRV frequency domain (FD) and time domain (TD) data were obtained. We analysed the five minutes before and after each session. Outcomes: Simulated altitude-induced hypoxia can cause changes in HRV in a group of healthy individuals. Statistically significant differences were also found between before and after the normobaric hypoxia test in the time-domain variables RRm, SDNN, HRm, HR STD, pNN50. In addition, in women statistically significant differences were found in RMSSD, and in the frequency-domain variables HF and LF/HF. While in males, statistically significant differences were found in SDNN. In both men and women, significant differences were observed in RRm, HRm and pNN50. Conclusion: The differences found in HRV after the hypoxia tolerance test indicate that females show a greater activation of the parasympathetic nervous system compared to males. While males showed greater sympathetic activation.
Keywords: Heart rate variability, normobaric hypoxia, stress, autonomic nervous system.

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Introduction

Heart rate (HR) is the number of heartbeats per minute and represents one of the most widely used parameters in the assessment of cardiac activity Heart rate (HR), measured as the number of heartbeats per minute, represents one of the most widely used parameters in the assessment of cardiac activity (Rodas et al., 2008). Heartbeats are not regular in their cycle (duration) (Tiwari et al., 2021). Such irregularity is called Heart Rate Variability (HRV) and is known as the variation in time between electrocardiogram (EKG) RR intervals (Hinde et al., 2021).

The most commonly used methods to analyse HRV are those based on the time domain and the frequency domain. The parameters used in the time domain include the following: RRSD, RMSSD, pNN50, SDNN. In relation to the frequency domain parameters we find: VLF, LF, HF, and the LF/HF ratio (Shaffer & Ginsberg, 2017). SDNN is a measure of global autonomic regulation; the high frequency (HF; 0.15-0.40 Hz) and low frequency (LF; 0.04- 0.15 Hz) spectral components reflect respectively the activity of the parasympathetic nervous system (PNS) and the combined activities of the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS). The LF/HF ratio indicates the index of the sympathetic-vagal balance. Whereas, the root mean square of the root of the difference of successive RR intervals (RMSSD) is a time domain parameter associated with parasympathetic activity (Taralov et al., 2015; Barreto et al., 2023; Nieto et al., 2020).

Since HRV was defined, numerous authors have described the factors that influence it, including breathing (Singh et al., 2018), age (Almeida-Santos et al., 2016), gender (Fatisson et al., 2016), temperature (Fatisson et al., 2016), altitude (Bhattarai et al., 2018), body position

(Plaza-Florido et al., 2019), body mass (Almeida-Santos et al., 2016), hydration (Fatisson et al., 2016), toxic habits (Yuksel et al., 2016) and Covid-19 (Mol et al., 2021), and psychological variables such as depression and chronic stress (Tiwari et al., 2021; Fatisson et al., 2016).

Sports training is also a factor influencing HRV, especially in altitude sports such as alpinism (Uryumtsev et al., 2020). It has been observed that physical training changes cardiorespiratory interaction patterns and that well-coordinated cardiovascular and respiratory systems under hypoxia can increase physical capacity and physiological energy exchange reserves (Uryumtsev et al., 2020; Młyńczak & Krysztofiak, 2019). In particular, in high-performance athletes, improvements in the mechanisms underlying the complex regulation of gas exchange can be expected, manifested in improved cardiorespiratory coherence (Młyńczak & Krysztofiak, 2019). Likewise, analysing the mutual relationships between cardiac and respiratory activity allows to better profile athletes and obtain information to improve training (Uryumtsev et al., 2020; Młyńczak & Krysztofiak, 2019). An example of the type of training that helps in increasing performance and endurance, as well as recovery capacity between workouts in athletes, is hypoxia training (Haase., 2013; Levine., 2002).

Hypoxia is another stressor that causes changes in HRV (Li et al., 2021). Hypoxia is a stressor that influences the regulation of the cardiovascular nervous system as parasympathetic activity decreases and the regulation of the autonomic nervous system is inhibited (Li et al., 2021). Upon entering a hypoxic environment, the blood oxygen saturation (SaO_2) of the human body decreases, and the regulation of the autonomic nervous system changes, often manifesting as an accelerated heart rate and shortened respiration (Mol et al., 2021; Li et al., 2021). Lower oxygen concentration can lead to acute mountain sickness, with symptoms such as headache and nausea (Botek et al., 2015). However, it has been shown that training at altitude, i.e. in a hypoxic situation, helps to improve athletic performance in athletes (Lizamore & Hamlin., 2017).

Currently, because not all athletes or their teams have the resources to travel to high altitude environments on a regular basis, numerous devices have been developed and promoted to simulate training at altitude and in hypoxic conditions, that is, techniques designed to "bring the mountain to the athlete" (Lizamore & Hamlin., 2017). These include hypoxia tents and special breathing apparatus to provide hypoxia at rest (sitting or lying on a stretcher) and during exercise (on a treadmill or exercise bike), in order to simulate what are perceived as critical elements of altitude training (Serebrovskaya & Xi, 2016).

Different methods such as time and frequency domains have been applied to assess how HRV changes when people are exposed to a hypoxic environment (Povea et al., 2005). In relation to changes in HRV, an increase in sympathetic activity and a decrease in parasympathetic activity have been suggested in situations of hypoxia at altitude (Aebi et al., 2020). The hypothesis of our study is that there will be changes in HRV after a hypoxia tolerance test, and the aim is to analyse whether the temporal and frequency domains of Heart Rate Variability are affected after a hypoxia tolerance test in healthy participants as a function of gender.

Material and methods

Design

The entire process was carried out in the biomedical research laboratory (LAIB) of the University of Murcia, where data were collected from the participants on their personal and/or family history of cardiovascular pathology and other possible chronic diseases by means of a questionnaire.

The research procedure and the proposed objectives were explained to all study participants. This study received approval from the Research Ethics Committee of the University of Murcia (ID: 4145/2022), in accordance with the Declaration of Helsinki (World Medical Association., 2013). The participants signed an informed consent form and could leave the study at any time.

Participants

In the present study, 23 healthy people aged between 19 and 29 voluntarily participated in the study. All participants were submitted to a HTT at a simulated altitude of 5050m above sea level with an oxygen saturation of 11%. The test was performed under medical supervision.

Criteria for Inclusion and Exclusion

Inclusion criteria were: age between eighteen and thirty years, willingness to participate and signing the informed consent for the study.

Pregnant women and people suffering from disorders or pathologies that prevented them from taking the test were excluded. Participants with experience in sports activities related to hypoxia training were also excluded.

Preliminary Procedures

The preliminary data collection process was structured in two main phases:

For the anthropometric study, height was recorded with a SECA® 213 measuring rod, and weight was obtained with an In Body® 120 scale. Waist and hip circumferences were measured with a Holtain® flexible metal tape.

Cardiac examination was performed by cardiac auscultation with a Littmann Classic stethoscope, a Beurer® upper arm blood pressure monitor was used to measure blood pressure and an echocardiogram (Cardioline® electrocardiograph) were performed to exclude cardiac pathologies.

After verifying that there were no pathologies contraindicating the test, Hypoxia Tolerance Test (HTT) was performed.

Hypoxia Tolerance Test

During HTT, participants were required to sit comfortably and correctly in an armchair. Thus, participants had to

remain seated for 5 minutes prior to the hypoxia test, while their blood pressure was measured and the procedure they were about to undergo was explained to them. In addition, the type of breathing to be performed during the hypoxia test was explained to them. It consisted of relaxed breathing at the usual rate. The investigator in charge of the test periodically reminded the subject to maintain a normal breathing rate.

$SatO_2$ was monitored through a pulse oximeter placed on the left ear, HR with the Polar H10® heart rate monitor and muscle oxygen saturation (SmO_2) with the Humon Hex® device placed in the middle of the right quadriceps (Albertus-Cámara et al., 2023).

After the previous 5 minutes, participants underwent a resting hypoxia tolerance test using the iAltitude® altitude simulator at a simulated altitude of 5050m equivalent to an oxygen saturation of 11%, while it was explained to them that they had to follow the instructions on the screen in front of their armchair and put on or remove the mask when the screen prompts them to do so.

The screen displayed one line according to $SatO_2$ levels and another according to HR. This way, the subject could see the evolution of each HTT for its entire duration.

The test ended when the maximum duration of the test, programmed at 10 minutes, was reached, or when a $SatO_2$ value of less than 83% was obtained. At that moment, the hypoxia simulator emitted audible and visual signals indicating the removal of the mask to breathe in normoxic conditions.

At the start of each hypoxia tolerance test, the $SatO_2$ and SmO_2 values were recorded. At the end of each hypoxia tolerance test and 5 minutes after the test, the values of the variables described above were taken again.

Heart rate variability analysis

Heart rate variability was recorded with a heart rate monitor (Polar H10, Kempele, Finland). HRV data were analyzed using specific software (Kubios HVR Standard). First, RR intervals were analyzed to remove ectopic beats from the recordings by automatic and visual inspections of the RR series. Next, HRV index in the time domain (RMSSD) and spectral power of the frequency bands were analyzed for: HF (0.15-0.50 Hz), LF (0.04-0.15 Hz) and total power (LF + HF). Finally, the LF/HF ratio was calculated to evaluate sympathovagal balance.

Data analysis

After ruling out the presence of errors, the data were exported to the Statistical Package for Social Science (SPSSv.28) to be analysed. Qualitative variables are described with absolute values and percentages, and compared using Chi-square. Quantitative variables are described by mean values (mean) and standard deviation. The mean values were compared using Student's t-test after checking the normality of the distributions of the initial characteristics using the Shapiro-Wilk test and the equality of variances using Levene's test. A minimum level of significance of $p < 0.05$ was established.

Results

Basal and anthropometric characteristics of the population

Basal characteristics

23 subjects participated. Among them, 12 (52.2 %) were male and 11 (47.8 %) were women. The mean age of the population was 23.1 years.

Table 1 shows the comparison of anthropometric values between men and women: age, height, weight, waist and hip circumference. Significant differences were found for all variables except age and hip circumference.

Table 1.
Gender comparison of anthropometric variables

Variable	Gender	n	Mean	SD	t	p
Age (years)	Male	12	22.6	3.4	-0.704	0.490
	Female	11	23.5	2.5		
	Total	23	23.1	2.9		
Height (cm)	Male	12	173.3	5.1	3.505	0.003*
	Female	11	163.5	7.8		
	Total	23	168.6	8.1		
Weight (Kg)	Male	12	71.2	8.1	4.720	0.000*
	Female	11	57.5	5.7		
	Total	23	64.7	9.8		
Waist circumference (cm)	Male	12	78.0	6.7	4.931	0.000*
	Female	11	66.9	3.7		
	Total	23	72.7	7.8		
Hip circumference (cm)	Male	12	93.3	3.8	-0.953	0.351
	Female	11	94.8	3.6		
	Total	23	94.1	3.7		

*p<0.05

Table 2 shows significant differences ($p<0.05$) between gender in the variables of systolic blood pressure and muscle oxygen saturation (SmO_2).

Table 2.
Gender comparison of oxygen saturation and cardiovascular variables in the pre- and post (HTT) phases of hypoxia exposure.

Variable	Gender	Pre-stage				Post-stage			
		Mean	SD	t	p	Mean	SD	t	p
Systolic blood pressure (mmHg)	Male	135.2	15.8	2.729	0.013*	121.1	22.3	1.514	0.145
	Female	118.8	12.7			106.6	23.3		
Diastolic Blood Pressure (mmHg)	Male	80.4	7.9	-0.055	0.957	76.2	10.0	-0.214	0.833
	Female	80.6	10.7			77.4	16.1		
SaO_2 (%)	Male	98.7	2.1	-1.450	0.172	85.8	6.1	0.044	0.966
	Female	99.6	0.5			85.7	5.4		
SmO_2 (%)	Male	68.4	5.1	2.841	0.043*	64.6	5.6	0.299	0.775
	Female	45.4	17.8			61.2	29.6		
HR (beats/min)	Male	76.7	16.6	-0.447	0.660	83.2	17.3	1.055	0.307
	Female	79.5	13.2			72.1	30.4		

MmHg: millimetres of mercury; SaO_2: arterial oxygen saturation; SmO_2: muscle oxygen saturation; HR: heart rate; bpm: beats per minute. *p<0.05

Table 3 shows no statistically significant differences in any of the pre-test hypoxia values for the time and frequency domains of HRV related to gender.

Table 3.
Gender comparison of HRV time and frequency domain variables in the pre- and post-hypoxia test phase.

Variable	Gender	Pre-stage				Post-stage			
		Mean	SD	t	p	Mean	SD	t	p
RR Mean (ms)	Male	945.8	178.3	1.598	0.125	910.8	164.4	1.681	0.108
	Female	840.6	136.1			809.4	123.5		
SDNN (ms)	Male	117.3	125.2	1.555	0.147	145.1	153.8	1.727	0.111
	Female	60.4	17.5			67.8	17.9		
HR Mean (ms)	Male	65.4	11.9	-1.562	0.133	67.8	11.9	-1.643	0.115
	Female	73.0	11.2			75.6	10.8		
HR STD (ms)	Male	1.6	0.8	1.005	0.329	2.2	0.9	1.926	0.073
	Female	1.3	0.4			1.6	0.4		
RMSSD (ms)	Male	121.0	198.3	1.140	0.278	131.3	252.4	1.233	0.243
	Female	55.2	25.5			41.2	19.3		
pNN50 (%)	Male	38.0	20.2	0.681	0.504	30.7	18.6	1.381	0.182
	Female	31.6	24.0			20.2	17.8		
Stress Index	Male	7.1	4.2	-1.304	0.207	7.3	4.2	-1.868	0.077
	Female	9.1	3.2			10.9	5.0		
VLF (ms^2)	Male	3251.8	4814.3	1.646	0.127	480.9	791.5	1.631	0.131
	Female	946.6	566.4			106.3	545.1		
LF (ms^2)	Male	14195.4	39589.9	1.182	0.262	144.1	414.8	1.102	0.294
	Female	690.1	404.9			123.7	100.9		
HF (ms^2)	Male	11309.4	34154.1	1.006	0.336	193.3	612.3	1.038	0.322
	Female	1386.5	1011.6			963.5	708.9		
LF/HF	Male	3.0	4.2	1.787	0.100	3.3	3.9	1.530	0.151
	Female	0.7	0.7			1,504	0.9		

RRmean: Mean of R-R intervals; SDNN: Standard deviation of R-R intervals; HRmean: Mean heart rate; HR STD: Standard deviation of heart rate; RMSSD: Square root of the average of the sum of the squared differences of R-R intervals; pNN50: Total % of the differences between R-R intervals; VLF: Very low frequency; LF: Low frequency; HF: High frequency; LF/HF: Low/High frequency ratio. *p<0.05.

Table 4.
Gender differences of heart rate variability before (A) and after (B) the hypoxia test in the time and frequency domains

Variable	Gender	Mean	SD	T	p
RR Mean (A-B) (ms)	Male	34.9	35.5	3.410	0.006*
	Female	31.1	34.9	2.953	0.014*
SDNN (A-B) (ms)	Male	-27.7	34.1	-2.817	0.017*
	Female	-7.3	18.8	-1.294	0.225
HR Mean (A-B) (ms)	Male	-2.3	2.3	-3.428	0.006*
	Female	-2.5	3.2	-2.624	0.025*
HR STD (A-B) (ms)	Male	-0.5	0.5	-3.663	0.004*
	Female	-0.2	0.4	-2.022	0.071
RMSSD (A-B) (ms)	Male	-10.3	54.8	-0.654	0.526
	Female	13.9	11.1	4.146	0.002*
pNN50 (A-B) (%)	Male	7.3	5.7	4.399	0.001*
	Female	11.4	10.5	3.600	0.005*
Stress Index (A-B)	Male	-0.1	1.6	-0.394	0.701
	Female	-1.7	2.5	-2.320	0.043*
VLF (A-B) (ms^2)	Male	-1555.1	3402.0	-1.583	0.142
	Female	-122.7	709.3	-0.574	0.579
LF (A-B) (ms^2)	Male	-225.5	2220.1	-0.352	0.731
	Female	-546.6	910.3	-1.992	0.074
HF (A-B) (ms^2)	Male	-7996.8	27086.6	-1.023	0.328
	Female	422.9	575.1	2.440	0.035*
LF/HF (A-B)	Male	-0.3	1.6	-0.663	0.521
	Female	-0.7	0.8	-2.896	0.016*

RRmean: Mean of R-R intervals; SDNN: Standard deviation of R-R intervals; HRmean: Mean heart rate; HR STD: Standard deviation of heart rate; RMSSD: Square root of the average of the sum of the squared differences of R-R intervals; pNN50: Total % of the differences between R-R intervals; VLF: Very low frequency; LF: Low frequency; HF: High frequency; LF/HF: Low/High frequency ratio *p<0.05

Gender comparison of heart rate variability before and after the hypoxia test in the time and frequency domains.

During the hypoxia tolerance test, the parameters of heart rate variability between genders were analysed in both the time and frequency domains (Table 4), comparing the differences obtained between the five minutes before the hypoxia test (A) and the five minutes after its completion (B).

In table 4, statistically significant differences were found in the variables mean RR, mean HR, pNN50 in both men and women. Significant differences were found in men for the variables SDNN and STD RR, while the variable RMSSD was statistically significant in women.

No statistically significant difference was found between before and after the hypoxia test in relation to the male gender. However, there were significant differences in HF and LF/HF in women.

Discussion

The results of this study revealed that simulated altitude-induced hypoxia can cause changes in HRV and HR in a group of healthy individuals. HR has been shown to increase significantly after the test. Statistically significant differences were also found between before and after the normobaric hypoxia test in the time-domain variables RRm, SDNNN, HRm, HR STD, pNN50. In addition, in women statistically significant differences were found in RMSSD, and in the frequency-domain variables HF and LF/HF. While in males, statistically significant differences were found in SDNN. In both men and women, significant differences were observed in RRm, HRm and pNN50 variables.

Several studies have evaluated HRV indices during hypoxia, but the results are not consistent, as the cardiac response may vary depending on the simulated altitude, the

time of exposure to hypoxia, the phase of the test in which the participants are (preliminary, hypoxia, recovery), the type of test (hypobaric, normobaric) and the protocol to be followed (Rodas et al., 2008; Krejci et al., 2018; Basualto-Alarcón et al., 2012). Thus, in the study conducted by Krejci et al., (2018), with a FiO_2 = 9. 6% at a simulated altitude of 6200m, they evaluated HRV and oxygen saturation responses to normobaric hypoxia by comparing 1 min segments with the baseline normoxic situation and found that normobaric hypoxia induced a decrease in global autonomic nervous system activity (NSSD), vagal inhibition (RMSSD) two minutes after the test and a relative increase in sympathetic activity (SDNNN/RMSSD) three minutes after exposure to hypoxia, which in turn induced tachycardia. These results contrast with those of our study, with a FiO_2= 11% at a simulated altitude of 5500m, where statistically significant differences in SDNN in males and RMSSD in females were found only when comparing before and after exposure to hypoxia after 10 minutes of exposure to HN. This contrast is probably due to differences in altitude and time between the two studies.

Similar studies such as Botek et al., (2015), with FiO_2= 9.6% for 10 min at a simulated altitude of 6200 m, also found a significant increase in HF and LF/HF sympathetic modulation. Wille et al., (2012) found a significant decrease in RRm and SDNN during hypoxia (FiO_2 = 11% at a simulated altitude of 5500m), which is consistent with our results. Whereas, in another study, they observed a significant decrease in RMSSD, but no significant change in SDNN during hypoxia (Buchheit et al., 2004). Botek et al., (2018), (FiO_2 = 9.6%; simulated altitude 6200 m) found statistically significant gender differences in HRV during the hypoxia period, with males showing a relatively higher sympathetic stimulation (LF/HF) compared to females, which contradicts our results showing a higher LF/HF ratio in females. In our study, HF and RMSSD variables were significantly higher in females, with greater parasympathetic nervous system activation in females.

Some studies, such as that of Basualto-Alarcón et al., (2012) comparing two hypoxia conditions (hypobaric and normobaric) at the same simulated altitude of 3000m, admit that both types of tests affect the cardiovascular and respiratory systems differently.

Other studies, such as Karinen et al., (2012) compared data on observed changes in heart rate variability at different altitudes: 2400m, 3000m, 3500m, 4300m, 5000m and 5300m. They observed a greater autonomic cardiac response with increasing altitude, being higher at 5000m and 5300m. Thus, they showed that changes in HRV were related to higher altitudes in all subjects, but was also associated with other variables such as acclimatisation. Therefore, it can be observed that there is a replicability crisis in the studies by following protocols with different altitudes and exposure times that make it difficult to compare between studies.

On the other hand, according to Basualto-Alarcón et al., (2012), the relationship between sympathetic activity and SpO_2 remains important since, at high altitude, an elevated sympathetic tone may be beneficial in activating compensatory homeostatic mechanisms. From this point of view, the study by Botek et al., (2015), suggest that the compensatory homeostatic response due to desaturation induced by exposure to normobaric hypoxia may be mediated exclusively by changes in the vagal pathway without excessive sympathetic stimulation in hypoxia-resistant subjects. Furthermore, there is a correlation between the level of desaturation and the change in sympathovagal balance, suggesting that when a lower saturation level is present, there may be a greater relative increase in sympathetic activity. In our study, a significant decrease in SaO_2 was observed at the end of the hypoxia phase. Five minutes after the hypoxia test (recovery time) there was a significant increase in SaO_2 and SmO_2. This is in contrast to studies such as Krecji et al., (2018) where five minutes after the onset of hypoxia, SaO_2 decreased significantly.

In conclusion, HRV measurement is a relatively new and widely used technique that non-invasively assesses autonomic nervous system during hypoxia-induced stress. Furthermore, it should be noted that the hypoxia simulation test at altitude is a very novel technique in the research field and has proven to be of great clinical applicability, as it offers a simple way to identify changes in HRV by simulating conditions at high altitude.

This study aimed to include healthy subjects and their impact on hypoxia exposure. This may limit a possible understanding of the effects of hypoxia on HRV in unhealthy subjects, particularly those with cardiac disease. However, it is hoped that this pioneering work in the field can serve as a reference for future experimental studies and/or reviews, targeting not only healthy but also unhealthy individuals such as hypertensive, Covid-19, diabetic and/or psychiatric patients.

Conclusion

The present study demonstrated that the influence of a stressor such as normobaric hypoxia induces changes in HRV in healthy subjects. Furthermore, upon entering a hypoxic environment, blood oxygen saturation (SaO_2) decreases, which may be associated with a change in cardiac autonomic regulation.

In relation to gender, the differences found in Heart Rate Variability after the hypoxia tolerance test indicate that females show a greater activation of the parasympathetic nervous system compared to males. While males showed greater sympathetic activation

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