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Differences in linear parameters of the basal autonomic balance between medical students and young baseball players

Víctor E. González-Velázquez[1]✉, MD; Elys M. Pedraza-Rodríguez[1], MD; Yoander Nápoles-Zaldívar[2], MD; José A. Sánchez-Guerra[3], MD; Gustavo A. Muñoz-Bustos[4], MSc; Jeniffer Rodríguez Nuviola[5], MD; David de J. Bueno-Revilla[5], MD; Erislandis López-Galán[5], MD; and Miguel E. Sánchez-Hechavarría[6], MD

[1] Hospital Universitario Clínico Quirúrgico Arnaldo Milián Castro, Universidad de Ciencias Médicas de Villa Clara. Santa Clara, Villa Clara, Cuba.
[2] Universidad de Ciencias Médicas de Holguín, Filial de Ciencias Médicas de Banes Urselia Díaz Báez. Banes, Holguín Cuba.
[3] Universidad de Ciencias Médicas de Granma, Filial de Ciencias Médicas de Bayamo Dr. Efraín Benítez Popa. Bayamo, Granma, Cuba.
[4] Faculty of Healthcare Sciences, Universidad de Las Américas, Head Office of Concepción. Concepción, Chile.
[5] Universidad de Ciencias Médicas de Santiago de Cuba. Santiago de Cuba, Cuba.
[6] Department of Basic Medical and Morphological Sciences, Medical Faculty, Universidad Católica de la Santísima Concep ción. Concepción, Chile.

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The authors declare no competing interests.

Abbreviations
HF: high frequency
HR: heart rate
HRV: heart rate variability
LF: low frequency
VLF: very low frequency

✉ *ME Sánchez-Hechavarría*
Alonso de Ribera 2850. CP 4090541. Concepción, Chile.
E-mail address:
misanchez@ucsc.cl and miguel.sanchez881119@gmail.com

ABSTRACT
Introduction: Cardiovascular autonomic modulation can be considered a useful tool in determining the physiological state of the interaction between the autonomic nervous system and the cardiovascular system.
Objectives: To determine the differences in linear parameters of the basal autonomic balance between medical students and young baseball players.
Methods: A cross-sectional analytical study was carried out in the Biomedical Basic Sciences Laboratory, Faculty No.1, of the University of Medical Sciences Universidad de Ciencias Médicas in Santiago de Cuba. The population and sample consisted of 36 individuals (Group 1: 18 high-performance young baseball athletes, Group 2: 18 medical students). Data was collected using an 8-channel PowerLab polygraph and it was processed using the Kubios® Software version 3.0.4 Premium.
Results: There were significant differences in the values between students and athletes: pNN50 (p=0.009), stress index (p=0.044) and in parasympathetic (p=0.005) and sympathetic (p=0.001) indexes. The discriminatory ability of the parasympathetic index to be associated with the best physical fitness of the athletes was good (area under the curve 0.784). The optimum cut-off point above which the parasympathetic index is associated with the group of athletes was set at 0.57.
Conclusions: The parasympathetic index was associated with the group of athletes, showing the vagal predominance in the modulation of cardiac activity in the individuals belonging to this group.
Keywords: Heart rate variability, Exercise, Athletes, Baseball, Medical students

Diferencias en los parámetros lineales del balance autonómico basal entre estudiantes de medicina y atletas juveniles de béisbol

Authors' contribution
VEGV, EMPR y MESH: Idea and design of the research; data collection, analysis and interpretation and manuscript writing.
YNZ, JASG, GAMB: Primary data obtaining as well as helping in the manuscript writing.
JRN, DJBR y ELG: Data analysis and interpretation as well as helping in the manuscript writing.
All authors critically reviewed the manuscript and approved the final report.

RESUMEN

Introducción: *La modulación autonómica cardiovascular puede ser considerada como una herramienta útil en la determinación del estado fisiológico de la interacción entre los sistemas nervioso autónomo y cardiovascular.*
Objetivo: *Determinar las diferencias en los parámetros lineales del balance autonómico basal entre estudiantes de medicina y atletas juveniles de béisbol.*
Método: *Se realizó un estudio analítico de tipo transversal en el Laboratorio de Ciencias Básicas Biomédicas de la Facultad Nº. 1 de la Universidad de Ciencias Médicas de Santiago de Cuba. Universo y muestra de 36 individuos (Grupo 1: 18 atletas juveniles de béisbol de alto rendimiento, Grupo 2: 18 estudiantes de medicina). Los datos fueron recolectados, mediante de polígrafo PowerLab de 8 canales, y fueron procesados usando el software Kubios® versión 3.0.4 Premium.*
Resultados: *Existieron diferencias significativas en los valores de pNN50 (p=0,009), índice de estrés (stress index [p=0,044]), y en los índices parasimpático (p=0,005) y simpático (p=0,001) entre estudiantes y atletas. La capacidad discriminatoria del índice parasimpático para asociarse con la mejor forma física de los atletas fue buena (área bajo la curva 0,784). El punto de corte óptimo por encima del cual el índice parasimpático se asocia al grupo de los atletas quedó establecido en 0,57.*
Conclusiones: *El índice parasimpático se asoció con el grupo de atletas, lo que evidencia el predominio vagal en la modulación de la actividad cardíaca en los sujetos de este grupo.*
Palabras clave: *Variabilidad de la frecuencia cardíaca, Ejercicio físico, Atletas, Béisbol, Estudiantes de medicina*

INTRODUCTION

In recent years, the analysis of the periodic intervals between heartbeats has demonstrated the complexity of cardiovascular nervous regulation[1]. Determining the differences between groups of healthy individuals in basal status allows to identify the characteristics that are associated with better physical fitness and heart function.

Heart rate variability (HRV) is defined as the variation taking place in the time interval between consecutive heartbeats[2]. The most commonly used techniques to assess it are the linear methods, which are based on time, frequency, and time-frequency domains[3]. Studies of non-linear methods have also proven their practical utility[4,5].

Autonomic modulation of cardiac function can be considered a useful tool in determining the physiological status of the interaction between the autonomic nervous system and the cardiovascular system. The spectral analysis of HRV in athletes has demonstrated the presence of adaptive changes in the sympathetic-vagal dynamics of cardiovascular autonomic regulation, always in relation to the applied training loads[6-8].

Young athletes experience high stress levels regarding their sports and academic performance[9-11]. Their sports performance is linked to nervous factors that can be measured through non-invasive methods such as HRV[12,13], and some authors[4,14] have supported its usefulness for the analysis of the psychophysiological profile, the determination of training zones and the detection of stress recovery processes.

In addition to its relationship with sport, HRV has been strongly associated with several physiological characteristics applicable to the field of medicine[15], such as stress levels among university students[16,17] and high blood pressure among young individuals[18,19]. Furthermore, the parasympathetic index has been related, by several authors[20,21], with an improved cardiovascular function and a better sports performance, while the sympathetic predominance has been linked to obesity and sedentarism[22,23].

A high correspondence between levels of sports performance and parasympathetic activity indexes in athletes[24] has been identified; however, some authors[25,26] affirm that these variables cannot be related to sport performance, but they can be related to a better physical and cardiovascular status.

The aim of this research was to determine the differences in linear parameters of the basal autonomic balance between medical students and young baseball players.

METHOD

A cross-sectional analytical study was carried out in the Laboratory of Basic Medical and Biomedical Sciences of the *Facultad N° 1* of the *Universidad de Ciencias Médicas* in Santiago de Cuba.

The study's population consisted of 36 young men, athletes and students, with ages between 17 and 19 years old, who were divided into two groups: one composed by 18 high performance athletes of the juvenile baseball team (mean age of 18.1±1.7 years old) and the other one, by 18 first and second year medical students from the *Universidad de Ciencias Médicas* of this province (mean age of 18.2±1.4 years old). The individuals of this last group were paired according to age and sex, and they were selected through a simple random sampling so that a 1:1 ratio could be obtained, thus, avoiding the biases inherent to selection.

None of those selected had a history of diseases that could interfere with the physiological cardiovascular dynamics or with its regulation by the autonomic nervous system and, as a requirement prior to the records, they could neither smoke, drink coffee, nor perform intense physical exercise from the previous day.

Physiological records and signal processing

Data was collected in the Laboratory of Basic Medical and Biomedical Sciences of the *Facultad N° 1* of the *Universidad de Ciencias Médicas* in Santiago de Cuba. Each measurement was registered by the same person, in order to minimize the methodology errors, in the location for body measurements of the aforementioned Laboratory of Basic Medical and Biomedical Sciences.

At the beginning of the electrocardiographic registrations' session (from 08:30 to 12:00 in the morning), the individuals were laid down on a comfortable stretcher, placed in a room with controlled temperature between 24 and 27 Celsius degrees and tenuous light, in an environment with controlled environmental noise and humidity, without distractions or interactions among the volunteers. Under these conditions, they were allowed to rest for 10-15 minutes until they were better adapted to the conditions of the room. There was no movement of personnel other than those in charge of the records inside the room.

The electrodes corresponding to the limbs' leads were placed to record the electrocardiographic trace during five minutes. The electrical signal was collected using the 8-channel PowerLab® polygraph produced in Australia by the AD Instruments Company (2016); it was then digitized at a sampling frequency of 1000 samples/second (1 kHz) using the Kubios® Premium version 3.0.4 (2018) software, produced in Finland. This software package allows the tabulation and export of the records, in *.mat format, to the MatLab® 2016 programming package of the Math Work Company.

The further processing of the digitized records included their visual inspection. The discrimination of the R-wave peaks of the digitized signal and the calculation of the RR intervals were carried out using the Sabarimalai Manikandan's method[27]. The set of the obtained RR intervals represented the data series from which all the subsequent analysis of the HRV were carried out through the aforementioned Kubios® software. Traditional HRV frequency bands were used, as recommended by the international consensus of experts of 1996 on HRV[28], which were for very low frequencies (VLF: 0.003-0.04 Hz); low (LF: 0.04-0.15 Hz) and high (HF: 0.15-0.4 Hz).

The following variables were taken into account[28, 29]:

- Heart rate (HR): mean value during measurement expressed in beats/minute.
- Min/Max HR: minimum/Maximum HR value during measurement (beats/minute).
- RR Interval: mean duration of RR intervals, expressed in milliseconds (ms).
- SDNN: standard deviation of all normal-to-normal (NN) intervals (ms). The NN one is the interval between adjacent normal QRS complexes, that is to say, they are normally produced by sinus rhythm.
- SMSSD: square root of the mean of the sum of the squares of differences between adjacent NN intervals (ms).
- NN50: number of consecutive RR interval pairs with a difference between them > 50 ms.
- pNN50: percentage of consecutive RR intervals with a difference between them > 50 ms.
- RR triangular index: geometric measurement that calculates the density of RR intervals divided by the height of their histogram.
- TINN (triangular interpolation of the highest peak of the histogram of all NN intervals): is the reference width of a RR interval histogram.
- Stress index: square root of the Baevsky stress index.

- Parasympathetic nervous system index (PNS index): calculated based on the recorded results of the mean RR, RMSSD and HF distance in normalized energy units (n.u.).
- Sympathetic Nervous System index (SNS index): calculated based on the recorded results of the mean HR, stress index and LF (n.u.).
- High Frequencies (HF) (n.u.): normalized energy in the spectrum of 0.15-0.4 Hz in which the time series of consecutive RR intervals is decomposed: HF = HF/(LF + HF). The HF is clearly related to the activity of the parasympathetic nervous system and it is also influenced by the respiratory frequency.
- Low frequencies (LF) (n.u.): normalized energy in the spectrum from 0.04 to 0.15 Hz in which the time series of consecutive RR intervals is decomposed: LF = LF/(LF + HF). It is the most controversial area in terms of interpretation since it can be attributed to influences from the nervous systems.
- Very low frequencies (VLF): composed of waves between 0.003-0.04 Hz, VLF is a much less defined component and the existence of specific physiological processes attributable to changes in HRV in the measurement period are even questionable.
- LF/HF ratio or quotient: Although it is controversial, it has been proposed as an indicator of the sympathetic-vagal balance.

For the variables' qualification as ordinal qualitative, the diagram of the multiparametric model provided by the Kubios® software was taken into account, as shown in the example of one of the individuals (**Figure 1**). The variables belonging to the parasympathetic tone (RR, RMSSD, HF intervals and parasympathetic nervous system index) and to the sympathetic tone (HR, stress index, LF and sympathetic nervous system index) were categorized according to their standard deviation (SD) in the following way: low (< -2 SD), normal (between ± 2 SD) and high (> 2 SD).

Statistical analysis

The SPSS software version 22.0 for Windows was used for data statistical processing. Means were compared through the Student´s t-test for independent groups in those variables that presented a normal distribution (normality was tested through the Kolmogorov-Smirnov test). Quantitative variables that were not normally distributed were compared through the Mann-Whitney U-test. For the qualitative analysis of the variables the Pearson's Chi-square was used. The difference was established as statistically significant when $p < 0.05$. Cohen's effect size was calculated by interpreting its results as low, medium, and high according to its value[30].

An analysis through the ROC (receiver operating characteristic) curve was carried out to determine the discriminatory capacity of the variables of interest to be associated with the group of athletes. Sensitivity and specificity values of the curve coordinates were taken and the cut-off point of the variable with discriminatory capacity was determined through the following formula:

$d=\sqrt{[0-(1-specificity)]^2 + (1-sensitivity)^2}$.

The entire analysis was performed with 95% of reliability.

Ethical considerations

The research was approved by the institution's Committee of Ethics. The personal data of the individuals were not published, and the principles set

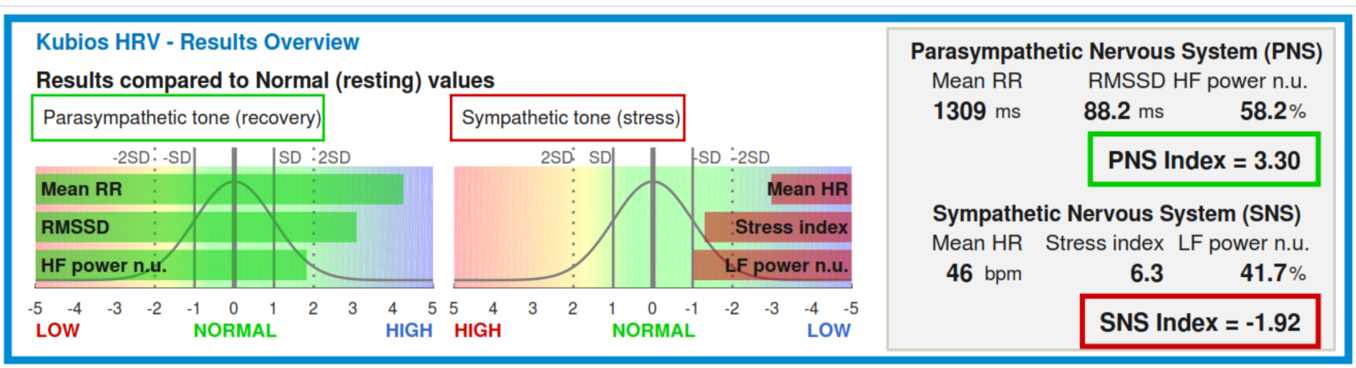

Figure 1. Qualification of the variables proposed by the Kubios® software.

out in the Declaration of Helsinki were followed. Every individual signed an informed consent.

RESULTS

Heart rate values were significantly lower in the group of athletes (p<0.001). Conversely, in this same group, the values of the RR intervals were higher (**Table 1**).

In **table 2** is shown a significant increase in the pNN50 values in the group of athletes, a variable that translates into a better capacity to experience high spontaneous variations in HR. Besides, it is observed that there were statistically significant differences in the stress index variables and the parasympathetic and sympathetic indexes, between students and athletes.

Table 1. Analysis of the heart rate and the RR intervals in students and athletes.

Variable	Total	Students	Athletes	Effect size	p[a]
HR	66.72 ± 11.74	74.89 ± 8.78	58.56 ± 8.09	1.93 (High)	< 0.001*
Minimum HR	59.17 ± 10.02	65.89 ± 8.14	52.44 ± 6.69	1.81 (High)	< 0.001*
Maximum HR	78.42 ± 14.19	88.61 ± 8.60	68.22 ± 10.97	2.07 (High)	< 0.001*
RR Interval	927.11 ± 172.70	810.50 ± 102.21	1043.72 ± 148.87	1.83 (High)	< 0.001*

[a] Mann-Whitney U test. The results are expressed in mean ± standard deviation.
* Statistically significant. HR, heart rate.

Table 2. Linear parameters of the basal autonomic balance in students and athletes.

Variable	Total	Students	Athletes	Effect size	p
SDNN	56.70 ± 25.14	50.85 ± 25.40	62.54 ± 24.15	0.47 (Medio)	0.166[b]
SMSSD	66.05 ± 43.01	52.83 ± 39.30	79.27 ± 43.53	0.64 (Medio)	0.064[b]
NN50	103.53 ± 68.58	81.33 ± 72.16	125.72 ±58.59	0.68 (Medio)	0.051[b]
pNN50	34.53 ± 25.09	23.91 ± 23.33	45.16 ± 22.64	0.92 (Alto)	0.009*[b]
RR triangular index	12.78 ± 4.79	11.68 ± 5.06	13.88 ± 4.36	0.47 (Medio)	0.172[b]
TINN	287.81 ± 121.99	260.61 ± 119.74	315.00 ± 121.38	0.45 (Medio)	0.185[b]
Stress index	8.73 ± 3.87	10.01 ± 4.16	7.44 ± 3.16	0.70 (Medio)	0.044*[b]
PNS index	0.88 ± 1.93	0.00 ± 1.66	1.76 ± 1.81	1.01 (Alto)	0.005*[a]
SNS index	-0.09 ± 1.36	0.64 ± 1.29	-0.82 ± 1.02	1.26 (Alto)	0.001*[a]
High frequencies (HF)	51.39 ± 17.48	50.94 ± 17.92	51.84 ± 17.54	0.05 (Bajo)	0.880[b]
Low frequencies (LF)	48.43 ± 17.52	48.88 ± 17.95	47.98 ± 17.59	0.05 (Bajo)	0.880[b]
VLF	4.27 ± 6.46	3.42 ± 2.14	5.12 ± 8.93	0.26 (Medio)	0.438[b]
LF/HF	1.31 ± 1.27	1.25 ± 0.97	1.33 ± 1.53	0.06 (Bajo)	0.853[b]

[a] Mann-Whitney U test. The results are expressed in mean ± standard deviation.
[b] Student's t test. * Statistically significant.
NN50, number of consecutive RR interval pairs with a difference between them >50 ms; **pNN50**, percentages of consecutive RR interval pairs with a difference between them > 50 ms; **PNS**, parasympathetic nervous system; **SDNN**, standard deviation of all RR normal intervals (ms); **SMSSD**, square root of the mean sum of the squared differences of all RR intervals (ms); **SNS**, sympathetic nervous system; **TINN**, reference width of a histogram of RR intervals; **VLF**, very low frequency.

In **figure 2** is shown how the value of the parasympathetic index turned out to be higher and predominantly positive in the group of athletes, while the sympathetic index in this group presented lower and predominantly negative values.

In **table 3** is shown the qualification of the variables that translate the characteristics of the parasympathetic and sympathetic tones, where it can be seen that the linear parameters: RR and RMSSD intervals, belonging to the vagal tone, were higher in the group of athletes and showed statistically significant differences.

The analysis of the ROC curve of the sympathetic and parasympathetic indexes in relation to the group of athletes shows that the discriminatory capacity of the parasympathetic index to be associated with the best physical fitness of the athletes was good (area under the curve 0.784 [**Table 4**]). The optimum cut-off point above which the index is associated with the group of athletes was set at 0.57 (**Figure 3**).

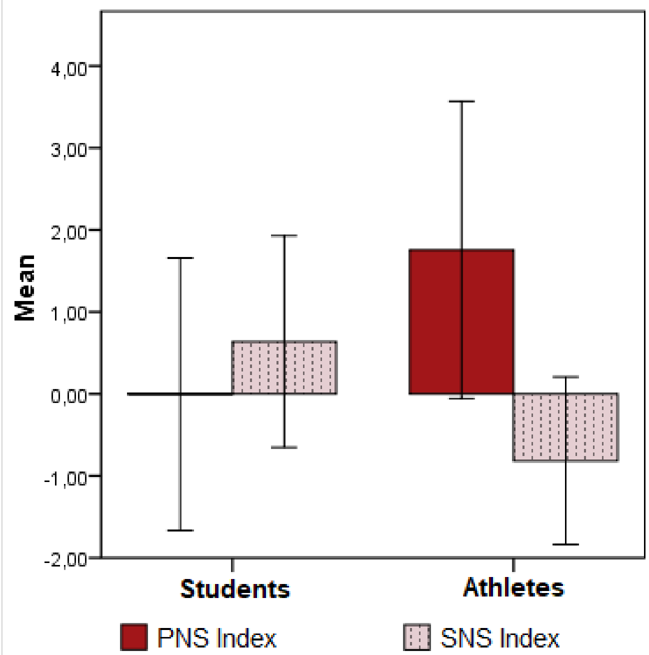

Figure 2. Comparison of the parasympathetic and sympathetic indexes in students and athletes.
PNS, parasympathetic nervous system; SNS, sympathetic nervous system.

DISCUSSION

The significant decrease in HR values in the group of athletes coincides with what is stated by other authors[4,31,32], since it is common to find a better functional cardiac reserve capacity in individuals who systematically practice physical exercise[33], given by a more effective premature contraction that trans-

Table 3. Qualitative analysis of the linear parameters of the basal autonomic balance in students and athletes.

Variable	Basal autonomic balance						p^a
	Low		Normal		High		
	Students	Athletes	Students	Athletes	Students	Athletes	
Parasympathetic tone							
RR Intervals	6 (33.3)	0 (0.0)	12 (66.7)	12 (66.7)	0 (0.0)	6 (33.3)	0.002*
SMSSD	0 (0.0)	0 (0.0)	15 (83.3)	8 (44.4)	3 (16.7)	10 (55.6)	0.018*
High frequencies (HF)	1 (5.6)	1 (5.6)	12 (66.7)	12 (66.7)	5 (27.8)	(27.8)	1.000
PNS index	0 (0.0)	0 (0.0)	15 (83.3)	11 (61.1)	3 (16.7)	7 (38.9)	0.264
Sympathetic tone							
Heart rate	0 (0.0)	5 (27.8)	8 (44.4)	13 (42.2)	10 (55.6)	0 (0.0)	<0.001*
Stress index	1 (5.6)	2 (11.1)	14 (77.8)	16 (88.9)	3 (16.7)	0 (0.0)	0.177
Low frequencies (LF)	4 (22.2)	3 (16.7)	13 (42.2)	14 (77.8)	1 (5.6)	1 (5.6)	0.767
SNS index	0 (0.0)	1 (5.6)	15 (83.3)	17 (94.4)	3 (16.7)	0 (0.0)	0.127

[a] Pearson's Chi-square. The results show absolute frequency (%).
* Statistically significant.
PNS, parasympathetic nervous system; **SMSSD,** square root of the mean sum of the squared differences of all RR intervals (ms); **SNS**, sympathetic nervous system.

lates into better perfusion to the peripheral tissues.

The results of this study show that the pNN50 value was significantly lower in the group of students. This result coincides with what Tonello *et al*[34] stated, who obtained a lower value of this variable in more sedentary individuals and with less aerobic capacity. According to Jarczok *et al*[35], pNN50 is useful in estimating the percentage of vagal activation, and its preponderance in athletes speaks in favor of a parasympathetic predominance in this group.

The stress index variable was significantly higher in the group of students, which identifies this group with a higher autonomic sensitivity to stress, perhaps because of a higher exposure to this stimulus. Previous studies[17,36,37] have shown that mental stress leads to a decrease in HRV, suggesting an increase in the sympathetic activity and a reduction in the parasympathetic one.

Heart rate variability measurement has previously been used to determine stress tolerance levels among different groups of healthy individuals[38,39]. The stress index characterizes the sympathetic regulation, which is in charge, during mental or physical stress, of stabilizing the rhythm, diminishing the duration of the RR intervals as well as making the intervals very similar[40]; this has been associated with depression[41], obesity[42,43] and sudden cardiovascular death[33].

The predominance of the parasympathetic index found in the group of athletes coincides with that obtained by Harriss *et al*[44], who obtained both a vagal predominance and a sympathetic decrease in athletes. The association between vagal index and positive cardiovascular adaptation to training in young athletes has been previously determined, Chen *et al*[45] demonstrated the benefits of reflexology massage in increasing parasympathetic tone as a post-training recovery strategy.

Changes in parasympathetic indexes of HRV, as a response to training, have been positively associated with improvements in several physical fitness markers in individual and team athletes[46,47]. However, recent physical training (last 24 hours), in untrained individuals, changes the balance of the autonomic nervous system to an increased sympathetic impulse and a parasympathetic decrease[48,49].

Table 4. Area under the ROC curve of the sympathetic and parasympathetic indexes to be associated with the athletes group.

Variables	Area	Typical error	p	Intervalo de confianza (95%)	
				Lower limit	Upper limit
PNS index	0.784	0.079	0.004*	0.630	0.938
SNS index	0.207	0.075	0.003*	0.060	0.354

* Statistically significant.
Invalid hypothesis: true area = 0.5
PNS, parasympathetic nervous system; SNS, sympathetic nervous system.

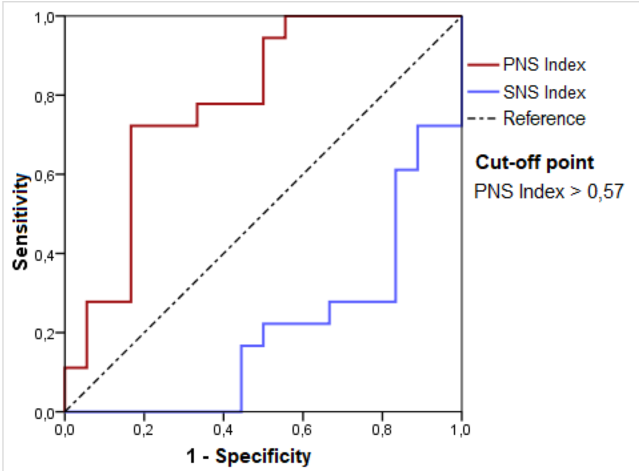

Figure 3. ROC curves showing the discriminatory capacity of the sympathetic and parasympathetic indexes to be associated with the athletes group.
PNS, parasympathetic nervous system; SNS, sympathetic nervous system.

The systematic practice of physical exercise contributes to the improvement of the autonomic modulation in young individuals, therefore higher values in the variables of the parasympathetic nervous system and lower values in those of the sympathetic one, translate into a better physiological status[50]. The findings of this research coincide with those described in a systematic review carried out by da Silva *et al*[51], who describe that the main results described in athletes, when compared with control groups, are the highest values of RR intervals and high frequency waves (vagal predominance). Furthermore, this same author states that Cohen's effect size shows that some factors, such as sports modality and protocol used for the records, influence these results.

In the current study, a qualitative analysis of the sympathetic and parasympathetic indexes was carried out using the multiparametric model proposed by the authors of the Kubios® software, in order to determine its usefulness. It was demonstrated that there were limitations regarding the qualification of the indexes of both components of the autonomous nervous system (sympathetic and parasympathetic), since these variables were significant when analyzing them quantitatively, however it did not result this way in their qualitative ordinal category. The authors of the current study consider that this model has limitations, since it uses reference values to establish cut-off points (normal, high and low) that are not applicable to all populations.

The determination of the cut-off point of the parasympathetic index in 0.57, to be associated to the group of baseball players, through the values of sensitivity and specificity provided by the analysis of the ROC curve, it is proposed by the authors of this research as a reference for future studies, taking into account that it was established in a group of healthy individuals and with an optimal autonomic modulation of the cardiovascular function.

CONCLUSIONS

The basal autonomic balance between medical students and baseball players experiences changes in several linear parameters of heart rate variability, which results in an improved autonomic adaptive capacity in athletes. Specifically, the parasympathetic index was associated with the group of athletes, showing the vagal predominance in the modulation of cardiac activity in the individuals belonging to this group.

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