

## **Time domain and frequency domain analysis of heart rate variability in elite Nepalese football players**

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### **Abstract**

**Objective:** There are conflicting reports in the literature concerning the time and frequency domain parameters of heart rate variability (HRV) in athletes. Furthermore, the exact impact of different sports disciplines on cardiac autonomic function is unclear. Thus, the study was destined to assess and compare HRV in the time and frequency domains between elite Nepalese football players and non-athletes.

**Methods:** Temporal and spectral HRV parameters determined from 5-minute continuous ECG during supine rest were studied in 27 elite male football players (age: 22.74±2.52 years) with excellent cardiorespiratory fitness, and 30 non-athletic male (age: 23.41±2.95 years) volunteers (control group). All HRV parameters were compared between the groups.

**Results:** Resting heart rate, systolic and diastolic blood pressure were significantly lower and all parasympathetic-related time and frequency domain indices, including root mean square of successive differences [RMSSD, 55.10(39.40-82.60) vs 25.70(20.10-44.45) ms, p=0.001], High frequency power in absolute value [HF, 1019(582-2127) vs 277(105.50-695) ms<sup>2</sup>, p=0.001] and in normalized unit [HFnu, 57.70(49.50-68.60) vs 42.20 (29.45-56.40)%, p=0.001], were higher in footballers compared to non-athletics. Similarly, standard deviation of all NN intervals (SDNN), determinant of global HRV, was higher in players (p=0.003). Furthermore, the power spectral components low frequency in normalized unit (LFnu), a sympathetic marker, and LF/HF, which reflect sympatho-vagal balance, were significantly lower in players.

**Conclusion:** The footballers had enhanced parasympathetic (higher RMSSD, HF and HFnu, and lower LF/HF ratio) and diminished sympathetic (lower LFnu) tone on heart. Football playing has favorable effect on the cardiac autonomic profile as indicated by high global HRV (higher SDNN).

**Keywords:** Time and frequency domain, heart rate variability, football players.

### **1. Introduction**

Heart rate variability (HRV) is a term used to describe the variations in consecutive R-R intervals or instantaneous heart rate. R-R interval refers to the duration between two adjacent R-wave peaks of normal QRS complex on standard electrocardiogram (ECG) [1]. The rhythm of the heart is controlled by the sino-atrial (SA) node, which is under the influence of sympathetic and parasympathetic branches of the autonomic nervous system. Continuous modulation of pacemaker by these autonomic branches results variations in instantaneous heart rate or consecutive R-R intervals [2]. These variations are analyzed by heart rate variability (HRV), which is considered as a powerful

non-invasive tool for the estimation of cardiac autonomic modulations [3,4]. The variations are calculated in the time and frequency domains; in this last condition they are expressed as sine wave power values (power spectrum) [1,5].

Several cross-sectional studies that have compared resting HRV between endurance-trained and untrained subjects have demonstrated inconclusive results. Some have shown that endurance-trained subjects present higher values of power spectral HRV, indicating increasing vagal activity [6,7]; others have reported higher values of the LF component of HRV suggesting higher sympathetic activity [8]. Lower levels of sympathetic

activation [9] and vagal activation [8] and, finally, no differences have been found between trained and untrained subjects [10]. The results regarding time domain HRV are also controversial, and some studies have shown differences in time domain that were not accompanied by corresponding differences in power spectral HRV [11].

Therefore, studies of HRV parameters on endurance trained and sedentary controls still remain necessary. Furthermore, the exact impact of different types of sports disciplines on cardiac autonomic function is still unclear. Additionally, the study is first of its kind in Nepalese football players. Thus, the aim of this study was to assess HRV in the time and frequency domains in elite football players and sedentary subjects in the supine position and compare between the two groups.

## 2. Material and Methods

### 2.1. Subjects

Twenty seven elite male Nepalese football players (age:  $22.74 \pm 2.52$  years) playing at league level volunteered to participate in the study. All of them demonstrated excellent cardio-respiratory fitness when assessed by three-minute step test. The reference group consisted of thirty non-athletic male subjects (age:  $23.41 \pm 2.95$  years). Their characteristics are shown in table 1. All of the subjects were apparently healthy, free from cardiopulmonary, metabolic, autonomic, and/or orthopedic disorders, and were not taking any prescription or over-the-counter medications.

### 2.2. Ethics statement

All subjects were informed of the study procedure, purposes, and known risks, and all gave their informed consent. This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethical committee of B. P. Koirala Institute of Health Sciences, Nepal.

### 2.3. Study design and procedure

This cross sectional comparative study was conducted over a year (2011-2012) in neurophysiology lab, department of basic and clinical physiology, BP Koirala Institute of Health Sciences, Dharan, Nepal. Each individual was screened for any history of drugs/alcohols intake, smoking or medical illness likely to affect the heart rate variability parameters.

Analysis of heart rate variability (HRV) was performed based on 5 minute ECG recorded at rest in the supine position. Recordings were taken in a quiet air-conditioned ( $22-24^{\circ}\text{C}$ ) laboratory during 08:00 am to 11:00 am. The subjects were instructed not to perform exercise 40 h before the day of the

experiment and to avoid drugs and caffeine 12 h before the test.

### 2.4. ECG recording and HRV analysis

The resting ECG at spontaneous respiration was recorded for five minutes in supine position. The standard limb leads were used for recording of ECG; the electrodes were applied on the upper and lower limbs after cleaning the skin adequately with methyl alcohol to decrease the skin impedance and then connected to the Coulbourn Instrument. To overcome the problem of trend and non-stationarity of the ECG signals, the subjects were allowed to rest in the laboratory in the supine position for at least 15 minutes to obtain steady state haemodynamics before commencement of the recording. The subjects were instructed to take normal breathing, relax and close their eyes but not to fall asleep. Five minutes ECG from any standard limb leads which has prominent R waves was recorded.

The ECG signals for HRV were captured using Coulbourn Instrument and its software Windaq pro/pro+ (Model no. DI-400 series, USA). The sampling frequency of the ECG was set at 1000Hz. Before any calculation of HRV were performed the recordings were edited and corrected manually for ectopic beats, arrhythmias, noise and trends from the Windaq Pro/Pro+ software. Then it was followed by 'R' wave detection of normal QRS complex by using Windaq Pro/Pro+ software and R wave detected ECG was edited manually to ensure all R waves but other waves were marked. After this, by the same software, QRS complex occurrence times were estimated. The file was saved as lotus file, which was readable by MS Excel. This Lotus file was opened in Excel and cumulative values of R-R intervals were converted into individual R-R interval series. Thus, the intervals between successive normal -to -normal QRS complexes (RR intervals resulting from sino-atrial node driven rhythm) or instantaneous heart rate values for each cardiac cycle were determined. RR intervals were saved in ASCII format. It was readable to "Kubios HRV version 2.0" which was used to calculate Time and Frequency domain measures of HRV.

The following HRV variables were analyzed: for the time domain - standard deviation of normal RR interval (SDNN, ms), root mean square of differences of successive RR intervals (RMSSD, ms); for the frequency domain - low frequency power (LF  $\text{ms}^2$ , 0.04-0.15 Hz), high frequency power (HF  $\text{ms}^2$ , 0.15-0.4 Hz), low frequency in normalized unit (LFnu), high frequency in normalized units (HFnu), and LF/HF - ratio of absolute LF power to HF power.

**2.5. Statistical analysis**

Statistical analysis was conducted with SPSS software (v 16.02, Chicago, IL, USA). The results are presented as median (interquartile range). Differences in variables between the groups were tested using Mann-Whitney U test. A p value of < 0.05 was considered significant.

**3. Results**

**3.1 Cardiorespiratory variables at rest**

Two groups of subjects were examined. Their biometric and cardiorespiratory characteristics are given in table 1. Resting heart rate, systolic, and diastolic blood pressure were significantly lowered in footballers compared to sedentary controls.

**Table 1: Comparison of anthropometric and cardiac parameters of football players (n= 27) and non-athletic controls (n=29).**

Variables	Football players	Non-athletics	p
Age (years)	22.74±2.52	23.41±2.95	0.365
Height(m)	1.70±0.06	1.69±0.05	0.905
Weight(kg)	61.81±7.51	61.76±4.61	0.973
BMI(Kg/m <sup>2</sup> )	21.40±1.87	21.42±1.86	0.976
Heart Rate(bmp)	62.25 ±7.60	74.44 ±7.89	0.001**
SBP(mm Hg)	111.33±10.24	118.41±7.75	0.005**
DBP(mm Hg)	70.67±10.713	78.34±6.76	0.003**

\*\* p is 0.01 or less

**3.2 Heart rate variability at rest**

Time domain variables, SDNN and RMSSD, were significantly higher in players as compared to sedentary controls (table 2, figure 1 & 2).

Frequency domain analysis of HRV had shown significantly higher HF and HFnu in players than in sedentary controls (table 2, figure 3 & 4). LFnu and LF/HF on the other hand, were significantly lowered in players (table 2, figure 5 & 6).

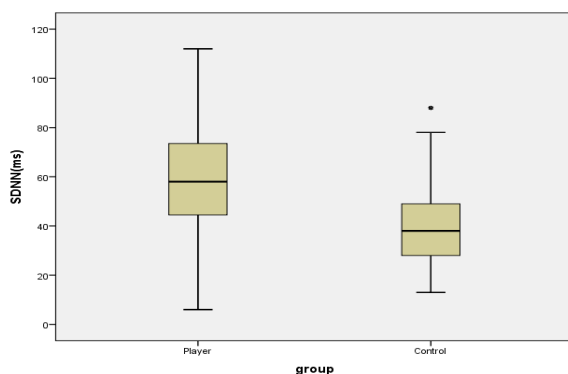
**Table 2: Comparison of heart rate variability parameters in time and frequency domains between players (n=27) and sedentary controls (n=30).**

Variables	Football Players Median (Q1-Q3)	Non-athletics Median (Q1-Q3)	p
SDNN (ms)	57.90 (43.0 – 73.90)	37.90 (27.60 – 50.40)	0.003**
RMSSD (ms)	55.10 (39.40 – 82.60)	25.70 (20.10 – 44.45)	0.001**
LF (ms <sup>2</sup> / Hz)	797.00 (384.00 – 1364.00)	417.00 (245.50 – 650.00 )	0.052
LF nu (%)	42.30 (31.40 – 50.50)	57.80 (43.60 – 70.55)	0.001**
HF (ms <sup>2</sup> /Hz)	1019.00 (582.00 – 2127.00)	277.00 (105.50 – 695.00)	0.001**
HF nu (%)	57.70 (49.50 – 68.60)	42.20 (29.45 – 56.40)	0.001**
LF/HF	0.734 (0.459 – 1.020)	1.372 (0.775 – 2.409)	0.001**

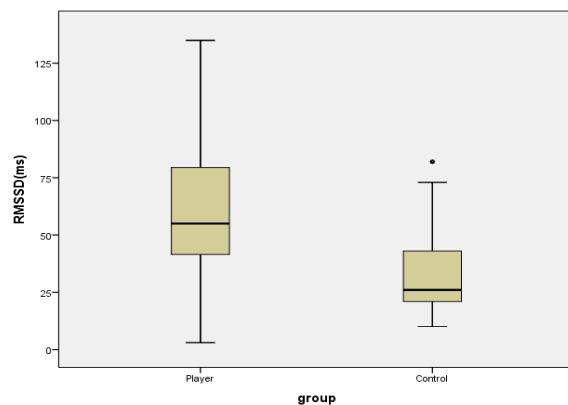
\*\* p is 0.01 or less

Data are reported as medians and interquartile range. SDNN = standard deviation of normal RR interval; RMSSD = Root mean square of differences of successive RR intervals (ms); LF, HF = low and high frequency power, respectively; LFnu

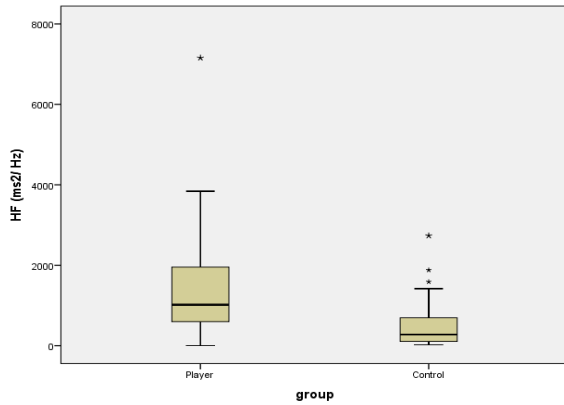
= LF power in normalized units; HFnu = HF power in normalized units; LF/HF = ratio of absolute LF power to HF power values. Frequency ranges: LF: 0.04-0.15 Hz and HF: 0.15-0.4 Hz.



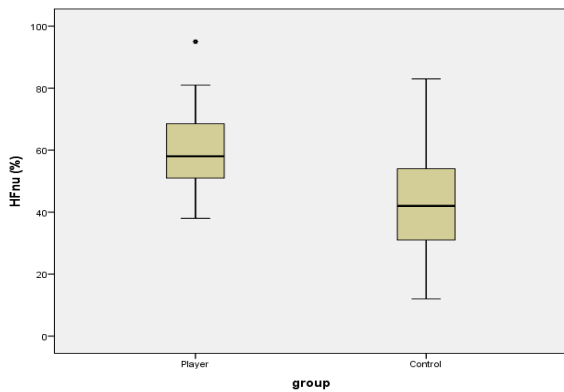
**Figure 1: Standard deviation of normal RR interval for players and sedentary controls**



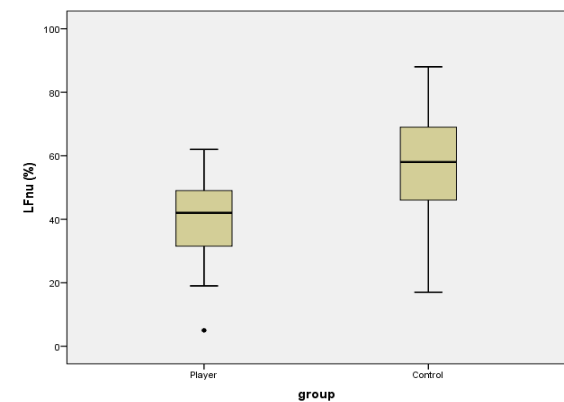
**Figure 2: Root mean square of differences of successive RR intervals for players and sedentary controls**



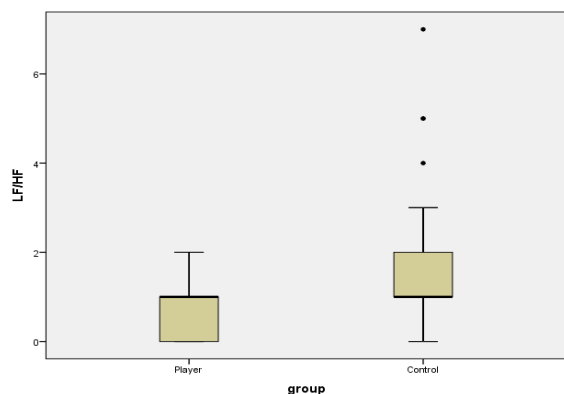
**Figure 3: High frequency power for players and sedentary controls**



**Figure 4: High frequency in normalized unit for players and controls**



**Figure 5: Low frequency in normalized unit for player and control**



**Figure 6: Low frequency-high frequency ratio for player and control.**

#### 4. Discussion

Both, the players and sedentary controls formed a homogenous population groups without significant differences in age, height, weight or body mass index, yet cardio respiratory variables differed significantly. The players had reduced resting heart rate, systolic and diastolic blood pressure when compared to controls.

Several investigations have been conducted regarding the mechanisms responsible for resting bradycardia in athletes. Alterations in the cardiac autonomic balance and changes in the intrinsic mechanisms acting on the sinus node are reported to contribute to this phenomenon. Human studies that have used cardiac autonomic blockade to investigate the effect of training on autonomic balance, reported the enhanced parasympathetic and/or diminished sympathetic activity on heart might contribute in part to the resting bradycardia [6,12]. The present study also indicates alterations in the autonomic control of the heart as it was evident by HRV analysis. However, similar type of studies on animals and humans involving autonomic blockade have related the resting bradycardia to reduced intrinsic heart rate [10,13].

There is good evidence from randomized controlled trials that dynamic physical training reduces blood pressure [14, 15]. The elite football players in this study also had reduced blood pressure. A study by Hsu *et al.* [16] reported the augmented GABAergic system in both paraventricular nucleus and posterior hypothalamic area might be the important mechanism for explaining how chronic exercise resets the resting blood pressure in normotensive rats.

The time and frequency domain parameters of HRV had shown considerable differences among football players and sedentary controls. The measured time domain variables, SDNN and RMSSD, were significantly higher in players. The result is consistent with the findings of Carter *et al.* [17] where trained individuals were compared with their age- and weight-matched sedentary controls. SDNN, the square root of variance, is mathematically equal to total power of spectral analysis, and it reflects all the cyclic components responsible for variability in the period of recording [1]. RMSSD reflects the short-term variance in HR and is the primary time-domain measure used to estimate the high- -frequency beat-to-beat variations providing an estimate of the parasympathetic regulation of the heart. Increased values in athletes like in our case would indicate a parasympathetic predominance [18].

Higher HF component both in absolute and normalized unit was observed in footballers. In

contrast, LF power expressed in normalized unit and ratio of LF power to HF power were significantly less in them. LF power though higher in footballers was insignificant. Several cross-sectional studies that have compared frequency domain HRV between endurance-trained and untrained subjects have demonstrated inconsistent results. Some investigators report significantly higher HF and LF (in absolute values) [19] in athletes compared with sedentary individuals, others reveal no such changes [20]. The trained individuals in the study of Melanson and Freedson [21] had significantly lower LF compared with their sedentary counterparts. Migliaro *et al.* [22] found no differences in HRV (as determined from spectral analysis: LF and HF) parameters between sedentary (n = 29; 15–24 years) and non-sedentary (n = 29, 15–24 years) young people.

The finding of higher HF power and HFnu in our study is supported by several cross-sectional studies [23,24]. These spectral components are considered as the marker of the efferent vagal activity in heart [1]. More controversial is the interpretation of the LF component which is considered by some as a marker of sympathetic modulation (especially when expressing it in normalized units) and by others as a parameter that includes both sympathetic and vagal influences [1]. Lowered LFnu evident in football players would therefore suggest diminished cardiac sympathetic activity. Further players were characterized with lower LF/HF ratio, similar result was reported by Janssen *et al* [25] in cyclists. The ratio of LF to HF is considered to reflect the sympatho-vagal balance. According to this view higher value suggests a sympathetic predominance and lower parasympathetic predominance [26].

## 5. Conclusion

The results of the present cross-sectional study suggest distinct physical training adaptations in professional Nepalese football players and were associated with alterations in cardiac autonomic activity. They had enhanced parasympathetic (higher RMSSD, HF power and HFnu) and diminished sympathetic (lower LFnu and LF/HF) tone on heart. Furthermore, our data indicate that the bradycardia found in players appears to be related to parasympathetic predominance.

## References

- [1] Camm J, Malik M, Bigger JT *et al.* Heart rate variability: standards of measurement, physiological interpretation, and clinical use. *Circulation* 1996; 93(5): 1043–1065.
- [2] Desaulniers P, Lavoie PA, Gardiner PF. Habitual exercise enhances neuromuscular transmission efficacy of rat soleus muscle in situ. *J Appl Physiol* 2001; 90: 1041-1048.
- [3] Dekker JM *et al.* Low heart rate variability in a 2- minute rhythm strip predicts risk of coronary heart disease and mortality from several causes. The ARIC study. *Circulation* 2000; 102: 1239-1244.
- [4] Hayano J, Sakakibara Y, Yamada A. Accuracy of assessment of cardiac vagal tone by heart rate variability in normal subjects. *Am J Cardiol* 1991; 67:199-204.
- [5] Akselrod S, Gordon D, Ubel FA, Shannon DC, Berger AC, Cohen RJ. Power spectrum analysis of heart rate fluctuation: a quantitative probe of beat-to-beat cardiovascular control. *Science* 1981; 213: 220-222.
- [6] Shin K, Minamitani H, Onishi S, Yamazaki H, Lee M. Autonomic differences between athletes and nonathletes: spectral analysis approach. *Med and Sci Sports and Exer* 1997; 29: 1482-1490.
- [7] Yamamoto K, Miyachi M, Saitoh T, Yoshioka A, Onodera S. Effects of endurance training on resting and post-exercise cardiac autonomic control. *Med and Sci Sports and Exer* 2001, 33: 1496-1502.
- [8] Pichot V, Roche F, Gaspoz JM, Enjolras F, Antoniadis A, Minini P, Costes F, Busso T, Lacour JR, Barthelemy JC. Relation between heart rate variability and training load in middle-distance runners. *Med and Sci Sports and Exer* 2000; 32: 1729- 1736.
- [9] Dixon EM, Kamath MV, McCartney N, Fallen EL. Neural regulation of heart rate variability in endurance athletes and sedentary controls. *Cardiovasc Res* 1992; 26: 713-719.
- [10] Loimaala A, Huikuri H, Oja P, Pasanen M, Vuori I. Controlled 5-mo aerobic training improves heart rate but not heart rate variability or baroreflex sensitivity. *J Appl Physiol* 2000; 89: 1825- 1829.
- [11] Sacknoff DM, Gleim GW, Stachenfeld N, Coplan NL. Effect of athletic training on heart rate variability. *Am Heart J* 1994; 127: 1275-1278.
- [12] Puig J, Freitas J, Carvalho MJ, Puga N, Ramos J, Fernandes P, Costa O, de Freitas AF. Spectral analysis of heart rate variability in athletes. *J Sports Med and Physical Fitness* 1993, 33: 44-48.
- [13] Stein RMC, Rosito GA, Zimmerman LI, Ribeiro J. Intrinsic sinus and atrioventricular node electrophysiologic adaptations in endurance athletes. *J Am Coll Cardiol* 2002; 39: 1033-1038.

- [14] Fagard RH. Physical activity in the prevention and treatment of hypertension in the obese. *Med Sci Sports Exerc* 1999; 31: S624-630.
- [15] Fagard RH, Tipton CM. Physical activity, fitness and hypertension. In: Bouchard C, Shephard RJ, Stephens T, editors. *Physical Activity, Fitness and Health*. Champaign IL: Human Kinetics, pp 633-655; 1994.
- [16] Hsu YC, Chen HI, Kuo YM, Yu L, Huang TY, Chen SJ *et al*. Chronic treadmill running in normotensive rats resets the resting blood pressure to lower levels by upregulating the hypothalamic GABAergic system. *J Hypertens* 2011; 29(12): 2339-2348.
- [17] Carter JB, Banister EW, Blaber AP. Effect of Endurance exercise on Autonomic Control of Heart Rate. *Sports Med* 2003; 33(1): 33-46.
- [18] Achten J, Jeukendrup AE. Heart Rate Monitoring - Applications and Limitations. *Sports Med* 2003; 33(7): 517-538.
- [19] Furlan R, Piazza S, Dell'Orto S *et al*. Early and late effects of exercise and athletic training on neural mechanisms controlling heart rate. *Cardiovasc Res* 1993; 27 (3): 482-488.
- [20] Stein R, Moraes RS, Cavalcanti AV *et al*. Atrial automaticity and atrioventricular conduction in athletes: contribution of autonomic regulation. *Eur J Appl Physiol* 2000; 82(1-2): 155-157.
- [21] Melanson EL, Freedson PS. The effect on endurance training on the resting heart rate variability in sedentary adult males. *Eur J Appl Physiol* 2001; 85(5): 442-449.
- [22] Migliaro ER, Contreras P, Bech S *et al*. Relative influence of age, resting heart rate and sedentary life style in short-term analysis of heart rate variability. *Braz J Med Biol Res* 2001; 34 (4): 493-500.
- [23] Aubert AE, Ramaekers D, Collier B *et al*. Comparison of the effect of different types of exercise on short-term heart rate variability. *Med Biol Eng Comput* 1999; 37: 568-569.
- [24] Dixon EM, Kamath MV, McCartney N *et al*. Neural regulation of heart rate variability in endurance athletes and sedentary controls. *Cardiovasc Res* 1992; 26 (7): 713-719.
- [25] Janssen MJ, de Bie J, Swenne CA *et al*. Supine and standing sympathovagal balance in athletes and controls. *Eur J Appl Physiol Occup Physiol* 1993; 67 (2): 164-167.
- [26] McCraty R, Watkins A. Autonomic Assessment Report - a comprehensive heart rate variability analysis. Heart Math Research Center, pp 1-42, 1996.