Patterns of QT Dispersion in Athletic and Hypertensive Left Ventricular Hypertrophy

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Objective: The objective of this article is to assess whether left ventricular hypertrophy (LVH) due to physical training or of hypertensive patients shows similarities in QT length and QT dispersion.

Methods: A total of 51 subjects were studied: 17 essential hypertensive patients (27.7 ± 5.6 years), 17 athletes involved in agonistic activity (canoeing) (24.8 ± 6.1 years), and 17 normotensive healthy subjects as control group (24.8 ± 3.6 years). The testing protocol consisted of (1) clinic BP measurement, (2) echocardiography, (3) 12-lead electrocardiographic examination (QT max, QTc max, QT min, QTc min, Δ QT, Δ QTc).

Results: There were no significant differences between the body surface area, height, and age of the three groups. Clinic blood pressure was higher in hypertensives ($146.5 \pm 45.2/93.5 \pm 4.9$ mmHg) versus athletes ($120.9 \pm 10.8/77.1 \pm 6.0$ mmHg) and controls ($123.5 \pm 4.8/78.8 \pm 2.9$ mmHg) by definition. Indexed left ventricular mass (LVM/BSA) was significantly greater in both athletes (148.9 ± 21.1 g/m²) and hypertensives (117.1 ± 15.2 g/m²) versus controls (81.1 ± 14.5 g/m²; $P < 0.01$), there being no statistical difference among them. LVH (LVMI > 125 g/m²) was observed in all athletes, while the prevalence in hypertensives was 50%. In spite of this large difference in cardiac structure there were no significant differences in QT parameters between athletes and the control group, while hypertensive patients showed a significant increase in QT dispersion versus the two other groups (Δ QT 82 ± 2.1 , 48 ± 1.3 , 49 ± 2.3 ms; $P < 0.01$; Δ QTc 88 ± 2.0 , 47 ± 1.4 , 54 ± 2.7 ; $P < 0.01$).

Conclusions: LVH induced by physical training activity is not associated with an increase in QT dispersion, whereas pathological increase in LVM secondary to hypertension is accompanied by an increased QT dispersion.

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QT dispersion; hypertension; LVH; athlete's heart

Left ventricular hypertrophy (LVH) represents an important mechanism of adaptation to compensate the excessive parietal stress due to chronic pressure overload.

It can appear as a consequence of both arterial hypertension and long-term training. The two conditions, in fact, respectively represent the main causes of pathological and physiological LVH.^{1–3}

In arterial hypertension, LVH is a powerful independent risk factor for cardiovascular complications, due both to an inappropriate coronary adaptation and an increased arrhythmogenic risk.

On the contrary, the LVH, physiologically consequent to physical exercise, has different biochemical and structural characteristics, which manifest as normal coronary reserve and normal or super-normal diastolic function.⁴

QT dispersion, which reflects the grade of disturbance in regional repolarization, could be considered as an independent risk factor for increased risk of ventricular arrhythmias in hypertensive patients.^{5–7} Past studies demonstrated that dispersion is pathologically increased in hypertensive patients and it correlates with LVH and its degree, while few data are actually available about the QT pattern of dispersion related to physiologic LVH of the athletes. In this study we examined QT dispersion in subjects with pathologic and physiologic LVH.

METHODS

The study population consisted of 51 subjects: 17 patients with never treated first-degree essential hypertension (group 1), 17 athletes involved

in agonistic activity (group 2), and 17 normotensive healthy subjects as control (group 3). The 17 athletes were involved in international competitions, in the discipline of canoeing (Olympics and marathon). They were tested at the same stage of their training program that consists of both aerobic and isometric exercises.

All the subjects were free from cardiac pathologies, diabetes mellitus, chronic renal failure, or other relevant diseases on the basis of previous accurate objective examination, electrocardiogram (ECG), echocardiogram, and laboratory analysis.

The testing protocol consisted of (1) clinic BP measurement, (2) echocardiography, and (3) 12-lead electrocardiographic examination (QT max, QTc max, QT min, QTc min, Δ QT, Δ QTc).

BP Measurement

BP was measured by a physician in the outpatient clinic using a mercury sphygmomanometer (1st and 5th phases of Korotkoff sounds taken as systolic and diastolic values, respectively) after 10 minutes rest in the sitting position during the morning. Three measurements were taken at 1-minute intervals, and the average was used to define clinic SBP and DBP.

Echocardiography

M-mode and two-dimensional echocardiographic studies were performed with subjects in the partial left lateral decubitus position using a Vingmed System FiVe apparatus (GE Medical Systems; New Orleans, LA) equipped with a 2.5 MHz imaging transducer. End diastolic left ventricular internal diameter (LVIDd), interventricular septum thickness (IVST), and posterior wall thickness (PWT) were calculated from two-dimensional guided M-mode tracings and measured in five consecutive cycles according to ASE criteria.^{8,9} Left ventricular mass (LVM) was determined by Devereux's formula¹⁰ and indexed (LVMI) by body surface area and height.^{2,7} LVH was diagnosed when LVMI exceeded 125 g/m² or 50 g/h.^{2,7} The relative wall thickness ratio (RWT) was obtained by the standardized formula: $RWT = (2 \times PWT)/LVIDd$. Patterns of left ventricular (LV) geometry were defined.

The Doppler inflow signals in the left ventricle during diastole at the mitral valve were studied to evaluate ventricular relaxation. The sample volume

was set at the tip of the mitral valve leaflets on the apical long axis view. A clear, diastolic, biphasic waveform was obtained. From the transmitral flow velocity pattern recorded, we measured deceleration time, early diastolic peak (E), atrial systolic peak (A) velocities, and their ratio (E/A).

Electrocardiography

All 12-lead resting ECGs were performed at 50 mm/s with standard lead positions. QT interval was measured on all possible leads by a single observer blinded to all clinical details. QT interval was taken to be from the onset of the QRS complex to the end of the T wave, which was defined as its return to the trace baseline. No Q waves were present. QT interval was corrected using Bazett's formula to compensate for its known dependence on heart rate. QTc dispersion was determined as the difference between the maximum and the minimum QTc interval in different leads. Subjects with an ECG showing bundle branch block were excluded from the study.

Statistical Analysis

Data are expressed as means $\pm$ SD or as percentages. Differences between the groups were assessed by analysis of variance (ANOVA) with the Scheffe post hoc test. Differences in prevalence between subgroups were assessed by chi-squared test. Univariate relation between variables was assessed by Pearson correlation coefficient; a 2-tailed P value of <0.05 was considered statistically significant. Data management and statistical analysis were performed using Statview SAS software.

RESULTS

Demographic and clinical characteristics of the subjects are reported in Table 1.

No significant differences were present between the body surface area, height, and age of the three groups.

Hypertensive patients had a higher body mass index when compared with the two other groups ($P < 0.01$). By definition, hypertensive patients had both clinic systolic and diastolic BP values significantly higher than the other groups ($P < 0.001$). No differences were found between athletes and controls.

Clinic heart rate was significantly lower in athletes than in the other two groups ($P < 0.01$) (Table 1).

Table 1. Clinic and Demographic Characteristics

	Hypertensives	Athletes	Controls
Age (years)	27.7 ± 5.6	24.8 ± 6.11	24.7 ± 3.7
BMI (kg/m ²)	27.6 ± 3.2	24.5 ± 2.0	23.3 ± 1.5
BSA (m ²)	1.98 ± 0.12	1.94 ± 0.07	1.85 ± 0.1***
SBP (mmHg)	146.5 ± 5.2*	120.9 ± 10.8	123.5 ± 4.8
DBP (mmHg)	93.5 ± 4.9*	77.1 ± 6.0	78.8 ± 2.9
HR (bpm)	73.6 ± 13.0	53.2 ± 7.3**	81.6 ± 9.7

Data are expressed as average ± SD. BMI, body mass index; BSA, body surface area; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate.

* P < 0.01 hypertensives versus athletes and controls.

** P < 0.01 athletes versus hypertensives and controls.

*** P < 0.01 controls versus athletes and hypertensives.

All the subjects were males, no one was taking drugs, and no one was a smoker.

Laboratory Analysis

No differences were found in blood glucose concentration, creatinine, electrolytes blood levels, and hematocrit. The total cholesterol level was similar in the three groups with a significantly higher HDL fraction in the athlete's group (P < 0.001) (Table 2).

Prevalence of LVH

Table 3 shows the echocardiographic characteristics of the subjects. LVM was significantly higher both in the athletes and in the hypertensive group than in the control group (P < 0.0001), there being no statistical difference among them.

LVM seemed to be higher in the athletes group when indexed for BSA, but this difference, due to the significantly higher weight of the hypertensives, disappeared when indexing LVM by height. With reference to the criteria used in defining LVH, its prevalence ranged between 80% and 50% in the

hypertensive patients (group I), was 100% in the athletes (group II), and was absent in the control group (III).

Eccentric hypertrophy was the most frequent geometric pattern observed both in athletes (58–64%) and in hypertensives (70–50%).

Mean systolic function was completely normal in the three groups (Table 3), but there were distinct significant differences in LV diastolic function between the groups. The peak E velocity was significantly higher (P < 0.01) and the peak A velocity significantly lower (P < 0.01) in athletes when compared with hypertensives' group. The difference was still present, even if less significant, between hypertensives and the control group (P < 0.05). No statistical differences were found between athletes and controls. The E/A ratio was clearly lower in hypertensives, even if it was still normal (P < 0.01 vs athletes; P < 0.05 vs controls).

QT and QT Dispersion

In spite of this large difference in cardiac structure there were no significant differences in QT

Table 2. Laboratory Analysis

	Hypertensives	Athletes	Controls
Cholesterol total (mg/dL)	204.6 ± 56*	176.9 ± 36	195.0 ± 21
HDL (mg/dL)	35.5 ± 8.7	66.5 ± 12.5**	48.0 ± 7.8
LDL (mg/dL)	137.8 ± 49.5	103.3 ± 27.5**	127.7 ± 21.3
GLY (mg/dL)	89.2 ± 6.5*	83.2 ± 6.2	83.1 ± 5.4
Creat (mg/dL)	0.9 ± 0.2	1.0 ± 0.1	0.9 ± 0.1
K ⁺ (mmol/L)	3.9 ± 0.2	4.0 ± 0.3	4.0 ± 0.2

Data are expressed as average ± SD. GLY, glycemia; Creat, creatinine.

* P < 0.05 hypertensives versus athletes and controls.

** P < 0.01 athletes versus hypertensives and controls.

Table 3. Echocardiographic and Doppler Data

	Hypertensives	Athletes	Controls
LVDd (mm)	52.2 ± 3.2	53.6 ± 3.8	47.8 ± 1.3**
IVST (mm)	10.7 ± 0.5	11.7 ± 1.1*	8.8 ± 1.0**
PWT (mm)	10.3 ± 0.6	10.8 ± 1.1	8.5 ± 0.8**
LVM (g)	232.6 ± 35.4	289.0 ± 43.5*	150.5 ± 29.1**
LVMI (g/m ²)	148.9 ± 21.1	117.1 ± 15.2	81.1 ± 14.5
LVMI (g/h ^{2.7})	62.2 ± 10	51.6 ± 6.9	32.9 ± 6.5
Peak E (cm/s)	71.7 ± 13.9	83.6 ± 11.5*	90.2 ± 14.2***
Peak A (cm/s)	71.2 ± 16.0	48.3 ± 6.0*	59.6 ± 12.3***
E/A	1.07 ± 0.3	1.76 ± 0.3*	1.54 ± 0.2***

Data are expressed as average ± SD. LVDd, left ventricular diastolic diameter; IVST, interventricular septum; PWT, posterior wall thickness; LVM, left ventricular mass; LVMI, left ventricular mass index; Peak E, left ventricular early diastolic filling; Peak A, left ventricular end diastolic filling.

* P < 0.01 athletes versus hypertensives.

** P < 0.01 controls versus athletes and hypertensives.

*** P < 0.01 controls versus hypertensives.

parameters between athletes and the control group, while hypertensive patients showed a significant increase in QT dispersion versus the two other groups (P < 0.01; see Table 4).

DISCUSSION

The results of our study clearly show that changes in the heart's structure related to hypertension and those due to physiological stimuli such as agonistic exercise have different patterns of QT dispersion.^{11,12}

A large number of studies on selected populations showed that an increase in QT dispersion could be associated with a larger risk for ventricular arrhythmias.^{13,14} A parallelism between LVH and increased QT has been largely demonstrated in patients with arterial hypertension.^{15–17} Otherwise, these days there are just a few and often not concordant data available on the relationship between a morphological athlete's heart modifications and patterns of QT dispersion.

Table 4. QT Length and QT Dispersion

	Hypertensives	Athletes	Controls
QT max (ms)	432 ± 55	451 ± 30	416 ± 22
QTc max (ms)	466 ± 47	446 ± 36	452 ± 36
QT min (ms)	349 ± 28	403 ± 30	367 ± 27
QTc min (ms)	378 ± 26	398 ± 31	399 ± 23
ΔQT	82 ± 21*	48 ± 13	49 ± 23
ΔQTc	88 ± 20*	47 ± 14	54 ± 27

Data are expressed as average ± SD.

* P < 0.01 hypertensives versus athletes and controls.

Our athletes were involved in canoeing, which is a sport with both a dynamic and a static component. LVH in these subjects can be, for this reason, either eccentric or concentric.^{18,19} We found 60% of eccentric LVH and 40% of concentric LVH. The geometric pattern of hypertensive patients was represented, instead, mostly by eccentric LVH (90%); this pattern reflects a hemodynamic profile characterized by a great cardiac output and normal or slightly increased peripheral vascular resistances.

The second difference between athletes and hypertensives has been the pattern of left ventricular filling that is an expression of the diastolic function. It was significantly higher in athletes than in hypertensives, even if the former had a greater LVMI: the ratio between Peak E and Peak A results in athletes were, in fact, significantly higher when compared with the E/A ratio of hypertensives (Table 3). These data demonstrate that an increase in LVM and in the wall's thickness is not enough by itself to explain the development of alterations in left ventricular compliance and filling.

The most relevant aspect of our study has been the demonstration that the pathological LVH due to hypertension comes with a significant increase in QT dispersion, and the physiological hypertrophy of athletes comes with a normal pattern of QT dispersion even for significantly greater LVMI. We can explain the differences observed between the groups as a consequence of two different processes in the development of LVH; myocardial modifications in hypertensives consist in myocyte hypertrophy with an increase in its collagen interstitial matrix (fibrous tissue),²⁰ in athletes, instead, LVH

seems to be mostly due to myocyte hypertrophy with just a little or no increase at all in interstitial fibrous matrix. This difference can also explain the absence of diastolic dysfunction in athletes in contrast with what is observed in hypertensives.^{21,22} Myocyte hypertrophy can cause an enlargement in the length of action potentials, whereas the growth of interstitial matrix can be associated with a length reduction of action potentials or electric rest.²³ There is also a well-demonstrated difference in coronary reserve found in the two kinds of hypertrophy. Coronary reserve is, in fact, reduced in hypertensive patients,²⁴ but preserved in athletes with even greater LVMs.

An increase in QT dispersion is also indexed as a marker of differences in ventricular repolarization and its heterogeneity can be underlined by myocardial ischemia. Nevertheless, none of the subjects we studied presented any kind of alteration of the ventricular repolarization phase on ECG.

CONCLUSIONS

Left ventricular hypertrophy induced by physical activity is not associated with any increase in QT dispersion, whereas pathological LVH due to hypertension demonstrates an increase in this value. The different patterns of QT dispersion add some new elements in defining the effective morpho-functional differences between physiological and pathological LVH.

The athletes seem to be free from the augmented risk for ventricular arrhythmias underlined in hypertensive patients, where the risk is due to QT dispersion increase.

In conclusion, we can affirm that the study of QT dispersion with ECG is a cheap and easy-performing parameter able to add important information in distinguishing physiological and pathological LVH. Nevertheless, further studies on larger populations are needed to confirm this method's potential as a possible reference parameter.

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