Cardiac Arrhythmias Triggered by Sudden and Dynamic Efforts

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Background: Some arrhythmias are triggered only during exercise. The aim of this study is to describe the frequency and type of arrhythmia induced by a standardized protocol of sudden and dynamic exercise, which tends to reflect routine situations of efforts (e.g., climbing stairs), and compare with those found on maximal cardiopulmonary exercise test (CPET).

Methods: A total of 2329 subjects (1594 men) aged 9–91 years (mean 52 years, SD $\pm$ 16) were submitted to a standardized protocol of sudden and dynamic exercise (4-second exercise test [4sET]) prior to a CPET. A continuous digital electrocardiogram (ECG) was recorded during 4sET and CPET, and later reviewed and interpreted by the same physician (who supervised all the procedures).

Results: A total of 1125 subjects (43%) had cardiac arrhythmias during one or both procedures. About 57% of the arrhythmias were supraventricular, but 47 subjects (2% of all subjects) presented more complex arrhythmias including 43 cases of nonsustained supraventricular tachycardia and four nonsustained ventricular tachycardia. While arrhythmias were more often exposed by the CPET ($P < 0.01$), in 221 cases (10% of the total sample) of arrhythmias they were only induced by 4sET; these included four cases of nonsustained supraventricular tachycardia.

Conclusion: 4sET-induced arrhythmias tend to be simple and were always short-lasting. In some cases, ECG recording during 4sET showed arrhythmias that would not be induced by a progressive maximal exercise test. Different situations of exercise, sudden and short versus maximal and progressive, tend to generate different arrhythmic responses and possibly complementary clinical implications.

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Palpitations are defined as sensations of fast or irregular heartbeat and are one of the most frequent complaints to cardiologists.¹ Although most presentations are benign, they often cause considerable discomfort to patients and, in some cases, may be manifestations or preliminary indications of more serious or potentially life-threatening medical conditions.² While palpitations can be a result of non-cardiac causes, such as drug use, anemia, and anxiety, palpitations triggered by cardiac arrhythmias are the most common.³

The palpitations caused by cardiac arrhythmias cannot always be diagnosed or documented in outpatient clinics, and they are often only triggered during exercise.⁴ Conventional protocols for exer-

cise tests, and even the maximal cardiopulmonary exercise test (CPET), which is increasingly used in diagnostic and prognostic cardiac assessment,⁵ can trigger palpitations and cardiac arrhythmias.⁶ However, these exercise protocols, which gradually increase and reach a maximum after several minutes, differ from the routine conditions of exercise that people usually do. In fact, most daily physical exertion is either held at a constant submaximal speed (e.g., walking) or is done with great variation in intensity and possibly at very short intervals (e.g., sexual activity, climbing stairs), some studies have identified the occurrence of cardiac arrhythmias in those exercise situations.^{7–9} Recently, Araújo & Vianna¹⁰ studied more than 700 individuals, each

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sequentially submitted to spirometry and CPET, under electrocardiographic monitoring and found that the occurrence of arrhythmias was quite distinct and, to some extent, complementary in both tests. Interestingly, these authors found that only 10% of subjects had arrhythmias exclusively during spirometry, including four cases of supraventricular tachyarrhythmias.

In this study, we demonstrate the implementation of a standardized protocol of sudden and dynamic exercise.¹¹ A 4-second exercise test (4sET) prior to CPET, which tends to reflect routine situations such as climbing a ladder or running across the street, was investigated. The resulting data were aimed to identify the type and frequency of arrhythmias triggered by this protocol and to compare them with those found on CPET.

METHODS

Sample

We reviewed medical data from 2329 subjects (1594 men) aged 52 ± 16 years (mean $\pm$ standard deviation), who were referred to our center for clinical diagnosis and/or exercise testing between January 2000 and May 2009 and who met the following inclusion criteria: (a) had both 4sET and CPET procedures carried out during the same visit; (b) performed a truly maximal CPET test; e.g., it was not stopped prematurely for medical reasons; (c) were in sinus rhythm; and (d) all data available to be studied. The subjects were then divided, according to clinical condition, into three groups: (a) apparently healthy ($n = 554$), (b) coronary artery disease (CAD) ($n = 539$), and (c) other diseases ($n = 1236$). The last group included, for example, diabetes mellitus, hypertension, thyroid disease, valvulopathies, and chronic obstructive pulmonary disease. In the individuals studied, there was no case with clinical signs of arrhythmogenic right ventricular, dysplasia, or Chagas disease, well-known causes of clinically relevant arrhythmias.

Classification of Arrhythmias

Arrhythmias were classified according to their origin and characteristics as: (a) one or more isolated supraventricular extrasystoles (SVE); (b) paired SVE or the sequence bigeminism, trigeminism, or quadrigeminism; (c) nonsustained

supraventricular tachycardia; (d) SVE + isolated ventricular extrasystoles (VE); (e) one or more isolated VE; (f) VE or paired sequences bigeminism, trigeminism, or quadrigeminism; (g) nonsustained ventricular tachycardia; (h) presence of wandering pacemaker; and (i) atrial flutter.

Clinical Data

We obtained a history of palpitations and regular use of beta-blockers, collected during a careful clinical history. These data were then related to the occurrence of arrhythmias in the two procedures.

Procedures

In a single visit, after signing a term of free and informed consent, the subjects were submitted to a clinical evaluation, followed by a 4sET and then a maximal CPET. No medical advice was given for suspension of medications in the days preceding the procedures. During the procedures, data were obtained from an electrocardiogram (ECG), with a single ECG derivation in continuous paper recording (Nihon Kodan model TEC 7100K, Tokyo, Japan) between 2000 and 2001, and since 2002, continuous digital ECG recording (Elite PC, Micromed, Brazil, versions 3.4.1.3 or 3.3.6.2). The tracings were analyzed by the same physician who performed the procedures for identification and classification of arrhythmias. The room temperature and relative humidity were controlled in the range of 20–23°C and 40–60%, respectively.

4-Second Exercise Test (4sET)

The 4sET, originally developed by Araújo et al.,¹¹ is used to evaluate the cardiac vagal tone by the magnitude of the transition between rest-exercise heart rates measured under standard conditions. Briefly, the 4sET consists of unloaded pedaling as fast as possible on a cycle ergometer, Catete EC 1600 (Catete, Osaka, Japan) or Inbrasport model CG-04 (Imbramed, Porto Alegre, Brazil), during seconds 4 to 8 of a 12-second maximal inspiratory apnea. Four verbal commands guide the actions to be sequentially performed at 4-s intervals, as follows: (1) a fast maximal inspiration, primarily through the mouth; (2) pedaling as fast as possible; (3) sudden cessation of pedaling; and (4) expiration.

Maximal Cardiopulmonary Exercise Test (CPET)

The CPETs were conducted using a cycle ergometer, Cateye EC-1600 (Cat Eye) or Inbrasport model GC-04 (Imbramed), or a treadmill, Inbrasport KT 10200 ATL or Inbrasport ATL (Imbramed), with direct collection and analysis of expired gases, VO2000 (MedGraphics; St. Paul, MN, USA), immediately after the 4sET. The test was performed according to an individualized ramp protocol, usually with duration between 8 and 12 min. The subjects were verbally encouraged to exercise to volitional fatigue (i.e., exhaustion), regardless of the maximum heart rate (HR) attained. A more detailed description of the aforementioned procedures can be found in other publications.^{12,13}

Statistical Analysis

The main characteristics of the groups were compared by ANOVA (followed by Bonferroni post hoc comparisons where appropriate), or the chi-square test, as appropriate. The frequencies of each type of arrhythmia were determined for the three groups and procedures and compared by the chi-square test. The statistical calculations were performed with SPSS software version 17.0 (SPSS, Chicago, IL, USA). A P value < 0.05 was considered statistically significant.

RESULTS

Among the 2329 subjects (1594 men), aged 53 ± 16 years (mean ± SD), 1225 subjects (53%) had

some type of arrhythmia in one or both procedures (Table 1 presents the demographic and major clinical characteristics for the whole sample and the three groups). The group classified as apparently healthy (AH) had fewer arrhythmias than the disease groups, 48% versus 72% (chi-square = 46.59, P < 0.01). It was observed that, among subjects with a disease, those who had CAD had a higher frequency of arrhythmia than those with diseases other than CAD, 84% versus 67%, respectively. The arrhythmias were more frequent in CPET when compared to 4sET (1000 vs 556, chi-square = 98.89, P < 0.01). Table 2 shows the type and frequency of arrhythmias in both procedures according to clinical conditions. The overall frequency of arrhythmias by origin and per procedure is presented in Figure 1.

In terms of the type of arrhythmia, 51% of the arrhythmias presented in 4sET were isolated SVE, while in CPET, this type of arrhythmia was responsible for 42% of the total. There were also 47 (3% of all arrhythmias) cases of tachycardia, including 43 cases of nonsustained supraventricular tachycardia (32% of these were during the 4sET) and four nonsustained ventricular tachycardia, all during the CPET. It should be noted that 221 subjects (18% of whom had some type of arrhythmia in one or both procedures) presented arrhythmias only during the 4sET; among these, 139 (61%) had SVE, 69 (31%) were VE, and 4 episodes of nonsustained supraventricular tachycardia. No episode of ventricular tachycardia was observed during the 4sET, while four episodes of nonsustained ventricular tachycardia occurred during CPET, including

Table 1. Demographic Characteristics

Characteristics	Total (n = 2329)	AH (n = 554)	CAD (n = 539)	Others (n = 1236)
Age (year)	52 ± 16 (9–91)	41 ± 14*† (9–84)	61 ± 12† (36–89)	53 ± 17 (10–91)
Height (cm)	170 ± 10 (128–203)	171 ± 9† (142–191)	170 ± 9 (140–195)	169 ± 9 (128–203)
Weight (kg)	77 ± 16 (37–128)	74 ± 14*† (37–122)	78 ± 13 (42–126)	74 ± 14 (39–128)
Gender (M/F)	1594/735	370/184	450/89	774/462
Hypertension (M/F)	764 (563/201)	-	271 (233/38)	493 (330/163)
Dyslipidemia (M/F)	748 (565/183)	-	316 (270/46)	432 (295/137)
Beta-blockers (M/F)	441 (330/111)	-	279 (234/45)	162 (96/66)

Average ± SD; (range).

AH = apparently healthy; CAD = coronary artery disease; others = presence of other diseases;

M = male; F = female.

*P < 0.05 between AH and CAD.

†P < 0.05 between AH or CAD and others.

Table 2. Frequency of Cardiac Arrhythmias According to Clinical Conditions and Procedures

Procedure	Total (n = 2329)	AH (n = 554)	CAD (n = 536)	Others (n = 1236)
Without arrhythmia	1104 (47%)	321 (58%)	206 (38%)	577 (47%)
4sET + CPET	340 (14%)	40 (7%)	121 (22%)	179 (15%)
Exclusively 4sET	221 (10%)	55 (9%)	48 (9%)	118 (9%)
Exclusively CPET	664 (29%)	138 (26%)	164 (31%)	362 (29%)

AH = apparently healthy; CAD = coronary artery disease; others = presence of other diseases; 4sET = 4-second exercise testing; CPET = maximal cardiopulmonary exercise test.

two cases in AH subjects, one episode in a subject with CAD, and a subject with other diseases. Even within each type of arrhythmia, it was observed that 29 subjects had polymorphisms of VE in CPET (3% of all arrhythmias in this procedure), while only four cases of polymorphic extrasystoles were observed in 4sET. Table 3 presents the type and frequency of arrhythmias in relation to the clinical condition and procedures.

Approximately 800 subjects (34% of total sample) complained of palpitations and arrhythmias were more frequent in subjects with CAD or other diseases (chi-square = 54.38; $P < 0.01$). Of the subjects with a history of palpitation, 442 had some type of arrhythmia in one or both procedures, 211 subjects

(26%) had some type of arrhythmia in 4sET, while 361 subjects (64%) had arrhythmia in CPET.

Regarding the use of beta-blockers, 441 subjects (19% of the total population) were using this type of medication and most of them (334 subjects) still showed arrhythmia in one or both procedures. Among these, 39 subjects (11%) only had arrhythmia during 4sET; i.e., they would be false negatives for arrhythmia if only CPET was considered. Two subjects, both using beta-blockers, showed a greater complexity of arrhythmia (nonsustained ventricular tachycardia) during CPET even under this medication effect. A difference in the presence of arrhythmias among groups using or not using medication was only found in CPET (chi-square = 10.72, $P < 0.01$). Among those not using beta-blockers (1888 subjects), 47% had arrhythmia in one or both procedures.

Figure 1. Frequency of arrhythmia by its origin and per procedure. 4sET = 4-second exercise test; CPET = maximal cardiopulmonary exercise testing; SVE = supraventricular extrasystoles; VE = ventricular extrasystoles. Values above bars are percent of cases.

DISCUSSION

The aim of this study was to identify, in a sample of 2329 subjects, if a standardized protocol of sudden and dynamic exercise, which simulates routine situations, would be able to trigger arrhythmias and also to compare the frequency and characteristics of the arrhythmias to those triggered by CPET. According to our results, we observe that, as expected by the clinical characteristics of our sample, most arrhythmias were triggered by CPET. However, in 216 subjects (9% of the sample), only 4sET was able to show cardiac arrhythmias that were not detected in CPET, which leads us to believe that either type of exercise—sudden or progressive—is capable of inducing arrhythmias. The type of arrhythmia also differs between the procedures and that the arrhythmias triggered by 4sET are, for the most part, clinically irrelevant, as was the case in another study using spirometry recently reported by our group.¹⁰ It is important to note that different

Table 3. Frequency and Type of Arrhythmia in Accordance with the Procedure and Clinical Condition in Relation to the Total Number of Arrhythmias (n = 1125)

Type of Arrhythmia	Total		AH		CAD		Others	
	4sET	CPET	4sET	CPET	4sET	CPET	4sET	CPET
SVE	23.6%	34.0%	4.3%	7.2%	6.5%	8.3%	12.8%	18.4%
VE	11.3%	16.0%	1.7%	3.2%	3.8%	4.3%	5.7%	8.0%
SVE + VE	2.7%	12.3%	0.1%	1.3%	1.3%	4.0%	1.3%	6.8%
NSSVT	1.1%	2.6%	0.2%	0.5%	0.5%	0.5%	0.5%	2.6%
NSVT	0.0%	0.3%	0.0%	0.2%	0.0%	0.1%	0.0%	0.3%

4sET = 4-second exercise testing; CPET = maximal cardiopulmonary exercise test; AH = apparently healthy; CAD = coronary artery disease; others = presence of other diseases; SVE = only one or isolated supraventricular extrasystoles; VE = only one or isolated ventricular extrasystoles; NSSVT = nonsustained supraventricular tachycardia; NSVT = nonsustained ventricular tachycardia; Obs = the sum of arrhythmias per procedure is not 100% cause only the more relevant arrhythmias were considered.

types of exercise are necessary for the appearance and eventual onset of arrhythmias, even in healthy subjects. Although, as mentioned previously, the arrhythmias are mostly irrelevant, they are an important source of anxiety for individuals who seek medical care, and thus, diagnosing and treating them, when necessary, will have a major impact on the quality of life of these individuals.

Our results showed that, although the majority of arrhythmias, in both procedures, were not accompanied by hemodynamic instability, 29 subjects in CPET and four during 4sET showed polymorphic VE. This type of arrhythmia has been linked to a rather unfavorable prognosis involving impaired ventricular function and cardiac electrical instability, which may precede the appearance of more complex ventricular arrhythmias.^{14–16}

When taking into account the clinical condition of subjects, it was observed that those who had some type of disease had a greater chance of triggering arrhythmia in at least one of the procedures. On 4sET, considering the very brief period of exercise and modest blood pressure increase, most likely, the mechanism involved in the onset of arrhythmias would seem to be the sudden vagal withdrawal or changes in the venous return to the heart resulting in sudden atrial distension.^{4,17,18} Franklin et al.¹⁹ have suggested several mechanisms, including those cited above, as responsible for physiological changes that accompany the acute responses to exercise and lead to the trigger of arrhythmias.

Arrhythmias are often accompanied by symptoms of palpitation, which may be described in different ways, including uncomfortable sensations in the chest or neck.^{3,20} Although there are several causes of palpitations, cardiac origins are the most

common,³ however, the majority of arrhythmias that lead to feelings of palpitation are benign or clinically irrelevant.² This finding was confirmed by our results, where we observed that, among subjects who had a positive history of palpitation, 71% had arrhythmia during the procedures; the CPET showed the largest number of arrhythmia-related palpitations, 81 (10%) subjects, while arrhythmias were not observed in 4sET. It should be emphasized that the type of arrhythmia differed on the clinical condition of subjects, being less frequent in AH patients. In addition, it was observed that 32% of arrhythmias were isolated SVE and only two (0.2%) arrhythmias associated with palpitations were nonsustained ventricular tachycardia, a more clinically complex condition. Araújo and Vianna¹⁰ found similar results when comparing triggered arrhythmias during spirometry with CPET, and, as has been described by other authors,^{3,20} even in patients with ambulatory monitoring, the majority of arrhythmias that generate the sensation of palpitation are composed of irrelevant extrasystoles (isolated ventricular or supraventricular).

Several studies^{6,19,21,22} have suggested that changes in adrenergic tone are involved in the genesis and maintenance of cardiac arrhythmias, including potentially life-threatening arrhythmias, and that the use of beta-blocking medication plays an important role as an anti-arrhythmic.²³ However, our results showed that most arrhythmias observed during CPET occurred in the group already using beta-blockers. A possible explanation for our findings is the fact that the group using beta-blockers was composed of subjects with CAD or other diseases and was older.

There are some potential limitations of this study that should be addressed, namely the fact that one potentially confounding clinical variable—regular smoking—was not formally controlled and that long-term ambulatory ECG monitoring (i.e., 24-hour Holter) records were not available. Although 24-hour Holter is the preferred method for the observation and analysis of cardiac arrhythmias, it is possible that quick and simple procedures, such as 4sET, even during a medical consultation, can help clarify a clinical complaint of palpitation. In our clinical experience, we have assisted many subjects with this condition, for whom the ambulatory monitoring of ECG has failed to show arrhythmias, and only 4sET triggered the arrhythmia (most commonly a single SVE during deep and fast inspiration) and sensation of palpitation, often reassuring the individual that it was most likely a benign symptom. Future prospective studies should be conducted to evaluate if the association of different types of exercise results in an increase in the identification and diagnosis of exercise-induced arrhythmias.

The main contribution of our study to this area of knowledge was to show that different situations of exercise, sudden and short versus progressive and maximal, tend to generate different arrhythmic responses and possibly complementary clinical implications. Considering the known relevance of more complex or frequent cardiac arrhythmias, especially those in the final and immediate post-exercise minutes of a CPET, to the prognosis of adult men,²⁴ it seems appropriate to propose that prospective studies should be aimed at examining whether the sudden and short exercise-induced arrhythmias have some prognostic clinical significance.

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