Dancers' Heart: Cardiac screening in elite dancers

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Abstract

Using electrocardiography and echocardiography, we screened elite men and women ballet dancers for abnormal cardiovascular conditions using an observation design with blinded clinical analysis of cardiac function tests. Fifty-eight (females n=33) elite professional ballet dancers (age: 26.0±5.7 years, body mass index: 19.9±2.2 kg/m^2) with no past or present history of cardio vascular disease volunteered**.** Participants were assessed via a 12-lead electrocardiography and two-dimensional echocardiography for cardiac function. Electrocardiography revealed that 83% of our dancers demonstrated normal axis, while 31% had incomplete right bundle branch block and 17% had sinus bradycardia; none showed any abnormal findings. Findings from the echocardiography were also normal for all participants and comparable to their counterparts in other sports. Significant differences ($p<0.05$) were detected in almost all studied echocardiographic parameters between males and females. In conclusion, heart function and structure seem to be normal in elite ballet dancers, placing them at low risk for sudden cardiac death and performance-related cardiovascular complications. Larger samples are required to confirm these findings.

Keywords: exercise, ballet, dance, echocardiography, ECG, athletes heart, screening

Introduction

Dance is a popular form of physical activity with approximately 7.8% of the population in England participating in dance (males=5.3%, females=9.8%) (Vassallo, Hiller et al. 2018). Full-time professional dancers form a smaller cohort, they are contracted for 35-40 hours of dancing per week (Twitchett, Angioi et al. 2010), which include daily classes, rehearsals and performances. In general, dance is a challenging activity where appropriate physical fitness is necessary for optimal performance (Angioi, Metsios et al. 2009, Angioi, Metsios et al. 2009, Twitchett, Koutedakis et al. 2009). Despite all these, however, dancers are relatively unfit compared to other athletes (Koutedakis and Jamurtas 2004). Elite ballet dancers, for instance, reveal cardiorespiratory fitness levels of approximately 50 and 43 $ml.kg^{-1}.min^{-1}$ for males and females, respectively (Wyon, Allen et al. 2016).

Dance has been classified as high intensity intermittent exercise (Wyon, Abt et al. 2004) that places a stress on both the aerobic and anaerobic metabolic systems, but for male dancers especially, also incorporates lifting partners above their head and holding them in that position before bringing them carefully down, during performance this equates to 2 lifts per minute (Twitchett, Angioi et al. 2009). This type of movement with the accompanying Valsalva manoeuvre causes highly elevated blood pressure, potentially employing additional strain on the heart (Mitchell, Haskell et al. 2005). Within the American College of Cardiology classification of sports, dance would be classified in the high dynamic category (Mitchell, Haskell et al. 2005), though unlike many sports where there is high repeatability in performance demands, dance performance can significantly vary in both time (20 to 150 minutes) and intensity, the latter being determined mainly by the adopted choreography (Wyon, Twitchett et al. 2011).

Nevertheless, the training hours for elite ballet dance are equal, if not greater, than those in other sports (Stubbe, van Beijsterveldt et al. 2015, Booth, Cobley et al. 2017), though the training intensity is significantly less than performance and rarely stresses the anaerobic system to the same extent as observed during performance (Wyon, Abt et al. 2004). At elite level, this has led to high incidents of burnout or overtraining (Koutedakis, Frischknecht et al. 1995, Koutedakis 2000) and musculoskeletal injuries (Twitchett, Brodrick et al. 2010, Allen, Nevill et al. 2013).

The aforementioned training and performance features may place elite ballet dancers at an increased risk for cardiovascular complications, which may suggest that these individuals may benefit from proper cardiac screening. The need for cardiac screening in this population has been confirmed by data in ballet dancers, revealing a 48% mitral valve prolapse (Cohen, Austin et al. 1987), or extra clinically important cardiac observations in other forms of dance (Whyte, George et al. 2003). Therefore, the aim of the present exploratory study was to investigate the cardiovascular condition of elite men and women ballet dancers, using electrocardiography and echocardiography.

Materials and Methods

The total of 58 (females n=33) professional dancers from an international touring ballet company volunteered; this equates to 20% of professional ballet dancers in the UK. All participants were healthy, free from any disease and had no family history of cardiovascular illness. The dancers were contracted for 52 weeks of the year, with 5-week holiday, equating to 36 hours of rehearsal and performances a week in addition to daily ballet classes. Supplemental training and rehabilitation were not timetabled and could be in addition to the contracted hours. The company has 169 performances a year encompassing 26 touring weeks in the UK or abroad. Following ethical approval from the lead author's university, participants were informed of the procedures and provided written informed consent. Data were collected during a single session at their work environment and consisted of following measurements:

Anthropometric measurements: Stature (cm) was measured to the nearest 0.1cm using a SECA 217 stadiometer (Germany) and body mass (kg) to the nearest 0.1kg with SECA 761 scales (Germany) wearing minimal clothing. Age was documented as a whole year.

Electrocardiography: All electrodes were placed carefully in standard positions for a 12-lead electrocardiogram (ECG). Prior to the standard 12 lead ECG participants rested for 5 minutes in a supine position. ECG's were recorded at a paper speed of $25mm.sec^{-1}$; PR and QT interval, QRS duration and QRS axis were measured. ECG criteria were categorised in line with the European Society of Cardiology 2016 guidance (Becher, Chambers et al. 2004) and the International criteria for ECG interpretation in athletes: consensus statement (Drezner, Sharma et al. 2017).

Echocardiography: All participants underwent echocardiography using a GE Logiq E ultrasound (General Electric) machine using a standardised protocol in line with British Society of

Echocardiography guidance (Becher, Chambers et al. 2004) and European Society of Cardiology protocols (Lang, Bierig et al. 2006).

Statistical analyses

All variables were tested for normality prior to analyses using the Kolmogorov-Smirnov tests of normality. Thereafter, descriptive statistics (mean±SD) were utilised to report average values for all measured outcomes, while one-way ANOVA was used to assess differences in cardiovascular condition between genders. The SPSS (version 22.0, SPSS Inc., Chicago, Illinois, USA) was utilised, whilst the level of significance was set at $p<0.05$.

Results

The gender-specific anthropometric characteristics for our participants appear in Table 1. Apart from age, all measurements were found to be significantly different between the two genders at $p<0.001$.

Table 1. Gender-specific anthropometric characteristics (n=58)

Variable	Females (n=33)	Males (n=25)	Total (n=58)
Age (yrs)	25.5±5.6	26.8±5.8	26.0±5.7
Height (cm)	163.4±5.9	179.3±4.2**	170.5±9.5
Weight (kg)	49.5±6.7	70.3±6.0**	58.8±12.2
Body Mass Index (kg/m^2)	18.5±1.6	21.8±1.2**	19.9±2.2
Body Surface Area (m^2)	1.5±0.1	1.9±0.1**	1.6±0.2

ANOVA: **significantly different between males and females at p<0.001

The electrocardiography (ECG) results appear in Table 2. The total of six individuals demonstrated axis deviation, one participant demonstrated left ventricular hypertrophy and 18 participants demonstrated incomplete right bundle branch block (IRBBB). In addition, findings from 10 participants revealed sinus bradycardia while one male demonstrated PR prolongation beyond 200ms (the upper limit of normal defined in a general population). No other findings were noted by the ECG examination.

Table 2. Electrocardiography data (n=58)

Variable	**Females**	**Males**	**Total**
Resting Heart Rate (b.min^{-1})	61.4±10.9	65.7±10.1	63.4±10.7
PQ interval (ms)	141.4±21.3	153.7±26.4	147.1±24.4
Normal QRS Axis (n)	25	23	48
QRS Right Axis Deviation (n)	1	2	3
QRS Left Axis Deviation (n)	3	0	3
LVH (n)	0	1	1
Incomplete RBBB	13	5	18
Early repolarisation (n)	1	7	8
Sinus bradycardia (n)	8	2	10
First degree heart block (n)	0	1	1

LVH: left ventricular hypertrophy, RBBB: right bundle branch block

Echocardiography findings for both genders appear in Table 3. ANOVA detected significant different in almost all variables studied between the genders, apart from left and right atria areas as well as the ejection fraction.

Table 3. Echocardiography data (n=58)

Variable	**Females**	**Males**	**Total**
LA area max (cm^2)	27.5±10.3	30.1±11.5	28.6±10.8
RA area min (cm^2)	9.8±2.1	11.9±2.6*	10.7±2.6
Mitral annular plane systolic excursion (mm)	14.3±1.5	16.1±3.8*	15.1±2.9
Tricuspid Annular Plane Systolic Excursion (mm)	18.8±2.3	20.7±3.5*	19.6±3.0
RV wall end-diastolic thickness (cm)	0.4±0.1	0.6±0.2**	0.5±0.1
RV wall end-systolic thickness (cm)	0.6±0.2	0.9±0.2**	0.7±0.2
RV internal dimension (parasternal long axis) at end-diastole (cm)	1.7±0.4	2.0±0.3*	1.9±0.4
RV inflow (cm)	2.6±0.3	3.3±0.4**	2.9±0.7
RV mid cavity dimension (cm)	2.5±0.4	3.0±0.6**	2.7±0.5
RV length (cm)	6.4±0.8	7.2±1.1*	17.8±0.5
Interventricular septal thickness at end-diastole (cm)	0.9±0.2	1.1±0.1**	1.0±0.2
Interventricular septal thickness at end-systole (cm)	1.2±0.1	1.4±0.2**	1.3±0.2
LV mass (g)	138.5±33.9	233.9±44.6 **	180.1±61.4
LV mass BSA indexed ($g.m^2$)	92.2±19.9	124.8±21.1 **	106.4±26.0
LV internal diameter at end-diastole (cm)	4.1±0.4	4.7±0.3**	4.4±0.5
LV internal diameter at end-systole (cm)	2.8±0.3	3.3±0.3**	3.0±0.4
LV end-diastolic volume (ml)	71.9±14.7	108.0±17.7 **	87.5±24.1
LV end-diastolic volume BSA indexed ($ml.m^2$)	47.7±8.4	57.6±9.4**	52.0±10.1
LV end-systolic volume ($ml.m^2$)	28.6±6.8	44.3±8.6**	35.4±10.9
LV end-systolic volume BSA indexed ($ml.m^2$)	18.9±3.9	23.7±4.7**	20.9±4.8
SV (l)	43.3±9.5	63.4±12.8**	52.0±14.9
Ejection Fraction (%)	60.2±5.3	58.6±5.2	59.6±5.2

LA: left atrium, RA: right atrium, RV: Right ventricle, LV: left ventricle, SV: stroke volume, BSA: Body surface area
ANOVA: significantly different between males and females: ** at $p<0.001$ and * at $p<0.05$

Discussion

This is the first study to describe elements of cardiovascular condition of elite men and women ballet dancers. The current data revealed that the elite dancer's heart is not characterised by functional or structural variations, as evaluated by both electrocardiography and echocardiography. However, significant gender differences were detected on echocardiography but not on electrocardiography.

With regards to electrocardiography results, it seems that a similar percentage of ballet dancers demonstrate sinus bradycardia compared to contemporary dancers (17% vs 16%, respectively), while both dance populations are characterised by a negligible prevalence of physiological left ventricular hypertrophy(Whyte, George et al. 2003). Sinus bradycardia is a very common characteristic seen in elite athletes and is thought to be associated with a high vagal tone; this, in turn, can reduce heart rate, however, scientific debate still exists in this field as to whether sinus bradycardia is indeed the direct result high vagal tone (D'Souza, Sharma et al. 2015). A recent study in elite athletes also demonstrated that vagal tone associates with the presence of ventricular hypertrophy in elite athletes (Oggionni, Spataro et al. 2019). As such, we cannot hypothesize that the present prevalence of sinus bradycardia may be attributable to vagal tone and/or hypertrophy in our elite dancers, given that vagal tone was not assessed (and was outside the scope of the present hypothesis) but also, the prevalence of left ventricular hypertrophy in the present sample was only observed in one participant. Moreover, RBBB was not detected in the ECG in any of the studied dancers, however, we found that incomplete RBBB (IRBBB) was considerably more prevalent in our elite ballet dancers vs. available data on contemporary dancers (31% vs. 9%, respectively)(Whyte, George et al. 2003), and higher than other athletic populations, where the prevalence in IRBBB ranges between 10%-20% (Kim, Noseworthy et al. 2011). IRBBB is thought to be common particularly in endurance athletes (Kim, Noseworthy et al. 2011, Abdesslem, Rejeb et al. 2019) and, based on studies examining normal, non-athletic populations, IRBBB does not associate with any adverse cardiovascular outcomes and/or mortality(Bussink, Holst et al. 2012). However, the higher than normal prevalence of IRBBB observed herein, may be a phenomenon that merits further scientific attention; particularly because IRBBB prevalence in our female elite dancers was higher than that of their male counterparts. In contrast, the Copenhagen City Heart study (n=18.441 individuals from the general population) suggested that IRBBB prevalence is higher in males compared to Females (Bussink, Holst et al. 2012). Nevertheless, our ECG results, which revealed a lack of high prevalence in important cardiac pathologies, suggest that elite ballet dancers may not be in a higher risk for performance-related cardiovascular complications than other physically active individuals.

Similarly, our echocardiographic data revealed that elite ballet dancers were not characterised by structural and functional changes and the prevalence of significant pathology was not of concern. Echocardiography, in conjunction with an ECG, is thought to increase the detection power of structural changes and pathology in athletes, as ECG sensitivity to detect potential causes of sudden cardiac death is approximately 70% (Perez, Fonda et al. 2009, Wheeler, Heidenreich et al. 2010). Hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy and anomalous origins of the coronary arteries, may increase the risk for sudden cardiac death and are, therefore, justifications for adding echocardiography to ECG in cardiac assessments (Grazioli, Sanz et al. 2015). No pathological anomalies were detected in the current sample. However, our echocardiographic data contradict another study on elite ballet dancers revealing that almost half of the studied population was characterised by mitral valve prolapse (Cohen, Austin et al. 1987). Finally, the observations with regards to the significant echocardiographic differences in almost all variables between genders were anticipated. Although the exercise-induced adaptation are similar in males and females, the absolute cardiac dimensions are comparable lower in females (Whyte, George et al. 2004).

It is reasonable to assume that the present results may have been influenced by certain methodological limitations. For example, due to the study’s observational nature, causality and changes through time cannot be established. The lack of a control age and gender matched group that would allow comparisons of the present findings with those of normal population is also a limitation. Further, the rather limited study sample size prevents us from making robust generalizations about the cardiovascular condition of this population. However, the present study benefits from a thorough cardiac investigation by a trained cardiologist and provides significant insights about the characterisation of the cardiovascular changes associated with elite ballet dance. Within the limitations of the current study it is concluded that elite ballet dancers do not appear to be prone to abnormal cardiovascular conditions, as assessed via the present methodologies. The low level of cardiac adaptation seen on echocardiography would suggest that the use of echocardiography in addition to ECG is one of affordability rather than justified by clinical need.

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Legends

Table 1. Gender-specific anthropometric characteristics (n=58)

Table 2. Electrocardiography data (n=58)

Table 3. Echocardiography data (n=58)