The Role of Three-Dimensional Echocardiography in the Assessment of Right Ventricular Dysfunction after a Half Marathon: Comparison with Cardiac Magnetic Resonance Imaging

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Background: Although marathon running is associated with transient right ventricular (RV) systolic dysfunction as detected by two-dimensional transthoracic echocardiography, quantitative assessment of the right ventricle is difficult because of its complex geometry. Little is known about the use of real-time three-dimensional echocardiography (RT3DE) in the detection of cardiac dysfunction after a half marathon. The aim of this study was to assess the extent of RV dysfunction after the completion of a half marathon using cardiac biomarkers, RT3DE, and cardiac magnetic resonance imaging (CMR).

Methods: A prospective study was performed in 15 individuals in 2009 participating in the Manitoba Half Marathon. Cardiac biomarkers (myoglobin, creatine kinase–MB and cardiac troponin T) were assessed and RT3DE and CMR were performed 1 week before, immediately after, and 1 week after the race.

Results: At baseline, cardiac biomarkers and ventricular function were within normal limits. Immediately following the half marathon, all patients demonstrated elevated cardiac troponin T levels, with a median value of 0.37 ng/mL. RV ejection fraction, as assessed by RT3DE, decreased from 59 ± 4% at baseline to 45 ± 5% immediately following the race ($P < .05$). On CMR, RV end-diastolic volume increased after the half marathon, and the RV ejection fraction was reduced, at 47 ± 5% compared with 60 ± 2% at baseline ($P < .05$). There were strong linear correlations between RV ejection fraction assessed by RT3DE and CMR at baseline and after the half marathon ($r = 0.69$ and $r = 0.87$, $P < .01$, respectively).

Conclusions: Compared with CMR, RT3DE is a feasible and reproducible method of assessing transient RV dysfunction in athletes completing a half marathon. (J Am Soc Echocardiogr 2011;24:207-13.)

Keywords: Real-time three-dimensional echocardiography, Cardiac magnetic resonance imaging, Half marathon, Endurance sport, Cardiac biomarkers

Marathon running has become increasingly more popular over the past decade, for both amateur and elite athletes. Research into the short-term consequences of endurance exercise on cardiac function, especially the right ventricle, has recently increased. Previous studies have found that the elevation of cardiac biomarkers in marathon runners, in particular myoglobin, creatine kinase (CK), and cardiac troponin T (cTnT), correlate with transient changes in right ventricular (RV) function as assessed by echocardiography.[1-14] Although multiple studies have demonstrated two-dimensional echocardiographic evidence of transient RV systolic and diastolic abnormalities after endurance sports, quantitative assessment of the right ventricle is difficult because of its complex geometry.[14-19]

The recent introduction of real-time three-dimensional echocardiography (RT3DE) has shown to be a feasible and reliable method of assessing RV ejection fraction (RVEF). A number of studies have compared RT3DE to cardiac magnetic resonance imaging (CMR) in the assessment of RV volumes and RVEF, demonstrating a high correlation with excellent intraobserver and interobserver reliability.[19-24] As a result, RT3DE has proven to be a cost-effective, a less invasive, and an accurate means of assessing RV function in a variety of cardiac disorders. Little is known, however, about the utility of RT3DE in the noninvasive assessment of the right ventricle after a marathon.

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Abbreviations

CK = Creatine kinase

CMR = Cardiac magnetic resonance imaging

cTnI = Cardiac troponin I

cTnT = Cardiac troponin T

FAC = Fractional area change

LV = Left ventricular

RT3DE = Real-time three-dimensional echocardiography

RV = Right ventricular

RVEF = Right ventricular ejection fraction

TAPSE = Tricuspid annular plane systolic excursion

TTE = Transthoracic echocardiographic

Recently, CMR has been used to validate RV systolic dysfunction following a full marathon.[25-27] Similar to previous echocardiographic studies,[14-19] CMR demonstrated transient RV systolic dysfunction immediately after a marathon that recovered within weeks.[25-27] The absence of delayed enhancement of the myocardium using CMR also revealed no evidence of permanent injury due to the strenuous exercise of full marathon running.[25] Whether transient RV systolic dysfunction occurs in the setting of a shorter distance such as a half marathon, however, remains ill defined.

The objectives of the current study were twofold: (1) to assess the extent and severity of changes in RV function following the completion of a half marathon, using serial cardiac biomarkers, RT3DE, and CMR, and (2) to determine the accuracy of RT3DE for determining RV dysfunction after a half marathon compared with CMR.

Table 1 Patient clinical characteristics (n = 15)

Characteristic	Baseline	After the race
Age (y)	22–39	
Gender		
Male	7 (47%)	
Female	8 (53%)	
Weight (kg)	70 ± 11	70 ± 11
Heart rate (beats/min)	66 ± 13	97 ± 11
SBP (mm Hg)	132 ± 13	118 ± 13
DBP (mm Hg)	74 ± 6	68 ± 4

Data are expressed as range, as number (percentage), or as mean ± SD.
DBP, Diastolic blood pressure; *SBP*, systolic blood pressure.

Table 2 Summary of serial cardiac biomarkers for total population (n = 15)

Characteristic	Baseline	After the race	1 week after the race
Myoglobin (mg/L)	25 (18–82)	698 (552–2,100)*	65 (44–88)
CK (U/L)	120 (117–190)	625 (441–1,922)*	210 (156–462)
cTnT (ug/L)	<0.01	0.37 (0.26–0.74)*	<0.01

Data are expressed as median (interquartile range).
*P < .05, after the race vs baseline.

METHODS

Study Population

A prospective study involving 15 healthy, nonelite volunteers participating in the 2009 Manitoba Half Marathon was performed. Subjects aged 18 to 40 years who completed the race were included. Patients with histories of coronary artery disease, hypertension, smoking, elevated lipids, diabetes, and/or contraindication to undergo CMR were excluded.

Cardiac Biomarkers

Myoglobin, CK, and cTnT were evaluated at three separate time points: (1) 1 week before the race, (2) immediately after the race, (3) and 1 week after the race. Myoglobin and CK levels were determined using a Roche Elecsys and a Roche 917 analyzer, respectively (Roche Diagnostics GmbH, Mannheim, Germany). Quantitative determination of cTnT levels was performed using a third-generation Roche Elecsys assay.

Echocardiography

All subjects underwent baseline transthoracic echocardiographic (TTE) imaging 1 week before the race, immediately following the race, and 1 week after race completion. Following completion of the half marathon, each patient was immediately transferred to the study hospital for performance of the TTE exam. The transfer time from the half marathon site to the study hospital was 10 min. All TTE studies were performed immediately upon arrival at the study hospital. All patients underwent TTE imaging using a GE Vivid 7 (GE Healthcare, Milwaukee, WI) at each time point. Left ventricular (LV) and left atrial cavity dimensions indexed to body surface area were determined from two-dimensional images in accordance with the guidelines of the American Society of Echocardiography.[28] RV cavity dimensions, RV fractional area change (FAC), and tricuspid annular plane systolic excursion (TAPSE) were also determined. Continuous-wave Doppler was used to measure the peak velocity across the tricuspid valve, and the maximal pulmonary arterial systolic pressure was estimated using the simplified Bernoulli equation.

Real-time three-dimensional TTE imaging was performed using a dedicated broadband, wide-angle, matrix-array transducer to acquire the entire RV cavity within the pyramidal scan volume. Acquisition of full-volume data sets was triggered to the R wave of every cardiac cycle to allow for an acquisition time of four heartbeats during an adequate breath hold. The subvolumes were automatically stitched to a sequence of full three-dimensional volumes covering the entire right ventricle and stored digitally for offline analysis using TomTec software (TomTec Imaging Systems, Unterschleissheim, Germany), as previously described.[29]

CMR

CMR was performed on all study participants at baseline and within 24 hours of completion of the half marathon using a 1.5-T scanner (Avanto; Siemens Medical Solutions, Erlangen, Germany). Specifically, following acquisition of the TTE images after the half marathon, each participant underwent CMR on an hourly basis, until all 15 studies were completed. Cine balanced steady-state free-precession short-axis images then encompassed the entire left ventricle from the base to the apex (stack of 10 sequential short-axis slices; repetition time, 64 ms; echo time, 1 ms; flip angle, 80°; slice thickness, 8 mm; interslice gap, 1.6 mm; matrix size, 192 × 132) to obtain the LV ejection fraction. To evaluate for myocardial edema, dark-blood T2-weighted turbo spin-echo short-axis images were obtained (repetition time, 1800–2100 ms; echo time, 74 ms; slice thickness, 8 mm; interslice gap, 4 mm; matrix size, 256 × 175). Late gadolinium enhancement images were obtained after 10 min of 0.2 mmol/kg injection