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ORIGINAL ARTICLE

High-Intensity Prolonged Endurance Activity Correlation to Abnormal Cardiac Strain as Measured by Speckle Tracking Echocardiography

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Abstract

Objective: To assess whether there is a dose-dependent relationship between burden of exercise and myocardial strain in endurance runners.

Patients and Methods: In total, 48 runners were selected based on an exercise questionnaire and after excluding individuals based on preexisting cardiovascular risk factors. Data collection was performed between November 9, 2020 and March 18, 2021. Runners were divided into 2 categories: group A consisted of individuals who had participated in at least 10 ultramarathons and/or Ironman competitions in 10 years (extreme-distance runners); and group B consisted of individuals who have competed in at least 10 marathons over 10 years (marathon-distance runners). Global and regional myocardial strain imaging was performed. Linear regression models were used to assess the relationship between runner groups and global as well as regional myocardial strain.

Results: There was no difference in mean global longitudinal strain between both cohorts. However, there was a statically significant difference in regional myocardial strain in the apical lateral (P =.0027) and apical septal (P=.0022) segments.

Conclusion: Ultramarathoners and Ironman athletes had evidence of regional differences in myocardial strain when compared with runners participating in shorter events, but no difference in global longitudinal strain. The clinical significance of this is not yet clear and additional studies are required.

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Research has detailed the various cardiovascular advantages that frequent aerobic exercise provides. Moderate exercise has been shown to be the most effective way in decreasing mortality rate. Data from large-scale, prospective studies have indicated that the increased longevity ascribed to regular physical activity may vanish because the duration and intensity of the exercise exceeds a moderate threshold.[1-5] Multiple studies demonstrate a U-shaped relationship between exercise volumes and mortality. The lowest mortality rates occur at modest activity levels. Individuals at the highest end of the spectrum for activity demonstrate mortality rates similar to the sedentary population.[6] We previously published a study demonstrating an increase in coronary artery calcium scores in ultra-athletes when compared with average runners.[7] Although this study demonstrated an increase in plaque within the coronary circulation, the effect of long-distance running on left ventricular (LV) global and regional function is unknown. Myocardial strain imaging has been playing an evolving role in the assessment of myocardial function. Research exists that suggests global longitudinal strain (GLS) may serve as a marker for myocardial fibrosis.[8] GLS can be found by using speckle tracking echocardiography and subsequently averaging the strain values of 18 predetermined segments.

A previous study using GLS demonstrated unique ventricular adaptation among elite

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soccer players. This study used speckle tracking echocardiography to attempt to identify a relationship between intensity of endurance activity and GLS as well as segmental myocardial strain.[9] We sought to assess GLS and segmental strain in long-term endurance runners. We also assessed whether any deviation in GLS or segmental scores in runners was dose-dependent by comparing such scores in ultramarathon participants with those who compete in standard marathons.

PATIENTS AND METHODS

Runners were recruited from local running clubs and by advertising in a local newspaper and at local competitive races. Respondents completed an exercise questionnaire that was later used to determine the experimental groups (questionnaire provided in the Supplemental Appendix, available online at http://www.mcpiqojournal.org). Individuals younger than 45 years; those with a history of active or remote tobacco use and known coronary artery disease (CAD); and those with a family history of premature CAD, diabetes mellitus, hypertension, or hyperlipidemia were excluded. Women who were pregnant were excluded. We recruited 52 runners who have run competitively for 10 or more years. Four runners were excluded because of failing to meet criteria for distance ran. Group A had individuals who had participated in at least 10 ultramarathons and/or Ironman competitions in 10 years (extreme-distance runners). Group B consisted of marathon runners who had competed in at least 10 marathons over 10 years (marathon-distance runners).

GE Vivid E9 transthoracic echocardiography platform was used to acquire data (application version 113 revision 1.4; system version 104.3.6). Automated functional imaging was used to obtain global and segmental myocardial strain values on all subjects. All imaging was obtained with participants in the left lateral decubitus position. An optimal electrocardiogram tracing with minimal heart rate variability was required for image acquisition. Imaging was obtained across 3 cardiac cycles in participants with normal sinus rhythm. Only the cardiac cycle with optimal endocardial delineation was selected for analysis. All imaging was obtained with frame rates >40 frames per second. Automated functional imaging is a decision support tool for regional assessment of ventricular systolic function, derived from 2-dimensional (2D) strain, which calculates the myocardial tissue deformation based on feature tracking on 2D grayscale loops. Aortic valve closure time was set via continuous-wave Doppler spectral analysis. Automated functional imaging was obtained in the apical views in the following order: apical long axis (apical 3 chamber), 4 chamber and 2 chamber views sequentially in 2D mode. Appropriate tracking was observed. When needed, manual adjustments were performed to ensure proper placement and region of interest. All regions were analyzed with no segments being excluded. The result is presented in a bull's eye pattern with a score index. GLS for each view and average GLS were recorded into the worksheet on the ultrasound unit and entered in Microsoft Excel for analysis.

Descriptive statistics were calculated and compared by study groups (extreme-distance runners [group A] vs marathon-distance runners [group B]) for all variables. Gender was compared using χ^2 analyses, and continuous variables (age, years of running, and miles run per week) were compared using *t* tests. A *P* value of .05 was defined as significant.

Multivariable linear regression models examined the relationship between the study groups with GLS and segmental strain. Covariates—age, gender, years running, and miles run per week—were included in all models. Least square means are reported. Data collection was performed between November 9, 2020 and March 18, 2021. SAS 9.4 was used for all analyses.

The study proposal was reviewed and approved by institutional review board at Vassar Brothers Medical Center in Poughkeepsie, New York. Informed consent was obtained from all participants.

RESULTS

Of the 52 male and female runners, we excluded 4 runners because they did not meet inclusion criteria for distance ran. There was no significant difference between group A and group B with regards to age, years of running, or gender. Additionally, there was no statistically significant difference in miles run per week between group A and group B (Table 1). Table 2 displays the least means produced by the multivariate models. There was no significant difference in segmental myocardial strain values between the runner groups within the apical lateral (AL) segment and within the apical septal (AS) segment. There was no significant difference in all other segments (Table 3).

TABLE 1. Comparison of Baseline Statistics Between Extreme-Distance and Marathon-Distance Runners

Participant characteristics	Extreme-distance runners	Marathon-distance runners	*P*
Age (y), mean (SD)	57.1 (9.6)	60.2 (10.0)	.32
Running duration (y), mean (SD)	25.5 (14.4)	27.3 (14.2)	.71
Sex, n (%)			.19
Male	28 (80)	8 (61.5)	
Female	8 (20)	5 (38.5)	
Miles run/wk, mean (SD)	42.6 (17.0)	32.7 (13.5)	.07

DISCUSSION

We designed this study to exclude any runners with CAD or risk factors for CAD including a history of or active tobacco use, diabetes, hypertension, or hyperlipidemia or a family history of premature CAD (first-degree relative with a coronary event at age <60 years). In addition, we wanted to compare marathoners and ultramarathoners in terms of myocardial strain values. We noted no difference in mean GLS scores between group A and group B. However, we did notice subsegmental reduction in GLS scores among the ultramarathon group. This was noted in the AL and AS segments.

Eun and Chae[9] evaluated the myocardial function of 29 elite Korean soccer players using 2D echocardiography and speckle tracking echocardiography. The LV regional strain data from the soccer players was compared with those of 29 healthy age-matched controls. Although there was no statistically significant difference in longitudinal strain during systole between the athletes and the controls, radial and circumferential strain was much greater in the athletes. The study suggests that the ventricular adaptation undergone by the hearts of the athletes, indicated by the increased apical radial and circumferential strain, could benefit the myocardial adjustment to exercise. Our study divided subjects into groups based on the length of their races, whereas Eun and Chae[9] conducted their study using a homogenous group of athletes. Comparing long-distance and short-distance runners allowed us to determine whether a stratified trend exists with respect to longitudinal and myocardial strain.

Ujka et al[10] assessed right cardiac chamber remodeling, as detected by speckle tracking echocardiography, in 47 marathon runners and 41 ultramarathon runners. Data from these groups were additionally compared with those of a sedentary population. It was observed that LV GLS and global radial strain were elevated in the marathoner and ultramarathoner groups with respect to those of a sedentary control group. This change was not accompanied by an LV anatomical or functional change. Furthermore, this study observed that the ultramarathoner group experience elevated right ventricular and right atrial morphologic and functional remodeling when compared with the marathoner group. Our study retained the stratificational grouping used by Ujka et al[10] and extended the use of 2D speckle tracking echocardiography more regionally to LV subsegments.

Our results support the conclusions of previous literature that extreme endurance running and athletic activity is correlated with myocardial adjustment. This study also makes an important contribution to existing research in this discipline. We observed a statistically significant change in regionally measured segmental values, specifically the AL and AS segments, across a spectrum of runners.

TABLE 2. Comparison of Least Square Mean GLS and Apical-Lateral and Apical-Septal Segmental Scores Between Extreme-Distance and Marathon-Distance Runners

Strain value	Extreme-distance runners	Marathon-distance runners	*P*[a]
GLS	−20.2	−21.7	.09
Apical lateral segmental score	−21.4	−26.5	<.01
Apical septal segmental score	−23.4	−28.4	<.01

GLS, global longitudinal strain.
[a]Results from multivariable regression controlling for study group, age, sex, and miles per week.

TABLE 3. Comparison of Least Square Means of Complete Segmental Score Analysis Between Extreme-Distance and Marathon-Distance Runners

Segment name	Extreme-distance runners	Marathon-distance runners	P[a]
Basal septal	−14.8	−13.8	.80
Mid septal	−18.9	−18.6	.33
Apical septal	−23.9	−26.8	<.01
Basal lateral	−18.2	−17.6	.06
Mid lateral	−19.2	−19.5	.85
Apical lateral	−22.1	−25.2	<.01
Basal inferior	−18.8	−19.3	.40
Mid inferior	−21.2	−21.9	.33
Apical inferior	−26.3	−28.3	.16
Basal anterior	−18.8	−18.8	.82
Mid anterior	−20.8	−20.4	.72
Apical anterior	−24.4	−26.1	.19
Basal posterior	−19.5	−18.2	.76
Mid posterior	−19.5	−19.7	.34
Apical posterior	−22.0	−23.7	.08
Basal anteroseptal	−17.1	−16.4	.86
Mid anteroseptal	−21.3	−21.2	.59
Apical anteroseptal	−24.5	−26.3	.29

[a]Results from multivariable regression controlling for study group, age, sex, and miles per week.

Extreme-distance runners, who expressed such myocardial change, may be vulnerable to the effects of myocardial strain and eventual fibrosis. A myocardial adjustment across a stratification of runners, although regularly theorized, requires additional research to confirm. Until additional studies are undertaken, our findings further emphasize the regional heterogeneity in response to exercise, the gray zone between physiologic adaptation and pathologic change, as well as the potential for a dose-dependent response.

One potential etiology is suggested by previous observations in individuals with stress-mediated (Takotsubo) cardiomyopathy. The suggested etiology for the disproportionate dysfunction in apical segments in Takotsubo cardiomyopathy has been correlated to higher levels of serum and myocardial catecholamines.[11] This same sensitivity may be behind our observation of differential AL and AS strain values in ultraendurance athletes. Further studies would need to assess whether this observation is related to either a cumulative effect or to a sustained event effect in those individuals participating in longer events such as Ironman races or ultramarathons.

Further data regarding the long-term cardiovascular outcomes that would provide clarity regarding the above observations is necessary. While all these studies identify a correlation between distance-running and myocardial strain values, the studies performed so far have not documented whether such deviation in segment strain values within these populations leads to detrimental outcomes. Global longitudinal strain has developed into a useful, cost-effective tool that can help detect myocardial fibrosis and dysfunction. What is not known at this time is whether this methodology used to predict dysfunction in the general population holds the same significance for extreme endurance athletes.

There are several limitations to our study. Athletes were grouped by their competitive races; however, their participation was not verified using race records, and self-reporting was relied on instead. Additionally, although the competitive event criteria for each group should correlate with the volume of daily training, exact daily exercise levels were not measured. Self-reporting was also relied on for atherosclerotic risk factors that would exclude subjects from the study, such as serum liquids and blood pressure. Although our study was relatively small with 48 subjects in the final analysis, it is comparable with other studies investigating the same topic.

Given that this is a preliminary study with a defined goal of seeking to establish and define a relationship between high-intensity prolonged running and abnormal cardiac strain, a power calculation comparing with a previous study was difficult to establish. Instead, in this study, it is thought to be more beneficial to compare our strain calculations with clinically, evidence-based already established thresholds for GLS. By comparing strain scores to these aforementioned thresholds, rather than measurements from a previous study, this may yield more clinically relevant significance.

CONCLUSION

Although mean GLS did not show a statistically significant difference based on intensity of endurance activity between ultramarathon runners and marathon runners, there was a significant difference in myocardial strain within AL and AS segments.

POTENTIAL COMPETING INTERESTS

Dr Wakefield has received consultancy fees or honorarium from Nuvance Health and VBMC for statistical analysis. The other authors have no competing interests to report.

ETHICS STATEMENT

This study proposal was reviewed and approved by institutional review board at Vassar Brothers Medical Center in Poughkeepsie, New York. Informed consent was obtained from all participants.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **AL**, apical lateral; **AS**, apical septal; **GLS**, global longitudinal strain

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