Cardiology in the Young (2015), **25**, 481–484
doi:10.1017/S1047951114000158

Original Article

Exercise-induced cardiac fatigue in low and normal birth weight young black adults

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Abstract The objective of the study was to compare the change in diastolic function, E/A ratio, in response to prolonged exercise in low birth weight and normal birth weight individuals. Using a case–control study design, 23 students of the University of Zimbabwe College of Health Sciences who had neonatal clinic cards as proof of birth weight were recruited into the study. Measurements of diastolic function, E/A ratio, were obtained using an echocardiogram before and after 75 minutes of exercise. Among the cohort, seven had low birth weight – <2500 g, three female patients and four male patients – and 16 had normal birth weight – six female patients and 10 male patients). The mean age was 20.7 ± 3.3 years. After prolonged exercise for 75 minutes of running on a treadmill, decreases in diastolic function, E/A ratio, were significantly greater in low birth weight than in normal birth weight individuals (0.48 ± 0.27 versus 0.19 ± 0.18 $p < 0.05$, respectively). There was a significant association between low birth weight and exercise-induced cardiac fatigue (the χ^2 test $p < 0.05$, odds ratio 4.64, 95% confidence interval 1.19–18.1). We conclude that low birth weight is associated with exercise-induced diastolic dysfunction in young adults.

Keywords: Low birth weight; exercise-induced cardiac fatigue; diastolic function

Received: 1 July 2013; Accepted: 18 January 2014; First published online: 9 April 2014

Birth weight is an important predictor of the future health condition of an individual.[1] Low birth weight is an important public health issue in developing countries.[2] The prevalence of low birth weight in Zimbabwe is 10%, higher in female individuals than in male individuals.[3] Low birth weight is associated with an increased risk for coronary artery disease,[4] hypertension,[5] and heart failure.[6] Babies that are growth restricted prenatally are more likely to have hearts with detrimental structural and functional changes.[4,7]

Research has shown that prolonged strenuous exercise produces a transient decrease in cardiac function, both diastolic and systolic function – a phenomenon referred to as exercise-induced cardiac fatigue. This has been demonstrated in both well-trained and untrained participants.[8,9] Low birth weight individuals may be particularly prone to exercise-induced cardiac fatigue because of the changes in structure and function as highlighted above.

Exercise-induced hypertension is used as a predictive tool for future hypertension and in asymptomatic normotensive individuals.[10,11] Similar methodology may be useful in using exercise-induced diastolic dysfunction among young adults to predict future heart failure in asymptomatic individuals.[8,9] Abnormalities in left ventricular diastology, as defined by the mitral inflow E/A ratio, among asymptomatic older individuals have been associated with subsequent development of heart failure.[12]

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The purpose of the study was to determine whether low birth weight predicts development of left ventricular diastolic dysfunction after prolonged exercise for 75 minutes in young black adults.

Materials and methods

A case–control study was conducted in the Department of Physiology, University of Zimbabwe College of Health Sciences. All participants volunteered and gave informed consent to take part in this study. Participants were required to produce their neonatal Ministry of Health and Child Welfare birth cards, which documents birth weight. Ethical permission was granted by Joint Parirenyatwa Hospital and College of Health Sciences Research Ethics Committee and the Medical Research Council of Zimbabwe.

A total of 23 eligible participants were randomly selected. A self-administered questionnaire was used to obtain variables such as age, history or clinical evidence of diabetes or cardiovascular diseases, and any form of diseases in the participant that can affect cardiovascular function. Weight and height of the participants were measured with the participants wearing light clothing and without shoes using an analogue scale, SECA model 770, on day 1 of the study protocol. 24 hours before the exercise test participants were advised to abstain from caffeine and taurine products such as coffee and energy drinks that may influence their cardiovascular perfomance during test.

Participants initially underwent graded exercise testing – Trojan Stamina 315 model – according to the Bruce protocol to determine maximal aerobic power, VO_{2max} on day 1 of the study protocol. These results were used to establish running velocities, eliciting heart rate 80% VO_{2max}, high intensity, during prolonged exercise sessions, which were conducted on the following day in a controlled laboratory setting. Graded treadmill exercise testing was performed to exhaustion.

Participants completed a high-intensity, 80% VO_{2max},[13,14] exercise challenge involving 75 minutes of running on a treadmill – Trojan Stamina 315 model – at room temperature. To minimise changes in the hydration state and cardiac-loading conditions, participants were encouraged to consume 250 ml of water every 20 minutes. Post-exercise measures were taken within 5 minutes after exercise completion.[13,14] Echocardiography was performed by a trained sonographer blinded to participant birth weight, using a portable ultrasound device – M-Turbo, SonoSite Inc, Bothell, Washington, United States of America. Pulse-wave Doppler flow velocities were recorded from the transthoracic apical window at the site of mitral valve leaflet tip coaptation. Diastolic function was determined before and after exercise as the ratio of the early mitral inflow velocity, E wave, to late mitral inflow velocity, A wave), represented as the unitless E/A ratio.[8,12]

Statistical methods

Low birth weight was defined as weight between 1900 and 2499 g at term. Normal birth weight was defined as weight between 2500 and 4000 g at term; no participants had birth weights outside these ranges. Exercise-induced cardiac fatigue was defined as ΔE/A ratio ⩾0.40.[8] Independent samples two-tailed t-test at 5% level of significance was used to compare the various means of metabolic parameters between the two grouping variables – that is, low birth weight and normal birth weight. Odds ratios were calculated using the Pearson χ^2 test in SPSS at 95% confidence interval. Participants' demographic characteristics and all additional data are reported as mean ± standard deviation. SPSS software version 16.0, SAS Institute, Cary, North Carolina, United States of America, was used to analyse the data. Tables were generated using SPSS 16.0 and Microsoft Excel 2010.

Results

A total of 23 young adult participants, 9 (39%) female individuals and 14 (61%) male individuals, with a mean age of 20.7 ± 3.3 years were recruited; of them, seven had low birth weight, three female individuals and four male individuals, and 16 had normal birth weight, six female individuals and 10 male individuals. Table 1 shows detailed demographic characteristics of the study sample.

According to Table 2, of the 23 participants studied, seven (30%) developed a ΔE/A ratio ⩾0.40, five low birth weight and two normal birth weight individuals. There was a significant association between

Table 1. Demographics of study sample

	LBW (n = 7)	NBW (n = 16)	p-value
Age (years)	21.2 ± 4.7	20.2 ± 1.6	0.335
BSA (m^2)	1.62 ± 0.17	1.70 ± 0.18	0.285
Mean DBP (mm/Hg)	73 ± 11	75 ± 8	0.529
Mean SBP (mm/Hg)	112 ± 16	116 ± 12	0.341
Mean HR (beats/minute)	79 ± 10	76 ± 6	0.310
Birth weight (g)	2260 ± 241	3320 ± 505	0.001*
VO_{2max} (ml/kg/minute)	59.04 ± 15	61 ± 12	0.224

HR = heart rate; LBW = low birth weight; NBW = normal birth weight; SD = standard deviation; BSA = body surface area; DBP = diastolic blood pressure; SBP = systolic blood pressure.

Formulae, $VO_{2max} = 14.8 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$ in male individuals and $VO_{2max} = 4.38 \times T - 3.9$ in female individuals.

*$p < 0.05$; significant difference between NBW and LBW individuals.

Table 2. Haemodynamic measurements

	LBW (n = 7)	NBW (n = 16)	p-value
Resting E/A ratio	1.77 ± 0.15	1.65 ± 0.33	0.097
Post-exercise E/A ratio	1.25 ± 0.22	1.55 ± 0.34	0.043*
ΔE/A ratio*	0.48 ± 0.27	0.19 ± 0.18	0.031*

ΔE/A ratio – change in the E/A ratio from rest to post-exercise. Exercise-induced cardiac fatigue was defined as ΔE/A ratio ⩾ 0.40.[8] Of the 20 participants who were studied, only seven developed EICF (exercise induced cardiac fatigue), five low birth weight and two normal birth weight individuals. There was a significant association between low birth weight and EICF (the χ^2 test $p < 0.05$, odds risk ratio 4.64 95% confidence interval 1.19–18.1).

*$p < 0.05$; significant difference between NBW and LBW individuals.

low birth weight and exercise-induced cardiac fatigue (odds risk ratio 4.64; 95% confidence interval 1.19-–18.1, $p < 0.05$).

Comment

This study is the first to elucidate the relationship between birth weight and exercise-induced cardiac fatigue. Compared with young adults with normal birth weight, those with low birth weight had greater diastolic dysfunction after prolonged aerobic exercise, as evidenced by mitral inflow E/A ratio. This supports the hypothesis that low birth weight individuals have permanent structural and functional cardiac impairments due to intrauterine growth retardation, making them more prone to exercise-induced cardiac fatigue.[4,7]

Prior study on exercise-induced cardiac fatigue has focused primarily on trained athletes participating in prolonged endurance.[8,9] The strenuous exercise and high motivation of athletes because of the competitive nature of these events provide a unique model in which to view cardiac dysfunction. The students in this study appeared to experience evidence of cardiac fatigue after a shorter amount of time and at lower exercise intensities compared with competitive and recreational endurance athletes.[8,9]

Low birth weight individuals showed even greater rates of exercise-induced cardiac fatigue. This may be explained by epigenetic modification that occurs in response to intrauterine hypoxia and lack of nutrition, leading to a decrease in protection against injury in the left ventricular myocardium,[4] besides structural and functional impairments in utero.[4,7]

Furthermore, the mechanisms of exercise-induced cardiac fatigue involve transient myocardial stunning and a decrease in sensitivity of myocardium to catecholamines, reducing the effect of adrenaline in improving both systolic and diastolic function during exercise.[8,9] These factors may be impaired to some extent in low birth weight individuals, thus making them more prone to exercise-induced cardiac fatigue. In fact, low birth weight is associated with chronic symphathoexcitation later in life, as measured by high noradrenaline "spillover" in low birth weight animals and children.[15,16] This also arises from the restricted growth leading to stress-induced increases in the circulating levels of cortisol and other glucocorticoids, and this prenatal excessive glucocorticoid activity might increase the hypothalamic–pituitary–adrenal axis with the resultant high symphathoexcitation.[15] Hence, if there is high sympathetic discharge at rest, β receptor sensitivity to catecholamines, which are already abundant, may easily and quickly decrease during exercise.

Limitations

The use of E/A ratio of transmitral valve flow by pulse-wave Doppler as an index of diastolic function is load dependent. Participants were asked to drink water during exercise, because post-exercise E/A changes may be influenced by sweating and changes in preload. Other sonographic measures of diastology were not systematically recorded, nor were natriuretic peptide levels obtained, both of which may have provided additional information about cardiac structure and function. Although the sample size was small, it was adequate to show statistically significant differences in the two groups of interest. Further studies with a larger sample size and more comprehensive physiological testing may provide enhanced understanding of subclinical cardiac changes in low birth weight individuals.

Conclusions

Low birth weight is associated with exercise-induced cardiac fatigue with diastolic dysfunction in young black adults. Hence, low birth weight may be a risk factor for the development of diastolic dysfunction and heart failure in low birth weight individuals later in life.

Acknowledgement

The authors thank Mr E. Nhandara and the Physiology Department technical staff, including Mr G. Musapatika, for their assistance.

Financial Support

The study was funded by the National Institute of Neurological Disorders and Stroke (NINDS), Office of the Director – National Institutes of Health (OD) and National Heart, Lung, and Blood Institute (NHLBI) through a Medical Education Partnership

Initiative (MEPI) Grant to the University Of Zimbabwe College Of Health Sciences (1 R24 TW008881 and 1 R24 TW008905).

Conflicts of Interest

None.

Ethical Standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the Medical Research Council of Zimbabwe (MRCZ) on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008, and have been approved by the Joint Parirenyatwa Hospital and College of Health Sciences Research Ethics Committee (JREC).

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