Journal of Exercise Physiologyonline

October 2015
Volume 18 Number 5

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

JEPonline

Fitness Status and Myocardial Morphology in Youth

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ABSTRACT

Wyatt FB, Baker JS, Buchan DS. Fitness Status and Myocardial Morphology in Youth. **JEPonline** 2015;18(2):1-12. The purpose of this study was to determine if fit adolescent males and females indicate myocardial morphology changes outside normal values. Twenty-two young adults 15 to 18 yrs of age acted as subjects. Resting measures included: age (yrs), height (ht, cm), weight (wt, kg), systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), percentage body fat (%BF), body mass index (BMI, kg·m^{-2}), waist circumference (WC, cm), waist/hip (W/H, ratio). A resting echocardiogram was used to determine the subjects' myocardial morphology, which included left ventricular mass (LVM, gm), left ventricular internal diameter end-diastolic (LVIDd, cm), left ventricular internal diameter end-systolic (LVIDs, cm), septal wall thickness (SWT, cm), and posterior wall thickness (PWT, cm). The subjects ran the Aerobic Fitness Shuttle Test and took the Physical Activity Questionnaire (PAQ). Statistical procedures included mean (±SD) for group measures. A Pearson Product R Correlation Coefficient determined bi-variate associations. *Post hoc* regression analyses established prediction equations between associated variables. The statistical significance was set at P≤0.05. Left ventricular internal diameter end-diastolic significantly associated with ht, wt, WC, LVIDs, LVM, and PWT. Posterior wall thickness, LM, and ST showed significant predictive qualities to the Aerobic Shuttle Test through regression analyses. Linear regression analyses determined specific myocardial morphologies can be determined through weight and fitness status. These include LVIDd, PWT, SWT, and LVM.

Key Words: Myocardial, Morphology, Adolescent, Fitness

INTRODUCTION

Myocardial structural changes have been noted through child and adolescent development, pathologies associated with obesity, and specific adaptations to athletic venues (2,3,9,10). In each case, myocardial morphologies are adapted to the stress or condition of the individual (7,15). For instance, in conditions associated with pressure load on the heart (such as hypertension and resistance lifting), left ventricular hypertrophy has occurred (18). Conversely, with repeated volume load stress associated with endurance training, myocyte phenotype changes lead to an increase in left ventricular cavity allowing for an increase in left ventricular diastole without increases in left ventricular mass (16). Lastly, studies investigating childhood obesity, body mass index, and associated left ventricular mass indicate a relationship between myocardial structure and body anthropometrics (4,5,8).

In the aforementioned associations to morphological changes in the myocardium, of concern are those considered pathological. Using ultrasound techniques with high frequencies (2D - 55 MHz), Dangardt and colleagues (6) investigated the intima thickness, intima-media thickness of radial and dorsal pedal arteries, and pulse wave velocities in overweight and obese children and adolescents compared to healthy controls. It was observed that obese adolescents were more than 3 standard deviations (SD) above their lean counterparts in association with body mass index (BMI). Moreover, the obese group had higher systolic and lower diastolic blood pressures and increased intima thickness (IT) of the radial arteries (RA) compared with the lean counterparts. This indicates structural alterations with hypertension. Additionally, the diameter of the RA was significantly ($P<0.05$) increased by ~20% in the obese subjects versus the lean controls (6).

In a study to determine blood pressure and left ventricular hypertrophy (LVH), Devereux and colleagues (9) compared echocardiographic images of left ventricular mass and relative wall thickness with blood pressure in 19 normal subjects to 81 subjects with mild hypertension. Interestingly, while the association of blood pressure and LVH was weak compared to blood pressure taken during rest periods, the relationship of LVH and hypertension was enhanced during stressful, workday situations. They concluded that cardiac hypertrophy was manifest more during periods of stress (i.e., increased cardiac output) than during restful conditions.

Blood pressure has been shown to be included in the etiology of cardiovascular disease and often associated with obesity in young and old adults. In fact, Shalitin and Phillip (19) noted that obese children may suffer from high blood pressure and other factors closely associated with cardiovascular pathologies. Additionally, their results indicated an increase waist circumference and insulin level were the most significant parameters associated with cardiovascular risk factors other than advanced age and a higher body fat percentage. Also important, the authors (19) determined that the frequency of cardiovascular risk factors may be more in children with two or more risk factors when compared to the children having only one risk factor.

Interestingly, as noted earlier, not all structural changes are pathological. In relation to a fit demographic, Manolas et al. (15) examined male athletes and non-athletes 9 to 20 yrs of age. They determined that left ventricular muscle mass (LVMM) was significantly greater (i.e., larger) in the 11 to 12 yrs of age group (15). Additionally, this difference was maintained in the older athletic groups. With this LVMM increase, the myocardial function of fractional shorting percentage did not change with a concomitant decrease in resting heart rate in the athletic groups (15).

While indications of morphology changes in the myocardium occur with obese children and adults, structural investigations with fit adolescent samples are warranted. Due to developmental changes in young adults, normal growth factors influence structural changes in the myocardium (5,7). Thus, the purpose of this study was to determine if fit adolescent males and females indicate myocardial morphology changes outside normal values. Should associations exist between fitness status and specific changes in the structure of the myocardium, a non-clinical prediction of change through regression analysis should be warranted.

METHODS

Subjects

Twenty-two (n=22) volunteers acted as subjects. Group means and standard deviations (±SD) were determined to establish demographics of the group and to maintain confidentiality.

Procedures

Resting Measures

A randomized controlled trial (RCT) was utilized as the research design. Resting measures included the following: age (yrs), height (ht, cm), weight (wt, kg), systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), percentage body fat (%BF), body mass index (BMI, kg·m^{-2}), waist circumference (WC, cm), Waist-to-hip ratio (WHR). In addition, resting echo-cardiograph measures were taken to establish morphology characteristics of the myocardium. These included left ventricular mass (LVM, gm), left ventricular internal diameter end-diastolic (LVIDd, cm), left ventricular internal diameter end-systolic (LVIDs, cm), septal wall thickness (SWT, cm), and posterior wall thickness (PWT, cm).

Stature, without shoes, was measured to the nearest 1 mm (Seca Stadiometer, Seca Ltd, Birmingham, UK). Weight in light indoor clothing, without shoes, was measured to the nearest 0.1 kg using calibrated electronic weighing scales (Seca 880, Digital Scales, Seca Ltd, Birmingham, UK). Percentage body fat (%BF) was estimated from skinfold thickness taken at the triceps and medial calf using Harpenden skinfold calipers (John Bull, British Indicators Ltd., Bedfordshire, UK) in accordance with standard procedures (21). Two measurements were taken at each site; a third was taken if the first two measurements differed by more than 1.0 mm. Percentage body fat (%BF) was estimated with sex-specific skinfold equations for adolescents (21).

Waist-to-hip ratio (WHR) was calculated to provide an index of relative fat distribution (12). Hip circumference was measured at the widest point between the buttocks and the iliac crest. Waist circumference was measured at the midpoint between the lower ribs and the iliac crest in accordance with standard procedures (12). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured with an automated monitor (Omron M10-IT Blood Pressure Monitor HEM-7080IT-E, Omron Healthcare UK Ltd, Milton Keynes, UK) after each subject had rested in the sitting position for 10 min as previously documented (1).

Echocardiography

Echocardiography was used to generate estimates of cardiac structural parameters. Using a commercially available ultrasound scanner (MyLabCV30, Esoate Biomedica, Italy) and an experienced sonographer, all subjects were studied at rest in the left lateral decubitas position. Standard images were obtained in the parasternal acoustic window in long-axis and short-axis planes. The LV wall thickness (septal wall and posterior wall; SWT and PWT) was measured from a two dimensional (2D) short-axis view at the level of the mitral valve at end-diastole, with the greatest measurement within the LV wall defined as the maximal wall thickness. Also, 2D guided M-mode echocardiograms at the level of the mitral valve tips were used to estimate the LV internal diameter end-diastolic (LVIDd) and the LV internal diameter end-systolic (LVIDs) in the long-axis plane. Left ventricular mass was calculated using the formula of Devereux et al. (9).

Aerobic Fitness Shuttle Test

For comparisons to fitness levels, the subjects were measured on the Aerobic Fitness Shuttle Test (number of shuttles) and they were given the Physical Activity Questionnaire (PAQ). Cardiorespiratory fitness (CRF) was estimated with the multi-stage 20-m shuttle run fitness test (20MSFT) (13). The subjects were required to run between two lines separated by 20 m while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed was set at 8.5 $km \cdot hr^{-1}$, which was increased by 0.5 $km \cdot hr^{-1}$ each min (1 min equates to 1 level). All subjects were instructed to continue for as long as possible until they reached their maximal effort. The test ended when the subject failed to reach the end lines before the audio signal on two consecutive occasions. The 20MSFT is familiar to most youth, and it is accepted as a valid test of CRF; a higher number of completed shuttles indicate a higher level of fitness. Performance in the 20MSFT was compared against gender- and age-specific normative values for European adolescents 12 to 17 yrs of age and, accordingly, youth who scored below the 10th age- and gender-specific percentiles were classified as at risk (17).

Statistical Analyses

Statistical procedures included mean (±SD) for group measures. A Pearson Product R Correlation Coefficient was run to determine statistically significant bi-variate associations. *Post hoc* regression analyses were run to establish prediction equations between associated variables. Statistically significant differences were established at the conventional $P \leq 0.05$.

RESULTS

The subjects included 22 post-adolescents with a mean (± standard deviation) age of 16.4 ± 0.74 yrs. Group data were reported to maintain confidentiality and remove the possibility of subject identification. Other demographic data can be seen in Table 1. Additional measured means (±SD) included resting systolic blood pressure and diastolic blood pressure (mmHg), 121.9 ± 12.4 / 66.5 ± 12.1; waist/hip ratio, 0.82 ± 0.06; fasting blood glucose ($mmol \cdot L^{-1}$), 3.46 ± 0.37; blood cholesterol ($mmol \cdot L^{-1}$), 3.52 ± 0.71; kilocalorie (kcal) intake, 1499.8 ± 370.9.

Table 1. Subject Demographics.

Variables	Mean	± Standard Deviation
Height (cm)	170.7	12.3
Weight (kg)	64.8	13.8
Age (yrs)	16.4	0.76
BMI ($kg \cdot m^{-2}$)	21.9	2.8
Body fat (%)	19.6	7.9
WC (cm)	72.7	8.8

BMI = body mass index; WC = waist circumference

Physical activity was assessed through a multi-stage aerobic fitness shuttle (AFS) test with the number of shuttles associated with levels of fitness. The group-mean (±SD) number of shuttles was 63.6 ± 25.3. Echocardiograph images are represented in Figure 1.

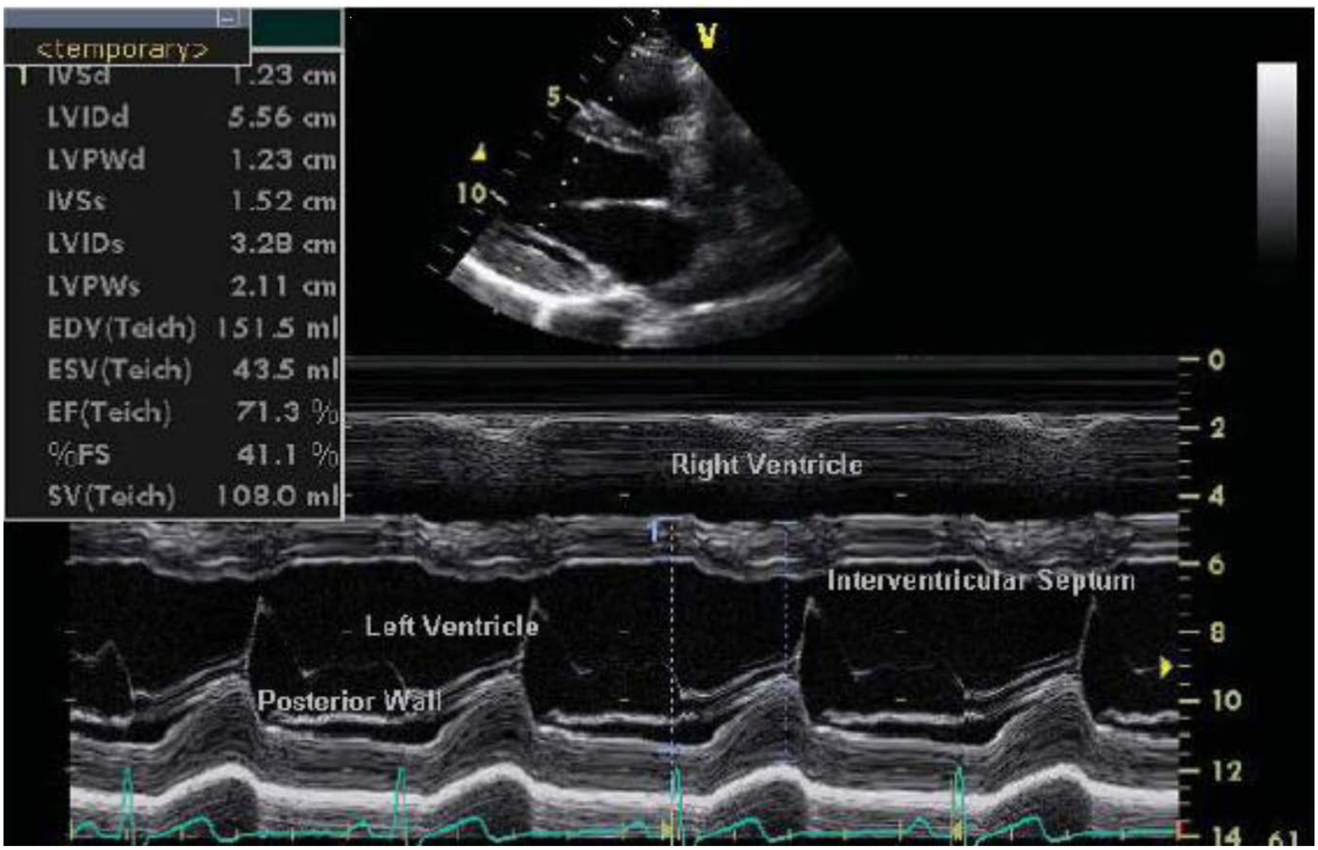


Figure 1. M-Mode Echocardiograph Image.

This image notes specific diameters during both systolic and diastolic periods of the cardiac cycle. Echocardiograph means (±SD) can be seen in Table 2. These include left ventricular mass (LVM, gm), left ventricular internal diameter end-diastolic (LVIDd, cm), left ventricular internal diameter end-systolic (LVIDs, cm), septal wall thickness (SWT, cm), posterior wall thickness (PWT, cm). Significant ($P<0.05$) bi-variate correlations were found between the following measured echocardiograph variables: LVIDd and height (r = .60); LVIDd and weight (r = .74); LVIDd and WC (r = .63); LVIDd and LVIDs (r = .84); LVIDd and LVM (r = .63); LVIDs and height (r = .66); LVIDs and weight (r = .71); LVIDs and WC (r = .70); LVIDs and PWT (r = .56); LVIDs and LVM (r = .57); LVM and height (r = .66); LVM and AFS (r = .88); LVM and %BF (r = -.62); LVM and ST (r=.97); LVM and PWT (r = .95); ST and height (r = .62); ST and AFS (r = .86); SWT and %BF (r = -.63); SWT and PWT (r = .83); PWT and height (r = .64); PWT and AFS (r = .82); PWT and %BF (r = -.55).

Table 2. Echocardiograph Measures.

Variable	Mean	± Standard Deviation	Normal Ranges
LVM (gm)	151	25	108-197
LVIDd (cm)	4.8	0.4	4.8-5.6
LVIDs (cm)	2.9	0.4	2.0-4.0
SWT (cm)	0.8	0.1	.83-1.1
PWT (cm)	0.8	0.1	.6-1.0

Left ventricular mass = LVM; left ventricular internal diameter end-diastolic = LVIDd; left ventricular internal diameter end-systolic = LVIDs; septal wall thickness = SWT; posterior wall thickness = PWT

Other significant ($P<0.05$) bi-variate correlations from the aforementioned measures include height and AFS (r = .72); height and WC (r = .73); weight and height (r = .79); weight and DBP (r = -.73); weight and WC (r = .92); SBP and DBP (r = .83); SBP and %BF (r = -.61); SBP and WC (r = -.68); DBP and WC (r = -.76); AFS and %BF (r = -.70). Given the significant associations noted above, multiple regression analyses were run to determine if non-invasive measures could predict myocardial morphologies in the subjects. Of particular interest were those predicted by fitness status based on the multi-stage aerobic fitness shuttle (AFS) test. Statistically significant (*) regression analyses were determined for the following:

PWT= 0.52 + .00389 (aerobic fitness shuttle) Equation 1
(P = 0.001)*

SWT= 0.61 + .003318 (aerobic fitness shuttle) Equation 2
(P = 0.002)*

LVM=102.97 + .75 (aerobic fitness shuttle) Equation 3
(P = 0.001)*

An additional *post hoc* multiple forward stepwise regression analysis was run to determine the weight of anthropometric measures versus fitness status in relation to LVM. The variables entered were height (cm), weight (kg), percentage body fat (%BF), body mass index (BMI), waist circumference (cm), and fitness status as evidenced through the AFS. This was done to ascertain the level of developmental (i.e., growth) influence on LVM versus the fitness status of the subjects. The dependent variable LVM showed no statistical significance with the aforementioned anthropometric measures, but it was shown to be highly significant (P = 0.001) in prediction (r = 0.77) for fitness status (AFS) as noted in Equation 3.

DISCUSSION

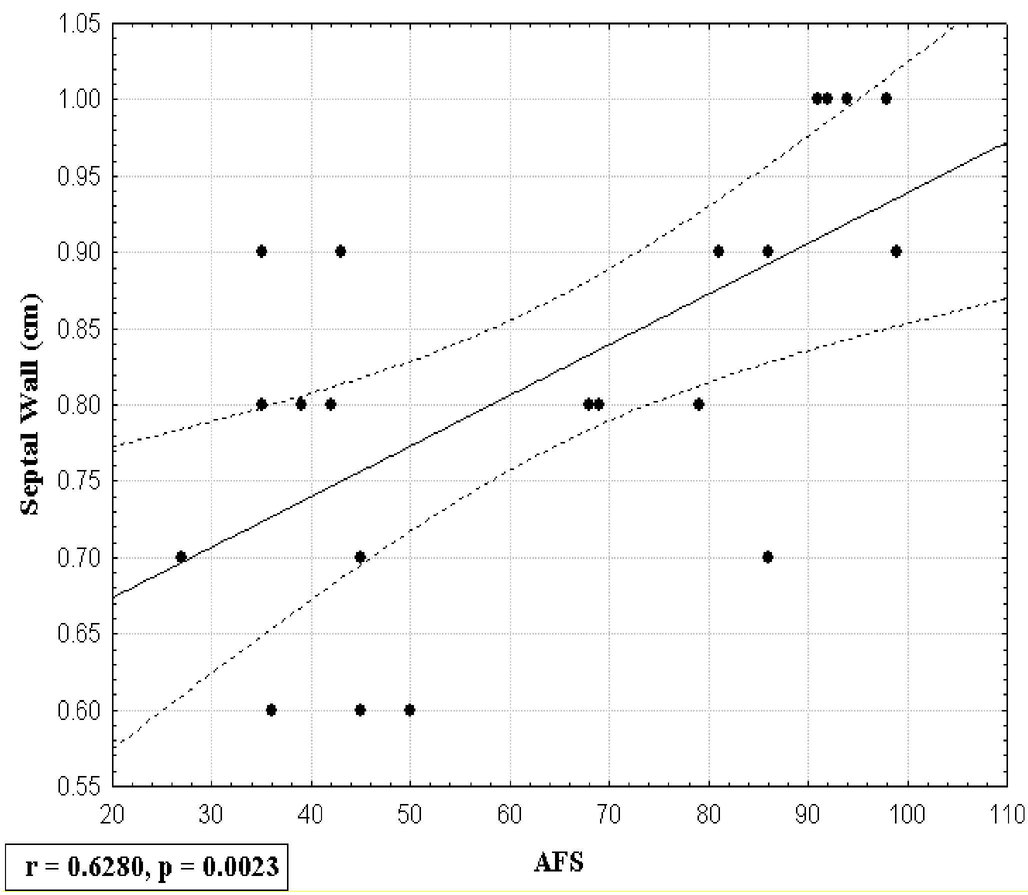
In the current study, measures of myocardial morphology were investigated in relation to the fitness status of a sample of adolescent males and females. Fitness pertaining to the current study was accessed through a multi-stage aerobic fitness shuttle test (AFS) with those achieving a greater number of shuttles seen as being more fit. Through this assessment, AFS showed correlations with several factors associated with cardiovascular health. Among those measures related to myocardial structure, septal wall thickness (SWT), posterior wall thickness (PWT) and left ventricular mass (LVM) associated significantly with the AFS test at r = .86, r = .82 and r = .88, respectively. Regression analyses indicates significant predictive equations for PWT (P = 0.001), ST (P = 0.002), and LVM (P = 0.001) in relation to AFS test. These findings indicate two possibilities related to the current study: (a) that morphological alterations are evident in fit adolescent males and females; and (b) myocardial function does not seem to be affected by these morphological changes. These findings are in agreement with others noting cardiac morphologies with athletic populations.

Petridis et al. (18) studied athletes versus non-athletes 15 to 18 yrs of age and found that left ventricular hypertrophy was noted in all athletic groups (i.e., endurance, power, and ball game). They found that sub-categorical measures indicated left ventricular internal diameter end-diastolic (LVIDd) was more pronounced in endurance athletes while left ventricular mass (LVM) was greatest in the power athletes. Their conclusions suggest sport specific structural changes in the myocardium with young athletes. Conflicting with this finding was a study that utilized elite male power lifters (10). Essentially they were investigating short and long term myocardial morphology with resistance training. In their conclusions, they note no significant changes in LVIDd, LVIDs, SWT, or PWT with short- or long-term resistance training. Where this may differ from the current study is that the mean age of their subjects classified as juniors and masters was 21 and 46 (yrs), respectively. This reiterates the need for continued research as it pertains to training mode and age factors associated with myocardial structural alterations.

In the current study, one indirect measure of fitness, percentage body fat (%BF) was shown to be negatively associated with various measures of myocardial structure. Of these, %BF showed significant ($P<0.05$) negative correlations to septal wall thickness (r = -.63), posterior wall thickness (r = -.55), and left ventricular mass (r = -.62). It should be noted that these myocardial structural measures are those showing high positive associations to fitness status through the AFS test. Moreover, further analysis shows an additional negative association between %BF and the AFS test (r = -.70).

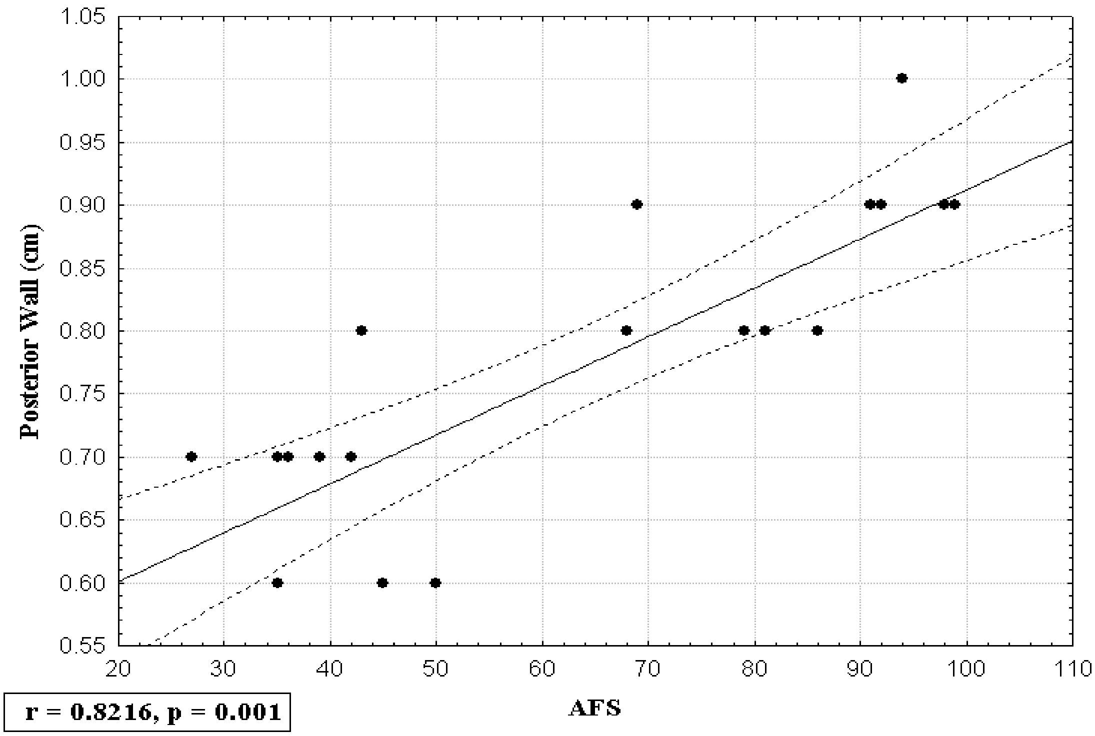
Within the current study, one could conclude from the findings that structural changes in the myocardium were fitness based as opposed to anthropometric growth factors. Dangardt et al. (6) studied the relationship of childhood obesity with adult cardiovascular diseases. Obesity in children has been shown to associate with dysfunctions of endothelium and carotid artery intima–media thickening. Dangardt and colleagues (6) noted this is often a precursor to atherogenesis, which manifests later as atherosclerosis. Singhal (20) found evidence consistent with atherosclerosis in obese children in the form of endothelial dysfunction and carotid stiffness. Notably, increases in carotid intima-media thickness are associated with cardiovascular risk factors including obesity (22). Viikari et al. (22) found indications that childhood obesity may increase the risk of intima-media thickness by up to 25%.

However, taking into account body composition, Daniels et al. (1995) and Dai et al. (2009) both allude to lean body mass as a greater determinant of left ventricular mass when compared to body fat. These findings recognize normal growth factors in this age demographic and seem an obvious factor when observing groups classified as fit or athletic (5,7). While it may seem evident in obese adults, body composition in youth is not the only factor influencing myocardial morphology. Figures 2-4 show regression associations between myocardial morphology and fitness status. Confidence limits at 0.95 were established to indicate strength of association between variables to the linear trend-line.



Note: AFS=Aerobic Fitness Shuttle

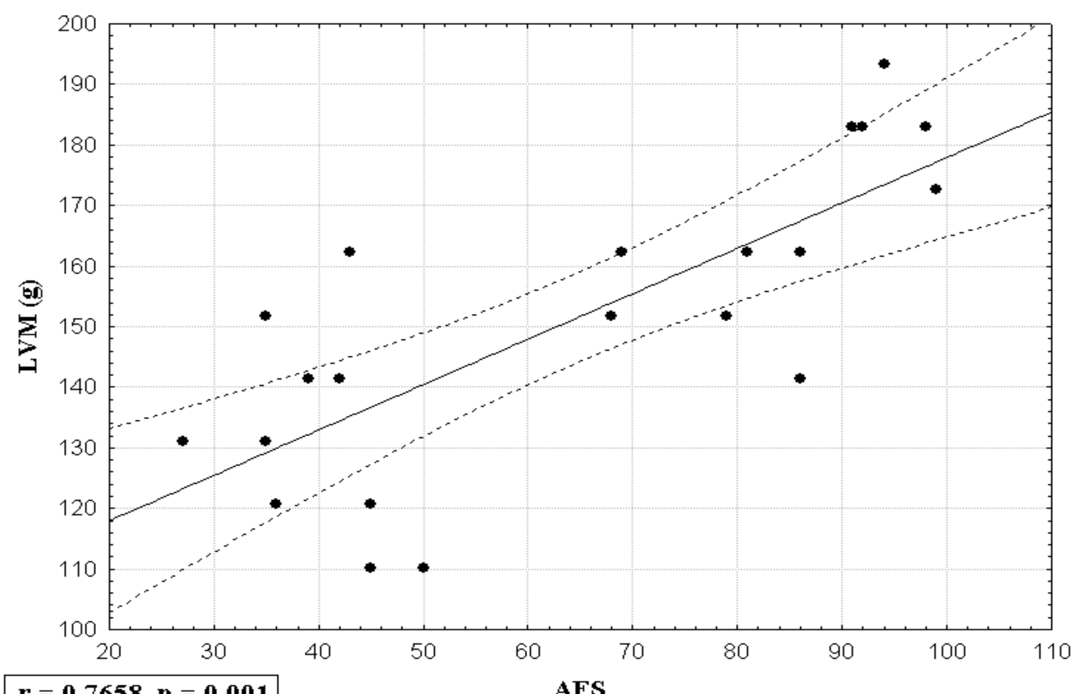
Figure 2. Scatter-Plot and Linear Regression AFS and Septal Wall (cm).



r = 0.8216, p = 0.001

Note: AFS = Aerobic Fitness Shuttle

Figure 3. Scatter-Plot and Linear Regression AFS and Posterior Wall (cm).



r = 0.7658, p = 0.001

Note: AFS = Aerobic Fitness Shuttle; LVM = Left Ventricular Mass

Figure 4. Scatter-Plot and Linear Regression AFS and Left Ventricular Mass (cm).

CONCLUSIONS

For purposes of diagnostic and possible prognosis, linear regression analyses determined that specific myocardial morphologies can be determined through weight and fitness status (AFS). These measures include posterior wall thickness (PWT), septal wall thickness (SWT), and left ventricular mass (LVM). While continued investigation is needed with this age group and fitness status, structural alterations in the myocardium are unequivocal. Increasing evidence of cardio-myocyte changes with exercise in adults is demonstrated in research (11). Additional work to separate growth factors with lifestyle influences on myocardial morphology in youth is warranted.

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