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Field Testing Adolescent Females for Cardiovascular Disease Risk

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ABSTRACT

Brahler CJ, Stephens WR, Donahoe-Fillmore, B. Field Testing Adolescent Females for Cardiovascular Disease Risk. *JEPonline* 2009;;12(3):24-33. Over-fatness and poor cardiovascular (CV) fitness are well-documented risk factors for cardiovascular disease (CVD) in adults, but less is known about their association with disease risk in adolescents. This study aimed to determine the relationship between anthropometrics, fitness and CVD risk. Six anthropometric indicators of body fatness, seven measures of fitness, and seven metabolic and hemodynamic CVD risk factors were measured in a convenience sample of 28 female high school students (15-18 years of age). A tally was made of the number of factors for which each subject was outside the normal reference range (CVD risk). Correlation analyses were completed to determine the association between CVD risk and other study variables and regression analyses were completed to determine if any fitness or anthropometric variables were significant predictors of CVD risk. All anthropometric indicators of fatness were highly significantly correlated with CVD risk ($P \leq 0.0001$) while only three fitness variables reached a lower level of significance ($P \leq 0.05$). WC was the single best anthropometric or fitness predictor of the variance in CVD risk factors ($r^2 = .742$; $p \leq 0.004$). While SBP was the single best predictor of the variance in CVD risk when all study variables were considered ($r^2 = .932$; $p \leq 0.0001$). Anthropometric indicators of body fatness were more significantly associated with and predictive of CVD risk compared to fitness variables in a convenience sample of 28 female high school students. Non-invasive measures that are easily obtained in the school setting and may be useful in identifying adolescent females at high risk for developing CVD.

Key Words: Risk Factors, Obesity, Women

INTRODUCTION

Predicting Cardiovascular Disease Risk

The pathophysiologies associated with cardiovascular disease (CVD) may begin in early childhood even though disease conditions may not be manifest until much later in life (1,2). Negative lifestyle habits develop during childhood and adolescence and can track forward into adulthood, significantly increasing ones risk for developing cardiovascular disease (2,3). Models that predict relative risk for CVD are readily available for adults (3-9) but not for children or adolescents (10-13). CVD risk prediction models assess the association between select metabolic, hemostatic, and hemodynamic measures and disease (4,5,7,8,11-15). Metabolic predictors include total cholesterol (TC), triglycerides (TG), high density lipoproteins (HDL), low density lipoproteins (LDL), very low density lipoproteins (VLDL), and blood glucose. Haemostatic predictors include tissue plasminogen activator (tPA), tPA inhibitor, tPA antigen, total plasminogen activator inhibitor type 1, and fibrinogen (4,11,12,15). Measurement of metabolic and haemostatic predictors of CVD risk is costly, time-consuming, and invasive, making it unlikely for most high schools to complete such assessments (16,17). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) are examples of hemodynamic predictors (4,11,12,15) that are not invasive, but that require special training and conditions to administer properly.

Anthropometric and Fitness Measures Associated with CVD Risk

It is well established that excess body fat increases the risk for CV disease and that high levels of fitness are cardioprotective (4,7,13,18,19). Anthropometric measures of body fatness and indices of physical fitness are independently predictive of CVD risk and of the more-invasive metabolic, hemodynamic and haemostatic risk factors listed above (4,5,8,11,12,15). Key advantages of measures of body fatness and CV fitness compared to the metabolic, hemodynamic and hemostatic variables mentioned above is that anthropometric measures of body fatness and indices of physical fitness can be measured in field conditions and can also be administered by most individuals without special training.

Common measures of body fatness include hydrostatic weighing, air displacement (Bop Pod), dual energy X-ray absorptiometry (DEXA) and skin-fold thickness (6,7,20-23) Though non-invasive, these measures still require expensive equipment and/or the services of a trained clinician. Field-based measures of body fatness such as BMI, WC, and BFP have also been demonstrated to be reliable measures of fatness (20,21). Measurement of BFP using bioelectrical impedance has been shown to be highly reliable when compared to hydrostatic weighing ($r=0.91$ for men and 0.83 for women) (20) and skinfold testing by a trained clinician ($r=0.79$ for adolescent women) (21). In addition to being non-invasive, these measures are inexpensive, require little time and training, and are efficient in assessing large groups.

The most common measure of CV fitness reported in the current literature is maximal oxygen uptake (VO_{2max}) (5,19,24). VO_{2max} is measured in the laboratory or clinic and provides a valuable indication of an individual's maximal capacity to consume oxygen into the respiring muscle tissue, however maximal testing requires expensive equipment, trained clinicians, and is time consuming. Alternatively, Mile run/walk time (MRW) is a measure of CV fitness that can be assessed in field conditions, with large groups and very inexpensively (23-25). Mile run/walk time has been demonstrated to be highly reliable as an estimate of VO_{2max} with test-retest reliability of $r=0.93$ for 8th graders and $r=0.98$ for 11th graders (25) and interclass reliability ranging between $r=0.83$ and $r=0.90$ (23). Additionally, the one mile run has been validated as an acceptable test of cardiorespiratory fitness for high school aged individuals in high school aged children (26). The FITNESSGRAM, the only health-related criterion-referenced physical fitness test endorsed by AAPERD, includes the 1 Mile run/walk test as one of 3 recommended field tests used (24). Other indices of physical fitness,

such as 40 yard dash time, pushups, shuttle run, curl ups, pull ups, and V sit and reach have not been investigated regarding their association with CVD risk. Although these activities are not directly related to cardiovascular fitness, the lack of evidence regarding their association with CVD risk warranted further investigation.

Current Trends

Although body fatness and CV fitness level are significantly associated with disease risk, surveys of American youth reveal that obesity rates are increasing and the amount of time spent in physical activity is decreasing (27,28). School sponsored physical education programs are often providing less than 30 minutes of physical activity per week (28). The link between health status as a child and health status as an adult is clear as 26-41% of obese preschool, and 42-63% school-age children become obese adults and the risk of adult obesity is at least twice as high for obese children than for non-obese children (1). Researchers are in universal agreement that obese children are more likely to become obese adults. Physical activity habits follow a similar pattern in that the greatest decline in physical activity is likely to occur between the ages of 15-18 years and the trend persists into adulthood (27).

Detecting Disease Risk

Early recognition of multiple CVD risk factors is imperative, as risk factors tend to cluster in individuals. Each risk factor is influenced and compounded when associated with additional risk factors. Furthermore, individuals with multiple risk factors are at increased risk of CVD compared to those with only one (7,10,12,29,)

In its position statement in 1996, the American Heart Association stated that primary prevention was the key to decreasing obesity, increasing physical activity and actually impacting societal change in the fight against cardiovascular disease (30). The need for intervention is clear; however, timely intervention is dependent upon identifying the children at risk for developing CVD.

The purpose of this study was, therefore, to determine if field measures of body fatness and/or fitness were predictive of more invasive and costly cardiovascular disease risk factors in female adolescents.

METHODS

Subjects

The University of Dayton Institutional Review Board for the protection of human subjects approved this study. Parents or legal guardians provided written informed consent for their child to participate. Participants were a convenience sample of 28 apparently-healthy female high school students (15-18 years of age) who were enrolled in a walking class. The walking class is a physical education alternative and is a regularly-scheduled, credit-bearing class that engages students in approximately 40 minutes of aerobic exercise each school day. Students who are interested in increasing their physical activity level self-select into the class.

Procedures

Anthropometric measurements were completed during the subjects' regularly-scheduled walking classes. Height and weight were measured using a balance-beam scale with a rigid vertical height rod (stadiometer). Body mass index (BMI) was calculated as weight/height squared. WC was measured to the nearest 0.1 cm at the level of the umbilicus and HC was measured at the maximum circumference of the buttocks. Upper-body bioelectrical resistance was measured with a hand-held bioelectrical impedance analyzer (Model HBF-300, Omron Healthcare, Vernon Hills, IL) at a fixed signal frequency of 50 kHz. The subjects' height, weight, age in years, and sex were entered into the Omron BIA device. Height was entered to the nearest 0.25 in., and weight entered to the nearest 0.5

lb. The subjects stood erect with feet shoulder-width apart, arms parallel to the ground, and elbows extended. The subject's hands and fingers maintained contact with source and sensor electrodes by firmly gripping the handles of the device. Relative body fat, estimated by the manufacturer's equation, was digitally displayed and recorded.

Metabolic and hemodynamic measurements were completed as follows: Subjects were 12-14 hours fasted when a certified phlebotomist collected blood samples, which were agitated, refrigerated, and then delivered to a local medical diagnostics laboratory for analyses. Plasma TC and TG levels were analyzed using conventional enzymatic methods (31). Plasma HDL, LDL, VLDL, and blood glucose concentrations were also determined. Subjects were seated in an upright position for a minimum of 5 minutes then a single measure of blood pressures was taken by University of Dayton graduate students and faculty using a mercury sphygmomanometer.

The high school physical education instructors conducted fitness testing on the students as follows: To measure abdominal strength/endurance the maximum number of curl-ups performed in one minute was assessed. Student lay on cushioned, clean surface with knees flexed and feet about 12 inches from buttocks and arms are crossed with hands placed on opposite shoulders and elbows held close to chest. With a partner holding the feet, the student raised the trunk, curling up to touch the outside of forearms and elbows to thighs and then lowered the back to the floor so that the scapulas (shoulder blades) touched the floor, for one curl-up. To start, a timer called out the signal "Ready? Go!" and began timing for one minute. The student stopped exercise on the word "stop."

To measure speed and agility, shuttle run performance was assessed. Two parallel lines were marked on the gymnasium floor 30 feet apart and two blackboard erasers were placed behind one of the lines. Students started behind the opposite line. On the signal "Ready? Go!" the student ran to the erasers, picked one up, ran back to the starting line, placed the eraser behind the line, ran back and picked up the second eraser and ran back across the starting line. Scores were recorded to the nearest tenth of a second.

To measure upper body strength/endurance the maximum number of pull-ups that could be completed was assessed. Each student hung from a horizontal bar with arms fully extended and feet free from floor, using either an overhand grasp (palms facing away from body) or underhand grip (palms facing toward body). Each student raised their body until their chin cleared the bar and then lowered their body to full-hang starting position. Each student performed as many correct pull-ups as was possible. Kicking or bending the legs and excessive swinging of the body was not permitted.

To measure upper body strength/endurance the maximum number of push-ups that could be completed was assessed. Each student started in push-up position with hands under shoulders, arms straight, fingers pointed forward, and legs straight, parallel and slightly apart (approximately 2-4 inches) with the toes supporting the feet. Keeping the back and knees straight, the student then lowered the body until there was a 90-degree angle formed at the elbows with upper arms parallel to the floor. A partner held her/his hands at the point of the 90-degree angle so that the student being tested could go down only until her/his shoulders touched the partner's hand, then back up. The push-ups were done to a metronome with one complete push-up every three seconds, until the student could do no more in rhythm. Only those push-ups done with proper form and in rhythm were recorded.

To measure flexibility of lower back and hamstrings, V sit and reach was assessed. A straight line two feet long was marked on the gymnasium floor as the baseline. A measuring line four feet long was drawn perpendicular to the midpoint of the baseline extending two feet on each side and marked off

in half-inches. The point where the baseline and measuring line intersect is the “0” point. Each student removed his/her shoes and sat on the floor with the measuring line between his/her legs and his/her soles placed immediately behind baseline, heels 8–12 inches apart. With hands on top of each other, palms down, the student placed them on the measuring line. With the legs held flat by a partner, the student slowly reached forward as far as possible, keeping fingers on the measuring line and feet flexed. After three practice tries, the student held the fourth reach for three seconds while that distance was recorded. Students were encouraged to reach slowly rather than “bounce” while stretching. Scores were recorded to the nearest half-inch, and are read as plus scores for reaches beyond baseline, minus scores for reaches behind baseline, zero for reaches to the baseline.

To measure cardiovascular endurance the fastest time to cover a one-mile distance was assessed, and to measure sprinting speed the 40 yard dash time was assessed. Students completed a one-lap warm up walk/jog on an indoor track. Students were tested in groups of six and began each run with “Ready? Go!”. Students completed the 40 yard dash test prior to completing the mile run/walk.

A tally was made of the number of factors for which each subject was outside the normal reference range (CVD risk). The reference ranges were as follow: HDL cholesterol levels lower than 35 mg/dl; (32); LDL cholesterol levels above 110 mg/dl (32); VLDL cholesterol levels above 40mg/dl (32); TC levels above 170 mg/dl (32); TG levels above 150 mg/dl (32); fasting blood glucose levels above 100 mg/dl (33); SBP above 125 mmHg (34); DBP above 81 mmHg (34); and BMI greater than age and gender adjusted point to pass through 25 kg/m² (35).

Statistical Analyses

Data were analyzed using SPSS (Statistical Package for the Social Sciences version 16.0). Descriptive statistics were calculated for means, standard error of the mean (SEM) and minimum and maximum values for each variable. Correlation analyses were completed to determine the association between the number of factors for which each subject was outside the normal reference range (CVD risk) and other study variables. Linear regression analyses were completed to determine if any fitness or anthropometric variables were significant predictors of CVD risk. Statistical significance was set at the $p \leq 0.05$ for all analyses.

RESULTS

Twenty eight adolescent females completed the study (average age 16.64 years). Descriptive data for anthropometric, fitness and cardiovascular variables are reported in Tables 1, 2, and 3, respectively. Subjects had an average of 2.64 CVD risk factors with a range of 0-7. In all, 16 girls had HDL cholesterol levels lower than 36 mg/dl, 16 had BMI greater than 25 kg/m²; 13 had TC values above 170 mg/dl; 11 had SBP above 124 mmHG; 8 had DBP above 81 mmHg; 6 had VLDL [above the normal range]; 2 had TG above 168 mg/dl, and 2 had fasting blood glucose values above 100 mg/dl. None of the girls had LDL cholesterol levels above 110 mg/dl. The girls had the risk factors in various combinations. Thirteen girls tested positive for 3 or more risk factors while fifteen had 2 or less positive risks.

Table 1. Anthropometrics.

	Minimum	Maximum	Mean	SEM
BFP	17.1	45.3	32.21	1.53
BMI	18.2	44.4	28.55	1.54
WC (inches)	25	58	33.30	1.86
HC (inches)	33.5	56.5	42.30	1.23
WHR	0.67	1.04	0.77	0.02
Wt (pounds)	103	286	173.57	10.76

All anthropometric indicators of fatness were highly significantly correlated with CVD risk ($P \leq 0.0001$; Table 4) while only three fitness variables significantly correlated with CVD Risk and at lower levels

Table 2. Fitness Measures.

	Minimum	Maximum	Mean	SEM
40 Yard Dash	6	10.8	7.98	0.25
Pushups	0	39	14.15	2.04
Shuttle Run	9.9	17.1	12.87	0.30
Curls Ups	6	44	24.11	1.79
Pull Ups	0	3	0.11	0.11
SitReach	-3	8	2.93	0.55
Mile Time (sec)	814	1348	1044.95	36.12

($P \leq 0.05$; Table 5). When only anthropometric and fitness variables were entered into a stepwise linear regression analysis, WC was the single best predictor of the variance in the number of CVD risk factors ($r^2 = 0.742$; $p = 0.004$). According to the prediction equation generated by this linear regression analysis, CVD risk could be predicted as $\text{CVD Risk} = (-4.48 + (\text{WC} * 0.209))$. When all study variables, including metabolic and hemodynamic variables, were

entered into a stepwise linear regression analysis, SBP was the single best predictor of the variance in the number of CVD risk factors ($r^2 = 0.932$; $p = 0.0001$). According to the prediction equation generated by this linear regression analysis, CVD risk could be predicted as $\text{CVD Risk} = (-36.56 + (\text{SBP} * 0.334))$.

DISCUSSION

There are many different CVD risk prediction models for adults and they vary in the number and type of factors they include (3-9,11-15). According to the National Heart, Lung, and Blood Institute an individual is at a greatly increased risk for CVD if he/she tests positive for any combination of three or more risk factors. The current study found that any one of six simple anthropometric measures of body fatness was highly correlated with the number of CVD risk factors for which an adolescent female tested positive. We propose that any one of these measures of body fatness may be helpful in identifying adolescent females at increased risk for developing CVD. Waist circumference was the best anthropometric or fitness predictor of CVD risk and could explain 74.2% of the variance in the number of CVD risk factors for which a subject tested positive. In contrast, fitness measures were less significantly correlated with CVD risk and were excluded by the stepwise linear regression models for predicting CVD risk.

Table 3. Metabolic and Hemodynamic Measures.

	Minimum	Maximum	Mean	SEM
Total Cholesterol	107	255	166.79	6.36
Triglyceride	20	559	98.04	19.39
HDL	19	70	45.32	2.21
glucose	58	155	101.77	4.39
VLDL	5	50	16.84	2.00
LDL	60	89	74.64	1.36
SBP	106	138	118.17	1.74
DBP	58	90	74.21	1.87

The current findings are consistent with the scholarly literature, which reports that measures of body fatness are better predictors of CVD risk than are fitness measures (4,6,9,18,23). In fact, in the current study, mile walk/run time was not even significantly correlated with CVD Risk. Perhaps the most interesting and unique finding of the current study is that several of the other fitness indicators included in the study were significantly associated with CVD Risk. Namely, the 40 yard dash, pushups, and shuttle run were correlated with CVD Risk at the 0.05 level of significance. These findings are surprising considering these tests are not indicators of cardiovascular fitness. The 40 yard dash assesses speed; pushups assess upper body strength and endurance; and the shuttle run assesses speed and agility.

Table 4. Correlations Between Number of CVD Risk Factors and Anthropometric Variables.

	<i>r</i> value	<i>p</i> value
BFP	0.637	0.0001
BMI kg/m ²	0.734	0.0001
WC (inches)	0.733	0.0001
HC (inches)	0.709	0.0001
WHR	0.698	0.0001
Wt (pounds)	0.713	0.0001

Another useful finding of the current study is that SBP could explain 93.9% of the variance in the number of CVD risk factors for which the adolescent female subjects tested positive. As such, a school nurse or other individual trained in taking blood pressures may be able to take student blood pressures as an inexpensive way to screen students for CVD risk.

This study is novel in that it focused on using non-invasive, inexpensive, field-based measures to predict CVD risk in adolescent females. It is especially unique in that it included a variety of physical fitness tests in the field based measures. The fact that BFP, BMI, WC, HC, WHR and body weight are significantly correlated with CVD risk in adolescents and WC and SBP are significantly predictive of CVD risk in adolescents means that many more adolescents should be screened for CVD risk and targeted for early intervention or referred for further testing.

CONCLUSION

Study Limitations

A quasi-experimental design was used in this study as subjects had self-selected into a walking class. The use of a convenience sample may limit the generalizability of this study to other groups. The small sample size is an additional limitation which affects the generalizability of the findings. The prediction models described in this report require further validity and reliability testing before they are recommended for use. Further research using random sampling from additional populations may be valuable in expanding the external validity of this study.

Table 5. Statistically Significant Correlations Between Number of CVD Risk Factors and Fitness Variables.

	<i>r</i> value	<i>p</i> value
40 Yard Dash	0.461	0.016
Pushups	-0.46	0.016
Shuttle Run	0.423	0.032

Not significant: Curl Ups, Pull Ups, Sit and Reach, Mile Time

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