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Fitness level and body composition indices: cross-sectional study among Malaysian adolescent

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Abstract

Background: The importance of fitness level on the well-being of children and adolescent has long been recognised. The aim of this study was to investigate the fitness level of school-going Malaysian adolescent, and its association with body composition indices.

Methods: 1071 healthy secondary school students participated in the fitness assessment for the Malaysian Health and Adolescents Longitudinal Research Team (MyHEART) study. Body composition indices such as body mass index for age, waist circumference and waist height ratio were measured. Fitness level was assessed with Modified Harvard Step Test. Physical Fitness Score was calculated using total time of step test exercise and resting heart rates. Fitness levels were divided into 3 categories - unacceptable, marginally acceptable, and acceptable. Partial correlation analysis was used to determine the association between fitness score and body composition, by controlling age, gender, locality, ethnicity, smoking status and sexual maturation. Multiple regression analysis was conducted to determine which body composition was the strongest predictor for fitness.

Results: 43.3% of the participants were categorised into the unacceptable fitness group, 47.1% were considered marginally acceptable, and 9.6% were acceptable. There was a significant moderate inverse association ($p < 0.001$) between body composition with fitness score ($r = -0.360$, -0.413 and -0.403 for body mass index for age, waist circumference and waist height ratio, respectively). Waist circumference was the strongest and significant predictor for fitness ($\beta = -0.318$, $p = 0.002$).

Conclusion: Only 9.6% of the students were fit. There was also an inverse association between body composition and fitness score among apparently healthy adolescents, with waist circumference indicated as the strongest predictor. The low fitness level among the Malaysian adolescent should necessitate the value of healthy lifestyle starting at a young age.

Background

Physical activity relates to any movement produced by the individual's skeletal muscles that results in energy expenditure [1]. Physical fitness is a set of attributes a person have or achieve, [1] which is linked to the person's capability to do physical activity [2]. Fitness is divided into health and skill related components, with the health component further consists of cardiorespiratory endurance, muscular

endurance, muscular strength, and flexibility [1]. An individual who is physically fit has the ability to do daily activities with vigour and alertness, without undue fatigue and still has enough energy to pursue leisure-time activities and prepare for emergencies that ensue [3].

In healthy adults, studies have shown that cardiorespiratory fitness is inversely associated with all-cause mortality and cardiovascular disease [4-6]. Low fitness levels and childhood obesity has been shown to continue into adulthood, with consequent health morbidity like cardiovascular and metabolic diseases [7].In adolescent, most commonly used measurements for adiposity are body

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mass index (BMI), waist circumference (WC), and waist height ratio (WHtR). BMI [8-10], WC [11-13] and WHtR [14-16] are strong predictors for cardio-metabolic risk factors in the paediatric population.

The previous studies that investigated the association between fitness and body composition indices in adolescent [17-20] used parameters such as BMI or WC. There are no studies that investigate these indices with WHtR, or determine which of the body composition indices in adolescent is the strongest predictor for fitness. This is of clinical interest for the purpose of mass screening and future population based health intervention.

In Malaysia, there are limited community based studies determining the fitness level among adolescent. A few used physical activity questionnaire to determine the physical activity level [21,22]. In this cross sectional study, we investigated the fitness level among Malaysian adolescent using step test. We determined the association between BMI, WC and WHtR to the fitness level and identified which body composition indices is the strongest predictor of fitness.

Methods

Study population
The Malaysian Health and Adolescents Longitudinal Research Team (MyHEART) is an on- going prospective longitudinal cohort study in Malaysia. The first phase (MyHEART I 2012) involved Form 1 students (13 years old) from 15 rural and urban secondary schools randomly selected in three states - Perak, Selangor and Kuala Lumpur. The study lasted for three months from March till May 2012.

Study design, sampling methods, data collection protocols and inclusion and exclusion criteria have been reported elsewhere [23]. Ethical approval which complied with the International Conference on Harmonization - Guidelines for Good Clinical Practice (ICH-GCP) and the Declaration of Helsinki was obtained from the Medical Ethics Committee of the University of Malaya Medical Centre, Malaysia (IRB number 896.34).Both written consent from parents and agreement forms from participants were obtained prior to the study.

Anthropometric and clinical data
The participants completed a standardised form, which socio-demographic data such as date of birth, age, gender, and ethnicity were collected. Systolic and diastolic blood pressures were measured with a stethoscope and mercurial sphygmomanometer (CK-101C, Spirit Medical Co., Taiwan).The participants sit upright with the right upper arm on the table at the level of the heart. They rested for 5 minutes prior to measurement. Pulse rate was obtained with a finger pulse oximeter (Baseline 12-1926 Fingertip Pulse Oximeter, Fabrication Enterprises Inc., USA).

Height was measured using a stadiometer (Seca Portable 217 Seca, UK) and recorded to the nearest 0.1 cm. Weight was measured with a digital electronic weighing scale (Seca 813, Seca, UK) and recorded to the nearest 0.1 kilogram. BMI was calculated by using weight in kilograms divided by the square of height in meters. BMI standard deviation (BMI SD) for age and gender was calculated using the World Health Organisation (WHO) Anthro Software version 3.2.2 for SPSS macro, based on WHO reference 2007 (WHO,Geneva, Switzerland). WC was measured with a non-elastic measuring tape (Seca 201, Seca, UK) mid-point between the lowest rib margin and the iliac crest, and recorded to the nearest millimetre. WHtR was determined by WC in cm divided by height in cm.

Sexual maturation was based on self-reported Tanner staging questionnaire[24]. External genitalia development and pubic hair in boys, and breast development and pubic hair in girls were used for Tanner staging.

Fitness test
Fitness test was conducted using the modified Harvard Step Test [25,26]. It utilized a 30 cm high step box which was readily available for fitness assessment in all secondary schools in Malaysia. A finger pulse oxymeter was attached to one of the fingers to continuously monitor the pulse rate and oxygen saturation (SpO_2). With a metronome set at 120 beats per minute, the participants stepped on and off the box with both feet for 5 minutes. Those with heart rates above 200 beats per minute, had difficulty in breathing, SpO_2 less than 90% or unable to finish, were stopped immediately. Once the participants have completed the step test or were stopped due to the aforementioned reasons, they quickly sit down on the box and rest. Heart rates at 0, 1 and 2 minutes of rest were recorded, as well as total duration of exercise in seconds. The fitness test was conducted under close supervision of a sports physician.

Physical fitness score (PFS) was calculated by the total duration of exercise in seconds × 100 and divided with the sum of three heart rates at 0, 1 and 2 minutes of rest. PFS < 55 is considered poor, 55 - 64 as low average, 65 - 79 as high average, 80 - 89 as good, and > 90 as excellent. The medium score (65-79) was used as a cut- off point to separate the participants of upper and lower PFS, thus <65 is considered unacceptable, 65-79 as marginally acceptable, and >80 as acceptable [25,26].

Statistical analysis
Test for normality was conducted for continuous variables. Analysis was done separately by gender. Mean ± SD was calculated for both baseline characteristics and exercise values. Independent t-test and chi square test were used where appropriate to compare between gender differences.

Partial correlation coefficient was used to examine the direction and strength between body composition indices with PFS, with controlling of factors - age and dummy coded gender, locality (urban/rural), smoking status, Tanner staging and ethnicity. Multiple regression analysis was performed to determine the strongest body composition predictor for PFS, with the same controlling factors stated. All statistical analyses were completed using SPSS version 20 and the level of significance at $p < 0.05$.

Results

Descriptive statistics

1361 students participated in the MyHEART study. However, 285 participants refused to be involved in the exercise test, while five were excluded due to illness or with pre-existing medical condition. Thus, PFS data was available from 1071 participants.

Table 1 and table 2 present the baseline characteristics and exercise parameters of the participants. Boys had a significantly higher WC and WHtR ($p < 0.001$) compared to girls. No significant difference for BMI and BMI SD in both genders. Boys had a higher mean PFS than girls (71.2 ± 13.1 vs. 61.1 ± 12.5, $p < 0.001$). When we further categorize the PFS (Figure 1), only 9.6% of the participants were in the acceptable range, with 21.8% of boys and 1.9% of girls. 47.1% were marginally acceptable (55.9% of boys, 41.7% of girls) and 43.3% were in the unacceptable fitness level (22.3% of boys, 56.4% of girls).

Table 1 Baseline characteristics of participants.

	Boys	Girls	p
n	405	666	-
Ethnicity (%)			0.87
Malay	82.3	83.0	
Chinese	8.2	7.0	
Indian	6.5	7.1	
Others	3.1	2.8	
Tanner staging (%)			<0.001
1	8.2	4.8	
2	30.5	18.2	
3	40.8	48.4	
4	17.7	25.3	
5	2.9	3.4	
Age (years)	12.8 ± 0.3	12.9 ± 0.3	0.024
Pulse rate (beats/min)	85.5 ± 14.0	90.1 ± 13.2	<0.001
SBP (mm/Hg)	110.6 ± 10.5	108.7 ± 11.8	0.006
DBP (mm/Hg)	68.8 ± 10.5	66.7 ± 10.3	0.001
BMI (kg/m^2)	19.8 ± 5.0	19.7 ± 4.4	0.729
BMI SD	0.17 ± 1.7	0.02 ± 1.4	0.130
WC (cm)	70.5 ± 13.1	67.5 ± 9.9	<0.001
WHtR	0.47 ± 0.1	0.45 ± 0.1	<0.001

Data are mean ± SD or percentage, SBP = Systolic blood pressure, DBP = Diastolic blood pressure, BMI = Body mass index, WC = Waist circumference, WHtR = Waist height ratio.

Table 2 Exercise parameters of participants.

	Boys	Girls	p
Pulse rate at 0 min rest (beats/min)	171.4 ± 17.8	180.2 ± 15.2	<0.001
Pulse rate at 1 min rest (beats/min)	125.8 ± 19.8	144.4 ± 15.7	<0.001
Pulse rate at 2 min rest (beats/min)	115.0 ± 17.5	131.1 ± 14.6	<0.001
Total duration of exercise (s)	289.8 ± 40.0	277.6 ± 54.2	<0.001
PFS (mean)	71.2 ± 13.1	61.1 ± 12.5	<0.001
PFS (%)			<0.001
Unacceptable	22.3	56.4	
Marginally acceptable	55.9	41.7	
Acceptable	21.8	1.9	

Data are mean ± SD or percentage, PFS= Physical fitness score

Correlation analysis and multiple linear regression analysis

Correlation analysis in Table 3 showed BMI SD, WC and WHtR were moderately inverse correlated with PFS ($r = -0.360$, $r = -0.413$ and $r = -0.403$ respectively, $p < 0.001$). The strongest correlation was with WC. Multiple regression analysis in Table 4 showed that WC was the only significant predictor for PFS (ß = -0.318, $p = 0.002$).

Discussion

Fitness level

This study showed that only 9.6% of Malaysian adolescent were considered fit (acceptable range) after the step test. The ratio of fitness for girls to boys was more than 1:10 (1.9% and 21.8% respectively). The low level of fitness among the study group emphasizes the need to identify and instil healthy lifestyle choices from young. Other Malaysian studies have shown that between 3%-20% of adolescent had high levels of physical activity, 50%-61.5% were moderately active and 30%-35.3% had low physical activity levels [21,22]. However, these studies were carried out only in schools of one district in a Malaysian state. Moreover, the result was based on physical activity questionnaire, which assessed reported behaviours of the participants, while the current study objectively assessed the fitness level of adolescent.

Our result also showed that boys were fitter than girls. This was in accordance to other adolescent population in Asian countries [27-29], Europe [20,30,31] and North America [32,33]. Gender difference of fitness level could be due to variances in haematological parameters and ventricular chamber sizes [34,35].

This low level of fitness is a global problem. Based on analysis of 50 studies involving 25 million children from 28 countries spanning from 1964-2010, our current children generation were 15% less fit than when their parents were at their age [36]. Low fitness level in the paediatric population is associated with higher risk of a cluster of cardio-metabolic risk factors [31,37-39]. Various studies have shown the benefits of intervention programs in improving
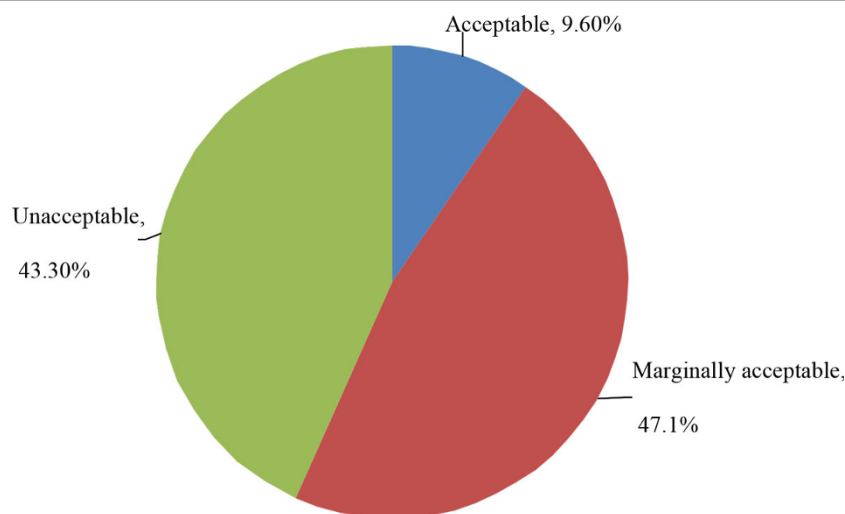
Figure 1 Physical Fitness Score (PFS) of participants.

Table 3 Correlation coefficient (*r*) between body composition indices and physical fitness score using partial correlation analysis*

Body composition	Physical fitness score	
	r	*p*
BMI SD	-0.360	<0.001
WC (cm)	-0.413	<0.001
WHtR	-0.403	<0.001

BMI = Body mass index, WC = Waist circumference, WHtR = Waist height ratio
*Control for age, gender, smoking status, ethnicity, locality and sexual maturity

Table 4 Standardised coefficient (ß) between body composition indices and physical fitness score using multiple regression analysis*

Body composition	Physical fitness score	
	ß	*p*
BMI SD	-0.007	NS
WC (cm)	-0.318	0.002
WHtR	-0.067	NS

NS = Not significant, BMI = Body mass index, WC = Waist circumference, WHtR = Waist height ratio
*Control for age, gender, smoking status, ethnicity, locality and sexual maturity

children's and adolescent's health status i.e. reduce body fat [40-43], improve metabolic syndrome score [44,45], positive effect on blood pressure [46,47], increase bone density [48,49] and academic performances [50,51].

Body composition indices and fitness
This study showed that BMI SD, WC and WHtR were all inversely correlated with fitness level. Our result was similar with findings from other studies [17-20]. Another study also showed that visceral adipose tissue measured with abdomen MRI was inversely correlated with aerobic fitness [52].Moreover, our study also investigated the correlation with WHtR, which is also considered as a marker of intra-abdominal adiposity in children and adolescent [53]. WHtR was shown to be a good predictor of cardio-metabolic risk factors [14-16].

WC was the strongest predictor to fitness in our findings. This reiterates the importance of WC as a measurement tool of health status for adolescent. It is a surrogate marker for intra-abdominal adiposity [54], and a strong predictor for cardio-metabolic risk factors in children and adolescent [11-13]. The actual relation of WC on cardio-metabolic risk factors is still unclear. A few possible hypotheses have been proposed. Intra-abdominal adiposity is an indicator of impaired energy storage regulation, which leads to an excess of fat collection in the liver, and subsequent compromised liver function of fat regulation. Thus, increased intra-hepatic fat storage consequently leads to dyslipidaemia and insulin resistance [55]. Another probable way is the release of free fatty acids through lipolysis of omentum and mesenteric adipocytes, which in turn triggers insulin resistance and hypercholesterolemia [56].

Other studies have investigated the influence of fitness on adiposity indices using multiple linear regression analysis. In one study, fitness was determined to be an independent predictor WC, visceral and abdominal subcutaneous adipose tissue after adjusting factors of age, gender, sexual maturity and BMI [17]. Another showed that VO_2max, a marker of fitness, was inversely associated with both BMI and WC after controlling factors of age, sexual maturity and active commuting to school

[19]. Interestingly, it showed that adolescent with low fitness level were associated with increased 5.6 cm and 2.9 cm of waist circumference in boys and girls respectively, as compared to those in the higher fitness level. A third study in Spain revealed cardiorespiratory fitness was the strongest predictor of BMI, sum of skinfold thickness and subcutaneous truncal fat, as compared to physical activity level [57]. All these warrant the importance of active intervention and healthy lifestyle to start at a young age.

American College of Sports Medicine recommends daily moderate to vigorous intensity aerobic exercise for ≥60 minutes per day for children [2]. Three hours per week sports participation has shown to reduce body fat and increase fitness level among boys [58]. A VO_2max of 45 ml/kg/min for boys and 40.7 ml/kg/min for girls may be the minimum level to limit accumulation of intra-abdominal adiposity [19].

School based intervention programs in Malaysia showed positive effects on fitness and flexibility [59]. However, these studies included additional physical activity programs on top of the compulsory physical education classes. Future studies are needed to investigate the implication of physical education classes on Malaysian adolescent's health status.

Strength and limitation

The strength of our study is the large sample of participants. To our knowledge, this is the first large cross-sectional study in Malaysia to determine the fitness level among school-going adolescent. This study utilized modified Harvard step test as a tool for fitness assessment, which does not require large space to conduct, minimal equipment and expertise, and a short duration of time to complete (less than 10 minutes). Further studies are needed to compare this step test with other fitness protocols.

There are limitations to this study. Cross-sectional design cannot capture cause-effect relationship. The cohort sample are of the same age group, thus this does not reflect the whole adolescent population. More than 80% of participants were Malays, which do not reflect the racial composition of Malaysian adolescent. However this study is still of importance since it is one of a few that assessed fitness level. Our next step would be in MyHEART II 2014 where a follow-up of the same participants would be conducted, thus a longitudinal association between body composition indices with fitness and changes in fitness level could be determined.

Conclusions

This study showed only 9.6% of Malaysian adolescent were categorised as fit, with ratio of girls to boys of 1:10. BMI SD, WC and WHtR were inversely correlated with fitness, and WC was the strongest predictor for fitness. The importance of being physically active and fit needs to be emphasized by all stake-holders and nurture healthy lifestyle choices for the young.

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References

1. Caspersen CJ, Powell KE, Christenson GM: **Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research.** *Public Health Rep* 1985, **100(2)**:126-131.
2. Pescatello L, American College of Sports Medicine: *ACSM's guidelines for exercise testing and prescription* Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2014.
3. Clarke H: *Phycial Fitness Research Digest Series 1 Number 1* Washington, DC: President's Council on Physical Fitness and Sports; 1971.
4. Laukkanen JA, Rauramaa R, Salonen JT, Kurl S: **The predictive value of cardiorespiratory fitness combined with coronary risk evaluation and the risk of cardiovascular and all-cause death.** *J Intern Med* 2007, **262(2)**:263-272.
5. Laukkanen JA, Rauramaa R, Kurl S: **Exercise workload, coronary risk evaluation and the risk of cardiovascular and all-cause death in middle-aged men.** *Eur J Cardiovasc Prev Rehabil* 2008, **15(3)**:285-292.
6. Aijaz B, Babuin L, Squires RW, Kopecky SL, Johnson BD, Thomas RJ, Allison TG: **Long-term mortality with multiple treadmill exercise test**

abnormalities: comparison between patients with and without cardiovascular disease. *Am Heart J* 2008, 156(4):783-789.

7. Velasquez-Mieyer P, Perez-Faustinelli S, Cowan PA: Identifying Children at Risk for Obesity, Type 2 Diabetes, and Cardiovascular Disease. *Diabetes Spectr* 2005, 18(4):213-220.

8. Freedman DS, Khan LK, Dietz WH, Srinivasan SR, Berenson GS: Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. *Pediatrics* 2001, 108(3):712-718.

9. Agirbasli M, Agaoglu NB, Ergonul O, Yagmur I, Aydogar H, Oneri T, Ozturk O: Comparison of anthropometric indices in predicting metabolic syndrome components in children. *Metab Syndr Relat Disord* 2011, 9(6):453-459.

10. Kim C, Kim B, Joo N, Park Y, Lim H, Ju Y, Yang S, Park S, Cho B, Park K: Determination of the BMI threshold that predicts cardiovascular risk and insulin resistance in late childhood. *Diabetes Res Clin Pract* 2010, 88(3):307-313.

11. Lee JM, Davis MM, Woolford SJ, Gurney JG: Waist circumference percentile thresholds for identifying adolescents with insulin resistance in clinical practice. *Pediatr Diabetes* 2009, 10(5):336-342.

12. Meng L, Luo N, Mi J: Impacts of types and degree of obesity on non-alcoholic fatty liver disease and related dyslipidemia in Chinese school-age children? *Biomed Environ Sci* 2011, 24(1):22-30.

13. Johnson ST, Kuk JL, Mackenzie KA, Huang TT, Rosychuk RJ, Ball GD: Metabolic risk varies according to waist circumference measurement site in overweight boys and girls. *J Pediatr* 2010, 156(2):247-252 e241.

14. Goulding A, Taylor RW, Grant AM, Parnell WR, Wilson NC, Williams SM: Waist-to-height ratios in relation to BMI z-scores in three ethnic groups from a representative sample of New Zealand children aged 5-14 years. *Int J Obes* 2010, 34(7):1188-1190.

15. Mokha JS, Srinivasan SR, Dasmahapatra P, Fernandez C, Chen W, Xu J, Berenson GS: Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. *BMC Pediatr* 2010, 10:73.

16. Schwandt P, Bertsch T, Haas GM: Anthropometric screening for silent cardiovascular risk factors in adolescents: The PEP Family Heart Study. *Atherosclerosis* 2010, 211(2):667-671.

17. Lee SJ, Arslanian SA: Cardiorespiratory fitness and abdominal adiposity in youth. *Eur J Clin Nutr* 2007, 61(4):561-565.

18. Brunet M, Chaput JP, Tremblay A: The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: the 'Quebec en Forme' Project. *Int J Obes* 2007, 31(4):637-643.

19. Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martin-Matillas M, Mesa JL, Warnberg J, Bueno M, Tercedor P, Gutierrez A, et al: Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007, 15(6):1589-1599.

20. Hussey J, Bell C, Bennett K, O'Dwyer J, Gormley J: Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10-year-old Dublin children. *Br J Sports Med* 2007, 41(5):311-316.

21. Dan SP, Mohd Nasir MT, Zalilah MS: Sex and ethnic differentials in physical activity levels of adolescents in kuantan. *Malays J Nutr* 2007, 13(2):109-120.

22. Hashim HA, Golok F, Ali R: Profiles of exercise motivation, physical activity, exercise habit, and academic performance in Malaysian adolescents: A cluster analysis. *Int J Collab Res Internal Med Public Health* 2011, 3(6):416-428.

23. Abu Hanifah R, Mohamed MNA, Jaafar Z, Abdul Mohsein NA-S, MY J: The Correlates of Body Composition with Heart Rate Recovery after Step Test: An Exploratory Study of Malaysian Adolescents. *PloS one* 2013, 8(12):e82893.

24. Tanner JM, Whitehouse RH: Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. *Arch Dis Child* 1976, 51(3):170-179.

25. Trevino RP, Marshall RM, Hale DE, Rodriguez R, Baker G, Gomez J: Diabetes risk factors in low-income Mexican-American children. *Diabetes care* 1999, 22(2):202-207.

26. Trevino RP, Fogt DL, Wyatt TJ, Leal-Vasquez L, Sosa E, Woods C: Diabetes risk, low fitness, and energy insufficiency levels among children from poor families. *J Am Diet Assoc* 2008, 108(11):1846-1853.

27. Gonzalez-Suarez CB, Lee-Pineda K, Zamora MTG, Sibug EO, Velasco ZF, Grimmer-Somers K: Cardiovascular Fitness and Caloric Intake in Filipino Obese Children: An Observational Study. *Asian Journal of Clinical Nutrition* 2012 2012, 4(3):88-97.

28. Chen LJ, Fox KR, Haase A, Wang JM: Obesity, fitness and health in Taiwanese children and adolescents. *Eur J Clin Nutr* 2006, 60(12):1367-1375.

29. Mak KK, Ho SY, Lo WS, Thomas GN, McManus AM, Day JR, Lam TH: Health-related physical fitness and weight status in Hong Kong adolescents. *BMC public health* 2010, 10:88.

30. Ostojic SM, Stojanovic MD, Stojanovic V, Maric J, Njaradi N: Correlation between fitness and fatness in 6-14-year old Serbian school children. *J Health Popul Nutr* 2011, 29(1):53-60.

31. Ortega FB, Ruiz JR, Hurtig-Wennlof A, Vicente-Rodriguez G, Rizzo NS, Castillo MJ, Sjostrom M: Cardiovascular fitness modifies the associations between physical activity and abdominal adiposity in children and adolescents: the European Youth Heart Study. *Br J Sports Med* 2010, 44(4):256-262.

32. Burns R, Hannon JC, Brusseau TA, Shultz B, Eisenman P: Indices of abdominal adiposity and cardiorespiratory fitness test performance in middle-school students. *J Obes* 2013, 2013:912460.

33. Willig AL, Hunter GR, Casazza K, Heimburger DC, Beasley TM, Fernandez JR: Body fat and racial genetic admixture are associated with aerobic fitness levels in a multiethnic pediatric population. *Obesity* 2011, 19(11):2222-2227.

34. Turley KR: Cardiovascular responses to exercise in children. *Sports Med* 1997, 24(4):241-257.

35. Rowland T, Goff D, Martel L, Ferrone L: Influence of cardiac functional capacity on gender differences in maximal oxygen uptake in children. *Chest* 2000, 117(3):629-635.

36. Tomkinson GR, Annandales M, Ferrar K: Global Changes in Cardiovascular Endurance of Children and Youth Since 1964: Systematic Analysis of 25 Million Fitness Test Results from 28 Countries [abstract]. *Circulation* 2013, 128:A13498.

37. Ruiz JR, Rizzo NS, Ortega FB, Loit HM, Veidebaum T, Sjostrom M: Markers of insulin resistance are associated with fatness and fitness in school-aged children: the European Youth Heart Study. *Diabetologia* 2007, 50(7):1401-1408.

38. Jimenez-Pavon D, Castillo MJ, Moreno LA, Kafatos A, Manios Y, Kondaki K, Beghin L, Zaccaria M, de Henauw S, Widhalm K, et al: Fitness and fatness are independently associated with markers of insulin resistance in European adolescents; the HELENA study. *Int J Pediatr Obes* 2011, 6(3-4):253-260.

39. Eisenmann JC, Welk GJ, Ihmels M, Dollman J: Fatness, fitness, and cardiovascular disease risk factors in children and adolescents. *Med Sci Sports Exerc* 2007, 39(8):1251-1256.

40. Berkey CS, Rockett HR, Field AE, Gillman MW, Frazier AL, Camargo CA, Colditz GA: Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics* 2000, 105(4):E56.

41. Wilks DC, Rank M, Christle J, Langhof H, Siegrist M, Halle M: An inpatient lifestyle-change programme improves heart rate recovery in overweight and obese children and adolescents (LOGIC Trial). *Eur J Prev Cardiol* 2012.

42. Ara I, Vicente-Rodriguez G, Perez-Gomez J, Jimenez-Ramirez J, Serrano-Sanchez JA, Dorado C, Calbet JA: Influence of extracurricular sport activities on body composition and physical fitness in boys: a 3-year longitudinal study. *Int J Obes* 2006, 30(7):1062-1071.

43. Hruby A, Chomitz VR, Arsenault LN, Must A, Economos CD, McGowan RJ, Sacheck JM: Predicting maintenance or achievement of healthy weight in children: the impact of changes in physical fitness. *Obesity* 2012, 20(8):1710-1717.

44. DuBose KD, Eisenmann JC, Donnelly JE: Aerobic fitness attenuates the metabolic syndrome score in normal-weight, at-risk-for-overweight, and overweight children. *Pediatrics* 2007, 120(5):e1262-1268.

45. Sacheck JM, Kuder JF, Economos CD: Physical fitness, adiposity, and metabolic risk factors in young college students. *Med Sci Sports Exerc* 2010, 42(6):1039-1044.

46. McMurray RG, Harrell JS, Bangdiwala SI, Bradley CB, Deng S, Levine A: A school-based intervention can reduce body fat and blood pressure in young adolescents. *J Adolesc Health* 2002, 31(2):125-132.

47. Danforth JS, Allen KD, Fitterling JM, Danforth JA, Farrar D, Brown M, Drabman RS: **Exercise as a treatment for hypertension in low-socioeconomic-status black children.** *J Consult Clin Psychol* 1990, **58(2)**:237-239.

48. McKay HA, MacLean L, Petit M, MacKelvie-O'Brien K, Janssen P, Beck T, Khan KM: **"Bounce at the Bell": a novel program of short bouts of exercise improves proximal femur bone mass in early pubertal children.** *Br J Sports Med* 2005, **39(8)**:521-526.

49. MacKelvie KJ, Khan KM, Petit MA, Janssen PA, McKay HA: **A school-based exercise intervention elicits substantial bone health benefits: a 2-year randomized controlled trial in girls.** *Pediatrics* 2003, **112(6 Pt 1)**:e447.

50. Donnelly JE, Lambourne K: **Classroom-based physical activity, cognition, and academic achievement.** *Prev Med* 2011, **52(Suppl 1)**:S36-42.

51. Dwyer T, Sallis JF, Blizzard L, Lazarus R: **Relationship of academic performance to physical activity and fitness in children.** *Pediatr Exerc Sci* 2001, **13(3)**:225-237.

52. Winsley RJ, Armstrong N, Middlebrooke AR, Ramos-Ibanez N, Williams CA: **Aerobic fitness and visceral adipose tissue in children.** *Acta Paediatr* 2006, **95(11)**:1435-1438.

53. Haas GM, Liepold E, Schwandt P: **Percentile curves for fat patterning in German adolescents.** *World J Pediatr* 2011, **7(1)**:16-23.

54. Brambilla P, Bedogni G, Moreno LA, Goran MI, Gutin B, Fox KR, Peters DM, Barbeau P, De Simone M, Pietrobelli A: **Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children.** *Int J Obes* 2006, **30(1)**:23-30.

55. Seppala-Lindroos A, Vehkavaara S, Hakkinen AM, Goto T, Westerbacka J, Sovijarvi A, Halavaara J, Yki-Jarvinen H: **Fat accumulation in the liver is associated with defects in insulin suppression of glucose production and serum free fatty acids independent of obesity in normal men.** *J Clin Endocrinol Metab* 2002, **87(7)**:3023-3028.

56. Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL, Nonas C, Kahn R: **Waist Circumference and Cardiometabolic Risk: a Consensus Statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association.** *Obesity* 2007, **15(5)**:1061-1067.

57. Ara I, Moreno LA, Leiva MT, Gutin B, Casajus JA: **Adiposity, physical activity, and physical fitness among children from Aragon, Spain.** *Obesity* 2007, **15(8)**:1918-1924.

58. Ara I, Vicente-Rodriguez G, Jimenez-Ramirez J, Dorado C, Serrano-Sanchez JA, Calbet JA: **Regular participation in sports is associated with enhanced physical fitness and lower fat mass in prepubertal boys.** *Int J Obes Relat Metab Disord* 2004, **28(12)**:1585-1593.

59. Rengasamy S: **A physical fitness intervention program within a physical education class on selected health-related fitness among secondary school students.** *Procedia Soc Behav Sci* 2012, **55(2012)**:1104-1112.