4-2019

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Pediatric Physical Therapy, Vol. 31, No. 2 (April 2019): 134-140. DOI.

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Abstract

Purpose:

To determines whether adolescents who are fit with overweight/obesity are similar in their metabolic profile to adolescents who are fit and normal weight.

Methods:

Adolescents participated in 3 sessions: (1) resting vitals and anthropometrics; (2) maximal aerobic treadmill test ($\dot{V}O_{2max}$) to determine physical fitness; and (3) dual-energy x-ray absorptiometry and fasting laboratory draw for analysis of insulin, glucose, high-density lipoprotein, triglycerides, and C-reactive protein.

Results:

Of the 30 fit adolescents who are normal weight and 16 adolescents who are fit and overweight/obese (OW/OB), metabolic syndrome was apparent in 1 adolescent who are normal weight and 4 adolescents who are OW/OB. Metabolic syndrome severity was positively associated with body mass index, waist circumference, total body fat, insulin resistance, and C-reactive protein but inversely associated with peak relative, but not lean $\dot{V}O_{2max}$.

Conclusions:

Despite good physical fitness, adolescents who are OW/OB demonstrated greater metabolic syndrome than adolescents who are normal weight. Future intervention research is necessary to explore the relation between physical fitness and metabolic syndrome.

INTRODUCTION

Health professionals often focus on weight status as related to body mass index (BMI) when determining health status in adolescents. Many adolescents exceed these recommended weight guidelines resulting in deleterious health effects. As weight increases, there is a greater risk for metabolic syndrome (MetS)—a cluster of interrelated risk factors that occur prior to type 2 diabetes and cardiovascular disease.[1,2] Identification of MetS severity in adolescents includes assessing obesity, triglycerides (TGs), high-density lipoprotein (HDL), systolic blood pressure (SBP), and fasting glucose.[3,4]

While not part of the diagnostic criteria, physical fitness levels are an important contributor to metabolic health in that children with poor physical fitness are at risk of developing MetS.[5–9] Specific to weight status, physical fitness can attenuate the metabolic risk score in children with overweight/obesity (OW/OB).[10] Furthermore, regular participation in moderate to vigorous physical activity, which can improve physical fitness, is a strong predictor of metabolic health in children who are obese.[11] Thus, physical fitness may be a distinguishing factor between adolescents with obesity who are metabolically healthy/unhealthy. This is an important distinguishing feature because many children with OW/OB also have low fitness levels.

This is the first study to control for physical fitness levels in identifying metabolic health for adolescents across weight status. The aim is to determine whether adolescents who are fit and OW/OB are metabolically healthy and similar in their metabolic profile to adolescents who are fit and normal weight. We hypothesize that adolescents who are physically fit will have minimal MetS severity, although the adolescents with higher weight status will have greater MetS severity than adolescents who are normal weight. A subaim will identify the relation between MetS severity, C-reactive protein (CRP), and central adiposity in adolescents who are fit across weight status. Understanding the effect of physical fitness in MetS severity could help clinicians in providing more effective rehabilitation for this condition.

METHODS

Subjects

Adolescents and their parent/legal guardian were recruited from a Midwestern United States metropolitan area. All adolescents (12-17 years) were screened via phone with parent/legal guardian. Adolescents were eligible for participation with the following exclusions: (1) exercise contraindications, (2) non-English speaking, (3) cognitive delays, (4) pregnancy, (5) claustrophobia, or (6) a history of mental health disorder. Marquette University Institutional Review Board approved the protocol.

Research Design

Data were collected as part of a larger study investigating pain, exercise-induced hypoalgesia, and conditioned pain modulation in adolescents across the weight spectrum.[12–14] Adolescents participated in 3 experimental sessions (approximately 1 week between sessions). In the first session, the adolescent and the parent completed written informed assent and consent, respectively. Resting vitals, anthropometrics, and self-reported physical activity levels were measured. During the next 2 sessions, adolescents completed either the treadmill or dual-energy x-ray absorptiometry (DXA) in a counterbalanced manner. The treadmill session included a maximal aerobic treadmill test ($\dot{V}O_{2max}$). The DXA session included a fasting laboratory draw and measurement of body composition. Gift cards were provided to the adolescent and the parent following the completion of each session as compensation.

Resting Vitals

Resting vitals (heart rate [HR], pulse oximetry, and blood pressure) were taken via standard procedures. SBP and diastolic blood pressure (DBP) absolute values were converted to *z* scores and percentiles for the participant's height, age, and sex. Participants were classified as having normal blood pressure (<90th percentile), prehypertension (90th-94th percentiles), and hypertension (>95th percentile).

Weight Status and Body Composition

Weight status was determined through height and weight, which were measured with a calibrated stadiometer and standing scale, respectively. BMI was calculated and plotted for percentiles and *z* scores. Adolescents were classified as normal weight (BMI *z* score <1.00), OW (BMI *z* score 1.00-1.63), and OB (BMI *z* score ≥1.64).

Circumferential measurements (centimeters) at the natural waist were also taken for each adolescent as a measurement of body composition. Waist circumference (WC) was compared to cutoffs for the 80th percentile based on sex and age.

Additional body composition measurements were completed using total body DXA scans via the Lunar GE Prodigy (GE, Madison, Wisconsin) bone densitometer. Scans were analyzed using Lunar GE Prodigy pediatric software to quantify total body fat (%), total lean mass, and trunk fat mass. Total body fat *z* scores for age and sex were determined via pediatric body composition reference charts.

Tanner Staging

Each adolescent completed a Tanner Staging questionnaire to self-report pubertal stage (Stage I [prepubertal], Stages II-IV [peripubertal], and Stage V [full maturity]).

Blood Collection and Analyses

Fasting blood samples were collected using standard venipuncture methods. Samples were transported to the Clinical and Translational Science Institute Core Laboratory (Milwaukee, Wisconsin) for analysis of insulin, glucose, HDL, TG, and CRP.

Total serum insulin was determined by radioimmunoassay (EMD Millipore Corp, Billerica, Massachusetts). The intra-assay coefficient of variability (CV) for human insulin is 3% to 4.5% and inter-assay CV is 3% to 4%. Glucose was determined using a glucose oxidase method (GM9 Analox Instruments, Lunenburg, Massachusetts); the CV ranges between 1.0% and 1.5%. Glucose between 60 and 100 mg/dL was considered normal. The calculation for the homeostatic model assessment of insulin resistance (HOMA-IR) was completed as follows:

$$\mathrm{HOMA-IR} = \frac{(\text{Fasting glucose in mg/dL})(\text{Fasting insulin in mU/L})}{405}$$

HOMA-IR values less than 2.00 were considered normal. HDL and TG were determined spectrophotometrically, using manufactured kits (Roche Diagnostics and Stanbio). The interassay CV is 2.0% (low concentrations) and 0.9% (high concentrations). An HDL 45 mg/dL or more and TG 125 mg/dL or less were considered normal. High-sensitivity CRP was determined using a solid phase enzyme-linked immunosorbent assay (ELISA) (MP Biomedicals, West Chester, Pennsylvania). The intra-assay CV was 2% to 4% and the inter-assay CV of 2.5%. CRP less than 3.0 mg/L was considered normal.

Metabolic Syndrome Severity Score

Previously, diagnosis of MetS was completed via categorical methods such as the World Health Organization and the International Diabetes Foundation, which base diagnosis on cutoff points for various components (eg, WC and blood pressure). However, a continuous model developed by Gurka et al[3] now allows for identification of metabolic syndrome severity, diagnosis of metabolic syndrome, and to track changes in severity via *z* scores. Using this model, the severity of MetS was calculated as a continuous *z* score using the following data: weight, height, birth date, test date, sex, race/ethnicity, TG, HDL, SBP, and fasting glucose, using the online calculator at http://mets.health-outcomes-policy.ufl.edu/calculator/. Adolescents with a *z* score cutoff of more than 0.75 were identified as having MetS.[3]

Maximal Treadmill Testing

Adolescents completed a maximal aerobic treadmill (T-2100, GE Healthcare, El Paso, Texas) test using a

$\dot{V}O_{2max}$

Bruce protocol. Twelve-lead EKG (CASE Cardiosoft V6.61, GE Healthcare, El Paso, Texas) and metabolic monitoring (eg, peak oxygen consumption) (Encore 29c, VMAX, Palm Springs, California) were performed. Adolescents reported rate of perceived exertion (RPE, 0-10) at the end of each 3-minute stage and at termination. Test termination was based on meeting at least 2 of the 3 following criteria: (1) volitional fatigue (RPE >8), (2) respiratory quotient more than 1.0, and (3) HR more than 85% HR max according to the American College of Sports Medicine (ACSM) guidelines. Verbal encouragement was given throughout the test.

Data points from the $\dot{V}O_{2max}$ protocol include peak relative $\dot{V}O_{2max}$ (mL/total body mass, kg/min), peak lean $\dot{V}O_{2max}$ (mL/lean body mass, kg/min), and absolute $\dot{V}O_{2max}$ (L/min) as per ACSM definitions. Each adolescent's relative $\dot{V}O_{2max}$, the current ACSM recommendation for cardiorespiratory physical fitness, was compared to the Healthy Fitness Zone cutoff values of the FitnessGram, a comprehensive pediatric health-related fitness assessment using criterion-referenced standards. The FitnessGram Health Fitness Zone standards (age and gender specific) are established based on how fit children need to be for good health. Adolescents were classified as fit using the peak relative $\dot{V}O_{2max}$ cutoffs.

Statistical Analysis

Data was analyzed using Statistical Package for the Social Sciences (SPSS 23, IBM, Chicago, Illinois). Mean ± standard deviations are shown in Table 1. Independent *t* tests were completed to identify health status differences in regard to age, resting vitals, anthropometrics, physical activity, physical fitness, MetS, and inflammation between the normal weight versus OW/OB groups. An α level of $P < .05$ was used for *t* tests.

TABLE 1: Description of All Fit Adolescent Subjects by Weight Status

	Normal Weight (n = 30)	**Overweight/Obese (n = 16)**
Demographics		
Sex, males, n (%)	16 (53)	7 (44)
Age, mean ± SD, y	15.7 ± 1.7	14.4 ± 1.7[a]
Ethnicity, n (%)		
Caucasian	28 (93)	12 (75)
African American	0 (0)	3 (19)
Hispanic	2 (7)	1 (6)
Resting vitals		
Systolic BP, mm Hg	106.9 ± 11.2	114.1 ± 11.5[a]
Systolic BP z score	−0.69 ± 0.93	0.21 ± 0.94[a]
Prehypertension systolic BP, 90th-94th percentiles), n (%)	1 (3)	2 (13)
Hypertension systolic BP, ≥95th percentile, n (%)	0 (0)	0 (0)
Diastolic BP, mm Hg	71.9 ± 6.5	74.1 ± 8.7
Diastolic BP z score	0.48 ± 0.60	0.53 ± 0.72
Prehypertension diastolic BP, 90-94th percentiles, n (%)	1 (3)	0 (0)
Hypertension diastolic BP, ≥95th percentile, n (%)	0 (0)	1 (6)
Weight status and body composition		
Weight status		
BMI, kg/m^2	21.2 ± 1.8	26.8 ± 2.4[a]
BMI z score	0.26 ± 0.43	1.59 ± 0.31[a]
Body composition (circumferential measurements)		
Waist circumference, cm	70.5 ± 5.6	80.5 ± 6.5[a]
Waist circumference >80th percentile, n (%)	0 (0)	9 (56)
Body composition (DXA)		
Total body fat, %	20.8 ± 9.4	37.8 ± 7.2[a]
Total body fat z score (age and gender)	−0.81 ± 1.01	1.38 ± 0.38[a]
Trunk fat mass, kg	12.3 ± 6.1	27.0 ± 6.6[a]
Total lean mass, kg	46.1 ± 10.7	43.6 ± 9.7
Aerobic physical fitness		
Peak relative $\dot{V}O_{2max}$, mL/kg/min	58.3 ± 12.6	47.2 ± 7.0[a]
Peak lean $\dot{V}O_{2max}$, mL/LBM kg/min	76.5 ± 10.6	79.2 ± 8.5
Absolute $\dot{V}O_{2max}$, L/min	3.5 ± 1.0	3.4 ± 0.8
	n = 29	**n = 15**
Metabolic syndrome components[b]		
Glucose		
Normal = 60-100 mg/dL	81.4 ± 7.5	84.8 ± 7.5
Above normal, n (%)	0 (0)	0 (0)
Insulin		
Normal ≤15 µU/mL	9.0 ± 2.5	15.1 ± 7.3[a]

Above normal, n (%)	1 (3)	5 (33)
Insulin resistance		
Normal <2.00	1.8 ± 0.6	4.3 ± 3.0[a]
Above normal, n (%)	10 (34)	13 (87)
HDL		
Normal ≥45 mg/dL	33.7 ± 10.5	38.4 ± 9.0
Below normal, n (%)	22 (76)	10 (67)
Triglycerides		
Normal ≤125 mg/dL	74.8 ± 33.2	75.0 ± 26.2
Above normal, n (%)	3 (10)	1 (7)
	n = 30	**n = 15**
C-reactive protein		
Normal <3.0 mg/L	0.58 ± 0.62	3.03 ± 3.21[a]
Above normal, n (%)	1 (3)	5 (33)
	n = 29	**n = 15**
Metabolic Syndrome Severity Score		
Normal	−0.07 ± 0.46	0.60 ± 0.43[a]
Above normal, n (%)	1 (3)	4 (27)

Abbreviations: BMI, body mass index; BP, blood pressure; DXA, dual-energy x-ray absorptiometry; HDL, high-density lipoprotein; HOMA-IR, Homeostatic
Model Assessment of Insulin Resistance; LBM, lean body mass; SD, standard deviation.

[a]Significance: P < .05.

[b]Subject numbers are designated within the column due to incomplete blood draw.

With continuous variables across the entire fit sample, Pearson's correlations were completed to determine whether relation existed between weight status (BMI *z* score), body composition (WC, total body fat *z* score, and trunk fat mass), SBP *z* score, physical fitness level (peak relative $\dot{V}O_{2max}$, peak lean $\dot{V}O_{2max}$, and MetS components (HOMA-IR, HDL, CRP, and Metabolic Syndrome Severity Score [MSSS]). A corrected α level of *P* ≤ .005 was used for correlations.

RESULTS

Subjects

Of the 62 subjects who were tested, 46 adolescents (15.3 ±1.8 years; 23 males) were classified as fit using the $\dot{V}O_{2max}$ FitnessGram criteria. Two participants had missing data points due to incomplete blood draw. Tanner stages were as follows by weight grouping: normal weight—Tanner I (n = 0), II (n = 1), III (n = 4), IV (n = 13), and V (n = 12); OW/OB—Tanner I (n = 0), II (n = 2), III (n = 4), IV (n = 5), and V (n = 5).

Based on their BMI *z* score, 30 adolescents were classified as normal weight and 16 adolescents as OW/OB (9 OW and 7 OB) (Table 1). The majority of both normal weight and OW/OB adolescents demonstrated normal blood pressure with the following exceptions: 3—prehypertension SBP, 1—prehypertension DBP, and 1—hypertension DBP. For body composition, 9 adolescents who were OW/OB had a WC more than 80th percentile while no normal weight adolescents were above the 80th percentile. Significant differences occurred for the normal weight in comparison with adolescents who were OW/OB: older (*P* = .02), lower SBP (*P* = .004), lower BMI (*P* < .001), lower total body fat percentage (*P* < .001), and lower trunk fat mass (*P* < .001). Total lean mass was similar between the weight groups (*P* > .05).

While all adolescents were classified as physically fit, adolescents who were normal weight had greater peak relative $\dot{V}O_{2max}$ (mL/kg/min) than the adolescents who were OW/OB ($P < .001$). No differences existed between weight groups for absolute $\dot{V}O_{2max}$ (L/min) or peak lean $\dot{V}O_{2max}$(mL/kg/min) ($P > .05$).

For laboratory values, glucose was not elevated in any of the adolescents, although 6 adolescents (1 normal weight, 5 OW/OB) had hyperinsulinemia, 23 adolescents (10 normal weight, 13 OW/OB) demonstrated insulin resistance, 32 adolescents (22 normal weight, 10 OW/OB) had low HDL, and 4 adolescents (3 normal weight, 1 OW/OB) had elevated TG. CRP was elevated in 6 adolescents (1 normal weight, 5 OW/OB) and MetS was seen in 5 adolescents (1 normal weight, 4 OW/OB). OW/OB adolescents had higher insulin ($P = .006$), insulin resistance ($P = .004$), CRP ($P = .01$), and MSSS ($P < .001$). No differences existed in glucose, HDL, or TG between the normal weight and OW/OB groups ($P > .05$).

Relation of MetS Factors in a Fit Adolescent Population

BMI *z* score, an indicator of weight status, was positively correlated with measures of body composition (WC, total body fat *z* score, trunk fat mass), SBP, insulin resistance, and CRP (Table 2). Physically fit adolescents with higher weight status demonstrate higher body fat, central adiposity, blood pressure, insulin resistance, and inflammation. Body composition measurements including total body fat *z* score and trunk fat mass were both inversely associated with peak relative $\dot{V}O_{2max}$; WC was positively correlated with total body fat *z* score, trunk fat mass, SBP, and insulin resistance but inversely associated with peak relative $\dot{V}O_{2max}$. Adolescents who are fit with greater central adiposity demonstrated higher body fat, insulin resistance, and lower physical fitness.

TABLE 2: Relation Between Weight Status, Body Composition, Physical Fitness, Inflammation, and Metabolic Syndrome

	Waist Circumference	Total Body Fat z Score Syndrome Severity	Trunk Fat Mass	Systolic BP z Score	Peak Relative $\dot{V}O_{2max}$	Peak Lean $\dot{V}O_{2max}$	Insulin Resistance (HOMA-IR)	HDL	CRP	Metabolic Syndrome Severity
BMI z score	r = 0.851, P < .001	r = 0.799, P < .001	r = 0.778, P < .001	r = 0.394, P = .007		r = 0.202, NS	r = 0.637, P < .001	r=−0.030, NS	r = 0.420, P = .001	r =0.819, P < .001
Waist circumference		r = 0.626, P < .001	r = 0.650, P < .001	r = 0.433, P = .003	r=−0.597, P < .001	r = 0.134, NS	r = 0.711, P < .001	r=−0.097, NS	r = 0.289, P = .027	r = 0.742, P < .001
Total body fat z score			r = 0.907, P < .001	r = 0.120, NS	r=−0.636, P < .001	r=−0.025, NS	r = 0.432, P = .003	r = 0.276, NS	r = 0.436, P = .003	r = 0.515, P < .001
Trunk fat mass				r = 0.238, NS	r=−0.707, P < .001	r=−0.045, NS	r = 0.467, P < .001	r = 0.054, NS	r = 0.606, P < .001	r = 0.588, P < .001
Systolic BP z score					r=−0.105, NS	r = 0.035, NS	r = 0.334, P = .027	r = 0.207, NS	r = 0.222, NS	r = 0.568, P < .001
Peak relative $\dot{V}O_{2max}$							r = −0.548, P < .001	r = 0.277, P = .035	r=−0.357, P = .006	r=−0.616, P < .001
Peak lean $\dot{V}O_{2max}$							r = 0.359, P = .017	r = −0.036, NS	r = 0.077, NS	r = 0.009, NS
Insulin resistance (HOMA-IR)								r=−0.317, P = .015	r = 0.259, NS	r = 0.678, P < .001
HDL									r=−0.018, NS	r=−0.356, P = .006
CRP										r = 0.422, P = .001

Abbreviations: BMI, body mass index; BP, blood pressure; CRP, C-reactive protein; HDL, high-density lipoprotein; HOMA-IR, Homeostatic Model Assessment of Insulin Resistance; NS, nonsignificant.

Peak relative $\dot{V}O_{2max}$ was inversely associated with insulin resistance. MSSS was positively associated with BMI *z* score, WC, total body fat *z* score, trunk fat mass, SBP *z* score, insulin resistance, and CRP but negatively associated with peak relative $\dot{V}O_{2max}$ (Table 2). Peak lean $\dot{V}O_{2max}$ was not associated with any other variables (Table 2).

DISCUSSION

This is a unique study that focused on a population of adolescents who are fit across the weight status using a continuous scale for MSSS. Interestingly, the adolescents who are fit had MetS rate (11%) that was similar to the overall prevalence of MetS in adolescents in the United States (10%),[15] which does not take into account physical fitness levels. Within the weight categories, 27% of the adolescents who were fit with OW/OB and 3% of the adolescents who were fit and normal weight met the cutoff criteria for MetS; this is similar to past National Health and Nutrition Examination Survey data showing higher prevalence of MetS with increasing weight status.[16] Thus, when controlling for physical fitness levels across the weight status, adolescents who are OW/OB with similar lean mass continue to have higher MetS severity, and physical fitness was moderately related to MSSS. Our data show that, even in a population that is fit, physical fitness, as measured by relative oxygen consumption including full body mass, could be a contributing factor to MetS.

Diagnosis of MetS has included a variety of factors including central adiposity, insulin resistance/glycemic homeostasis, hypertension, and dyslipidemia.[1,17–19] However, other factors such as physical fitness and inflammation can contribute to MetS. Within our adolescents who were fit, several MetS factors were within normal adolescent limits or had minimal percentages above normal (ie, normal fasting glucose, no evidence of systolic hypertension, minimal diastolic hypertension, and minimal elevated TGs). Besides weight status, the only other significance between weight groups who were fit were insulin, insulin resistance, and SBP; adolescents with OW/OB demonstrate higher levels than the adolescents who are normal weight.

Insulin resistance, an important factor in health status, is described as a major contributor to MetS.[20] Despite insulin resistance being different between the weight groups, fasting glucose was similar between the weight groups who were fit; all participants demonstrated normal levels. It is often clinically misleading when adolescents have both fasting glucose and insulin within normal limits, but the interaction between these values is indicative of insulin resistance (HOMA-IR), a precursor to type 2 diabetes. Therefore, the HOMA-IR is a better clinical indicator of health status in contrast to evaluating glucose and insulin independently.

Another important component of metabolic syndrome is dyslipidemia, which is impacted by the imbalance of high low-density lipoprotein and low HDL levels. HDL levels also parallel physical activity participation[21] and were found to be similar for the adolescents who were fit between the weight groups. More of the adolescents who were fit and normal weight, however, had lower than recommended HDL levels than the adolescents who were fit and OW/OB (76% and 67%, respectively). Even though there was no difference in reported physical activity levels, more of the adolescents who were normal weight were also at risk of developing MetS based on the Physical Activity Questionnaire PAQ scores (57% normal weight and 50% OW/OB) despite all being deemed physically fit. Significant differences did not exist between the weight groups, but lower PAQ scores parallel the lower HDL level in the group that was normal weight. While regular participation in physical activity is often associated with less risk for MetS, others have shown that physical activity participation is not related.[22] In the current study, physical activity levels were similar between the weight groups, but physical fitness was higher in adolescents who were normal weight. Furthermore, physical fitness but not physical activity was associated with MSSS. Therefore, even in an adolescent population that is physically fit, physical fitness as measured by relative oxygen consumption (relative $\dot{V}O_{2max}$[mL/kg/min]) appears to contribute to MSSS.

Beyond weight status, body fat distribution (ie, central adiposity) has been implicated in better metabolic profiles in individuals with similar BMI.[23] Central adiposity may negatively affect metabolic health, as intra-abdominal obesity increases inflammation and negatively affects metabolic health.[24–26] Furthermore, individuals with less abdominal fat have better metabolic profiles than individuals with comparable BMIs but more abdominal fat.[23,27] Our adolescents who were fit did not demonstrate significant differences in lean body mass between weight groups, yet those with OW/OB exhibited more central adiposity, as measured by both a feasible clinical measure (WC) and a gold standard measure (DXA trunk fat mass) than the adolescents who were normal weight. Furthermore, higher WC and trunk fat mass were positively associated with MSSS and negatively associated with physical fitness in these adolescents across the weight spectrum. In agreement with our results, WC has been identified by others as an independent predictor of metabolically healthy obesity.[11] In addition, physical activity levels may be an important determinant in developing abdominal obesity. Following 2 weeks of reduced daily activity in adults, an increase in intra-abdominal fat mass but not in total fat mass occurred.[2] Additional pediatric studies are necessary to thoroughly assess the relation between weight, physical fitness, MetS, and body composition (DXA).

Inflammation is linked with both central adiposity and MetS[25,28] to the extent that obesity is now considered a low-grade inflammatory state. In our adolescents, weight status did influence CRP levels with adolescents with OW/OB demonstrating higher CRP in contrast to the adolescents who were normal weight. Physical fitness and inflammation were inversely related indicating that physical fitness may circumvent inflammation in the fit population. Across the entire adolescent sample, CRP was also positively associated with central adiposity and MSSS. Current literature still debates whether fatness or fitness contributes to inflammation to the same extent.[29–32]

CONCLUSIONS

This study shows that MetS is minimal in an adolescent population that is fit across weight status, and physical fitness can attenuate some components of MetS. Despite all adolescents being physically fit, MetS was associated with central adiposity (measured by WC and trunk fat mass) and inflammation across weight status. Clinicians working with adolescents should consider identification of metabolic syndrome severity in addition to weight status, body composition, and physical fitness levels. Measurement of WC is a feasible clinical tool to provide feedback to patients in the clinical setting in regard to fat distribution and risk of metabolic health concerns. Finally, additional research is warranted to identify the effect of physical fitness on MSSS and the recommended increases in physical fitness necessary to improve metabolic health.

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