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Increased Oxidative Stress in Healthy Children Following an Exercise Program: A Pilot Study

Melita M. Nasca, PhD^{*}, Renliang Zhang, MD, PhD[†], Dennis M. Super, MD[‡], Stanley L. Hazen, MD, PhD[†], and Howard R. Hall, PhD, PsyD[§]

^{*} Department of Medicine, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA

[†] Center for Cardiovascular Diagnostics and Prevention, Cleveland Clinic Foundation, Cleveland, OH

[‡] MetroHealth Medical Center and Case Western Reserve University, Cleveland, OH

[§] Department of Pediatrics, Rainbow Babies and Children's Hospital, Case Western Reserve University, Cleveland, OH

Abstract

Exercise can induce oxidative stress or an imbalance between reactive oxygen species and cellular antioxidant defenses.

Objective—We investigated the effect of a real-life exercise program on systemic oxidative stress measured by urinary concentrations of 8-isoprostaglandin $F_{2\alpha}$ (8-iso-PGF $_{2\alpha}$), a noninvasive index of lipid peroxidation, in a well-characterized pediatric group.

Methods—Healthy but primarily sedentary, 8- to 10-year-old children ($n = 6$, mean age 8.8 ± 0.9 years) of equally distributed healthy weight, overweight, and obese categories, participated in a 5-week exercise program (track and field summer camp, 2 hours/day, 1–2 days/week).

Results—By using high-performance liquid chromatography with online electrospray ionization tandem mass spectrometry (LC/ESI/MS/MS), we found a significant ($p = .028$) increase in group mean urinary 8-iso-PGF $_{2\alpha}$ concentration from 8.163 ± 6.919 ng/mg creatinine pre-exercise program to 32.320 ± 16.970 ng/mg creatinine post-exercise program. The increase was also measured at each individual level. We found preliminary evidence that pre- and post-exercise program urinary 8-iso-PGF $_{2\alpha}$ concentrations selectively correlated with children's cardiometabolic characteristics and mood.

Conclusion—Our results warrant further exploration of the relationships between pre/post-exercise oxidative stress marker 8-iso-PGF $_{2\alpha}$ and cardiometabolic characteristics, exercise habits, eating habits, and mood to determine whether increased post-exercise oxidative stress in healthy children is part of their normal adaptation to exercise or mediator of oxidative injury.

Index terms

oxidative stress; free radicals; lipid peroxidation; mood; LC/ESI/MS/MS

Address for reprints: Howard R. Hall, PhD, PsyD, Division of Developmental/Behavioral Pediatrics and Psychology, Rainbow Babies and Children's Hospital, Case Medical Center; Howard.Hall@uhhospitals.org.

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Regular exercise is linked to reduced risk of developing obesity, hypertension, cardiovascular disease, diabetes, cancer, depression, and osteoporosis and helps prevent premature death.¹ Not surprisingly, it is widely advocated by health care providers attempting to alleviate such chronic burden. Moreover, the current emphasis is on increasing the “levels” of physical activity across all age groups, with the least fit and/or overweight people expected to be the main beneficiaries.²

However, acute exercise (session of short duration and progressive intensity) induces oxidative stress or an imbalance between reactive oxygen species and cellular antioxidant defenses, although the mechanisms and, especially, the significance are not completely understood.³ Generally in adults, long-term aerobic exercise is considered to be an effective nonpharmacologic intervention to decrease systemic oxidative stress.⁴ However, scarce information is available regarding the effects of repeated exercise on oxidative stress in healthy children.^{5,6}

Currently, measurement of F₂-isoprostanes (F₂-IsoPs) serves as the most established, noninvasive method to quantitate systemic oxidative stress in vivo, in humans.⁷ A relatively novel family of prostaglandin F₂ isomers, F₂-IsoPs, are free-radical induced, bioactive peroxidation products of arachidonic acid. Their urinary excretion provides an index of nonenzymatic lipid peroxidation,⁸ with 8-isoprostaglandin F_{2α} being one of the most often studied F₂-IsoPs in protocols involving human research. Such a high interest was largely driven by the fact that urinary excretion of 8-isoprostaglandin F_{2α} was found in conditions associated with elevated oxidative stress, including overweight or obesity,⁹ atherosclerosis,⁷ type 2 diabetes,¹⁰ and neurodegenerative diseases.¹¹

Intriguingly, in healthy adults, shorter term (2 hours to 7 days) exercise was shown to increase,¹² decrease,¹³ or have no effect¹⁴ on IsoPs concentrations. Such apparently contradictory results may be at least partially attributed to the modulatory role of exercise mode, duration, volume, and intensity and individual fitness status on the amount of lipid oxidation during and after exercise. Nevertheless, there is no current consensus regarding the long-term effects of exercise on IsoPs concentrations variations or their clinical significance in healthy adults, whereas experimental data in asymptomatic children are just emerging.^{15,16}

These facts are particularly surprising in light of the cardinal role exercise plays in young human growth, development and chronic disease prevention and the now acknowledged differences in metabolic and psychologic effects of exercise in children compared to adults.⁶

Equally important, but scarcely approached so far, is an understanding at cellular level of exercise effects in healthy children. Such knowledge is necessary to elucidate the mechanisms involved in normal growth and development, as well as for chronic disease prevention. From clinical application standpoint, this should ultimately translate into pediatric specific, as opposed to the currently available adult extrapolated, exercise design, implementation, and optimization. Knowledge of the effects of different real-life type, such as community-based, exercise programs have on healthy children should help health care providers make effective, individualized recommendations for each specific young patient.

Therefore, the purpose of this study was to investigate the effect of a real-life exercise program (track and field summer camp) on systemic oxidative stress as measured by urinary concentrations of 8-isoprostaglandin F_{2α} in a well-characterized group of healthy children. It was initiated as a pilot project to test the feasibility of a full-scale research study.

METHODS

Study Participants

Six children (3 boys and 3 girls) aged 8 to 10 years, representing 26% of a recreational outdoor track and field summer camp's 23 enrollees, agreed to participate and completed the study. All study participants were healthy, asymptomatic, and not on medications, as documented by medical history questionnaire. Written informed assent was obtained from each child and written informed consent from one of their parents or guardians. All procedures were approved by the Institutional Review Board for Human Investigation of the University Hospitals of Cleveland.

Study Design and Experimental Procedures

The summer camp was exclusively conducted on a synthetic outdoor track and its adjacent jumping and throwing areas. The exercise program addressed in this study consisted of 8 workout sessions distributed over 5 weeks: 2 hours/day, 1 to 2 days/week (Tuesdays and Thursdays). Participants engaged in workouts at approximately equally distributed low, moderate, and high intensity exercise (33% each per session) of approximately equally distributed: runs, jumps, and throws (33% each per session). The children varied their exercise intensity according to the cue words "easy" (for low intensity), "fair" (for moderate intensity), and "hard" (for high intensity). This combination of aerobic, anaerobic, and strength exercise was accomplished through drills, games, and track and field event-specific, age-appropriate techniques. Each workout session started with 20 minutes warm up of jogging and drills and concluded with 10 minutes cool down of jogging. Brief rest/water breaks were allowed throughout the workout sessions at each individual child's need and request. Of note, because the great majority of participants were younger, nearly sedentary children (based on their age, physical appearance, motor skills level, and reported exercise experience by children and their parents), coaches decided to minimize injury risk by beginning the camp with 4 preparatory sessions distributed over 2 weeks, 2 hours/day, and 2 days/week (Tuesdays and Thursdays) of low and moderate intensity track and field-specific drills, basic running, jumping, throwing, and running pacing techniques. These 4 preparatory sessions preceded the actual study and were, therefore, not included in it. To characterize participants' anthropometry, blood pressure, heart rate, mood states, and cardiorespiratory fitness, field measurements were performed at the pre-exercise program time point.

After children arrived at the camp and rested quietly for 5 minutes, measurements were performed by the same registered nurse practitioner. Height was measured with a wall mounted stadiometer and weight with a calibrated electronic scale with children lightly dressed and without shoes. Body mass index (BMI) was calculated for each individual child as the weight (kilograms) to height² (meters) ratio. Centers for Disease Control and Prevention growth charts¹⁷ were used to obtain BMI percentiles (BMI %). Waist circumference (WC) was measured with a fiberglass tape at just above the uppermost lateral border of the right ilium, with subjects in the standing position and at the end of a normal expiration. Age-, sex-, and ethnicity-specific tables based on the third National Health and Nutrition Examination Survey (NHANES III) data in children¹⁸ were used to obtain WC percentiles (WC%). Blood pressure at rest was measured in the right arm by standard auscultation technique using a pediatric size cuff. The mean of 2 readings was recorded and used in calculations.

NIH pediatric hypertension classification¹⁹ was used for subject's systolic blood pressure or diastolic blood pressure. Heart rate was measured by palpation at the right radial artery site. The Profile of Mood States questionnaire modified and adapted by Williamson et al²⁰ for pediatric exercise use (self-reported 16 items, 8 positive adjectives and 8 negative

adjectives, respectively; each of these categories scored additively, item-by-item on a 0 to 4 scale; coefficient alpha reliabilities of 0.67 for positive mood and 0.61 for negative mood) was administered to assess children's positive mood and negative mood, respectively. Currently, there are no pediatric Profile of Mood States reference norms or any consensus on a reliable research or clinical instrument to measure mood in healthy prepubertal children. Such data would be a useful addition to general health checks and also helpful for diagnosing mood disorders in this young age group.

All children participating in this study were fluent in English at a level required to understand and follow coaches' instructions exclusively given in this language. The 1-mile run/walk, the field test of cardiorespiratory fitness recommended and frequently used in most national test batteries with young children,²¹ was used as the field test of cardiorespiratory fitness in this study. The 1-mile run/walk took place at pre-exercise program time point, immediately following the anthropometric, physical, and mood measurements and after completion of the usual warm up for that given training session.

Each child collected at home morning, fasting urine samples into sterile specimen cups at pre-exercise (first of the study's 8 workout sessions) and post-exercise program (last day of camp) time points. The samples were kept in refrigerator until brought to the track, then immediately placed on dry ice and transported to the Cleveland Clinic laboratory, and stored at -80°C until analysis. All samples were analyzed in a single batch.

High-performance liquid chromatography online electrospray ionization tandem mass spectrometry (LC/ESI/MS/MS) was used to quantify the F2-IsoPs and precursor arachidonic acid concentrations in urine. Analyses were performed using electrospray ionization in negative-ion mode with multiple-reaction monitoring of precursor and characteristic product ion specific for each analyte monitored. The transitions monitored were mass-to-charge ratio (m/z): m/z 303 $\rightarrow$ 259 for arachidonic acid; m/z 353 $\rightarrow$ 193 for 8-isoprostaglandin $\text{F}_{2\alpha}$; and m/z 357 $\rightarrow$ 197 for the deuterated internal standard prostaglandin $\text{F}_{2\alpha}\text{-d}_4$. Urinary 8-isoprostaglandin $\text{F}_{2\alpha}$ concentrations are reported indexed to creatinine. Method accuracy was 96.6% and precision 92.7%.

Overall health status and living habits were assessed with modified Heyward questionnaires,²² the Medical History Questionnaire (self-reported, qualitative, 29 items on personal present and past 12 months medical symptoms, illnesses, and medication history and on family history of chronic illnesses) and Lifestyle Evaluation (self-reported, 10 items in combination of qualitative, yes/no, and multiple choices on exercise habits and eating habits). Children were allowed to maintain their usual eating and exercise habits throughout the study. They were permitted to receive assistance from their parents in completing any or all forms.

Statistical Analyses

A Wilcoxon signed ranks test was used to test for statistical significance of pre- versus post-exercise program F2-IsoPs levels. A nonparametric Spearman rho correlation was used to test for statistical significance between pre/post-exercise program IsoPs and each of the following: age, height, weight, BMI, BMI%, WC, WC%, systolic blood pressure, diastolic blood pressure, heart rate, positive mood score, negative mood score, mile run time, frequency of physical activity, duration of physical activity/session, fried foods eating/week, and eating out/week. A significance level of $p \leq .05$ was set. Group values are expressed as mean $\pm$ SD.

RESULTS

Cardiometabolic characteristics of the small but diverse group of children participating in this study (3 African American, 2 white, and 1 Hispanic, as disclosed in questionnaires) are presented in Table 1.

Both the mean and individual participant ages were below the reported national maturation values.²³ Although the children declined to complete the growth/development self assessment, all the girls disclosed not having reached menarche. Taken altogether, these characteristics are indicative of a prepubertal sample population. Of note,^{17,24} one third of our pilot study volunteers were of healthy weight (body mass index [BMI] percentiles for age and gender in the 5th to 84th range), one third were overweight (BMI percentiles in the 85th to 94th range), and one third were obese (BMI percentiles equal to or greater than 95th).

The group mean positive mood score was 19.2 ± 11 (range 4–31). Similarly, the group mean negative mood score was 3.0 ± 3.2 (range 0–8). Higher positive mood scores and lower negative mood scores are characteristic of healthy children. A group mean mile run/walk time of 14.3 ± 4.2 minutes (indicative of their cardiorespiratory fitness) was measured. These children, not regular vigorous exercisers (with one exception), had a reported habitual physical activity group mean of 2.4 ± 1.4 sessions/week with mean duration of 22.5 ± 18.7 min/session. Their reported physical activity habits included recreational running (50% of the children), recreational basketball (2 children), and recreational swimming and school-based running (1 child).

All (but one) children reported daily consumption of meat/eggs and regularly taking children's multivitamins. With the exception of 2 of them, participants reported daily fruit/vegetable consumption. Only 2 children reported daily refined carbohydrates consumption. Reported eating out ranged between 1 and 3 times a week and fried food inclusion in menu between 1 and 6 times a week in all but one of the participants. One child chose not to disclose personal information on eating out and fried foods consumption.

The children had a group mean pre-exercise program urinary 8-isoprostaglandin $F_{2\alpha}$ concentration of 8.163 ± 6.919 ng/mg creatinine and a group mean post-exercise program urinary 8-isoprostaglandin $F_{2\alpha}$ concentration of 32.320 ± 16.970 ng/mg creatinine (Figure 1), indicative of a 4-fold increase in group mean systemic oxidative stress. A Wilcoxon signed ranks test confirmed that the increase in pre-exercise program versus post-exercise program urinary F2-IsoPs levels was statistically significant ($p = .028$). Remarkably, each individual study participant demonstrated greater post- versus pre-exercise program F2-IsoPs values. Arachidonic acid concentrations were below the detection limit of 50 pmol/ml urine, thus assuring minimal post-sample collection autooxidation. A nonparametric Spearman rho correlation found pretraining urinary F2-IsoPs concentrations to be negatively correlated with baseline positive mood scores ($r = -.943$, $p = .005$).

Post-exercise program F2-IsoPs were negatively correlated with baseline: BMI ($r = -.886$, $p = .019$), BMI % ($r = -.812$, $p = .050$), waist circumference ($r = -.943$, $p = .005$), waist circumference percentiles ($r = -.841$, $p = .036$), heart rate ($r = -.841$, $p = .036$), and habitual physical activity frequency ($r = -.971$, $p = .001$). Interestingly, post-exercise program F2-IsoPs were positively correlated with frequency of habitual fried foods consumption ($r = .941$, $p = .005$) and with frequency of habitual eating out ($r = .820$, $p = .046$). No manifest injuries occurred in either the research study volunteers or the other camp participants, over the entire camp duration.

DISCUSSION

To our knowledge, this pilot research work is the first study to find increased systemic oxidative stress as measured by urinary excretion of lipid peroxidation index 8-isoprostaglandin $F_{2\alpha}$ (8-iso-PGF $_{2\alpha}$) in healthy children on unrestricted diets following a real-life exercise program.

By using high-performance liquid chromatography with on-line electrospray ionization tandem mass spectrometry, we found a significant increase of urinary 8-iso-PGF $_{2\alpha}$ in a group of healthy children aged 8 to 10 years following a real-life, 5-week exercise program (track and field summer camp, 2 hour/day, 1–2 day/week). Another novel preliminary finding from our study was the negative correlation of children's pre-exercise program urinary 8-iso-PGF $_{2\alpha}$ concentrations with their positive mood scores.

When compared with available age and gender matched data, the values in Table 1 and throughout the results are indicative of a predominantly sedentary,²⁵ unfit,^{21,26} and overweight or obese^{17,18,24} group of children participating in this study.

Our pre-exercise program urinary concentrations of 8-iso-PGF $_{2\alpha}$ were comparable with previously reported baseline values in healthy children of similar age.^{27,28} However, the reasons for greater baseline F $_{2}$ -IsoPs in healthy children from those studies and ours compared with healthy adults^{10,11} are unclear. Higher levels of IsoPs increase were reported in moderately trained or untrained exercising adults²⁹ as compared with trained adults,¹² suggesting a role training status may play in IsoPs response to exercise. Moreover, in a report on moderately trained adults, peak IsoPs values were observed at 72 hours post-exercise.²⁹ It is, therefore, possible that children's sedentarism and a similar post-exercise collection timing may help explain the dramatic post-exercise program IsoPs increase in our study. The negative correlation between physical activity frequency and post-exercise IsoPs found by us is supportive of previous reports linking regular training with protection against subsequent oxidative stress.⁴

Acute exercise is known to increase oxidative stress, mainly via mitochondrial hydrogen peroxide and superoxide generation and through neutrophil activation, ischemia reperfusion, and catecholamine autooxidation.³⁰ However, regular training in adults eventually provides protection against further exercise-induced oxidative stress by increased endogenous antioxidant production and improved mitochondrial respiratory control.³¹ Hence, it is possible that our children's IsoPs response to the brief, intermittent program of predominantly low frequency, low-to-moderate intensity exercise, may be more reflective of an initial phase of adaptation to exercise or acute like, rather than chronic exercise type of response.

In adults, up to 80% IsoPs increase was reported to be induced by exercise.^{12,29} Previous research found that during submaximal exercise, lipid oxidation rate was significantly higher in healthy prepubertal children than adults.³² Such differences in substrate utilization may at least in part account for the much higher IsoPs increase measured in our exercising children compared with existent data in adults.

Two research studies including IsoPs data in exercising asymptomatic but exclusively overweight children^{15,16} each found divergent effects. In one of them,¹⁵ 19 overweight youth (8 to 17 years, mean 13 ± 0.5 years) underwent a 2-week lifestyle residential program with high-fiber, low-fat, ad libitum diet and daily (2–2.5 hours of) play-type activity (beach games, tennis, and gym exercises). This combined diet and exercise intervention resulted in a more than 5-fold significant ($p < .01$) decrease in serum concentrations of measured (enzyme-linked immunosorbent assay-based kit) 8-iso-PGF $_{2\alpha}$ (44.6 ± 11.1 pg/ml pre-

lifestyle modification vs 8.3 ± 3.3 pg/ml post-lifestyle modification). Important to note is the observation of the authors that because of the combined lifestyle nature of their study, the individual contribution of diet and exercise components to the overall IsoPs results cannot be discerned.

In the other study¹⁶ with 19 overweight prepubertal children on unrestricted diets, 9 of them (mean age 10.8 ± 0.67 years) underwent a laboratory-based, structured, aerobic exercise training program (8 weeks, total of 4 times/week, 30–50 min/session stationary cycling at 50–80% of maximal intensity) with the other 10 children (mean age 11.0 ± 0.71 years) serving as controls (not participating in the laboratory exercise protocol but maintaining their usual levels of physical activity). No significant differences were found between the groups in plasma concentrations of 8-isoprostane levels (enzyme-linked immunosorbent assay-based measurements, baseline exercising group 13.7 ± 2.5 pg/ml to 11.8 ± 2.4 pg/ml post-intervention vs baseline control group 11.7 ± 1.2 pg/ml to 12.0 ± 1.7 pg/ml post-intervention). Differences in exercise mode, duration, intensity, frequency and total intervention length, and participants' cardiometabolic and general individual characteristics and training status may have been at least partly responsible for the divergent trends on IsoPs concentrations between those 2 studies and compared with ours.

In our pilot study, we found that post-exercise program 8-iso-PGF_{2α} were positively correlated with frequency of habitual fried foods consumption and with frequency of habitual eating out, possibly including arachidonic and linoleic acids-rich foods. Previous research showed that eating out and fried food consumption may be reflective of extra intake in fat-rich, energy-dense food.³³

In addition, in our study, all but one of the children reported daily consumption of meat/eggs, which are arachidonic acid- and linoleic acid-rich foods. Supporting previous findings in adults,³⁴ we found no correlations between these variables and pre-exercise program F2-IsoPs.

However, repeatedly increased oxygen uptake because of exercise, coupled with abundant IsoP substrate availability, may be accountable for the increased post-exercise program F2-IsoPs, despite these children's daily fruit/vegetable and regular vitamin consumption.

In a group of otherwise healthy obese children of comparable age, evidence of vascular endothelial cell activation, including increased circulating levels of s (soluble) intercellular adhesion molecule-1 s (ICAM-1), vascular cell adhesion molecule-1 (VCAM-1) and sE-selectin, in obese children was recently provided.³⁵ In addition, platelet activation with elevated levels of plasma sP-selectin and sCD40 ligand was present in these children when compared with lean controls. Furthermore, all these markers of early atherogenesis but sE-selectin directly correlated with increased plasma levels of 8-iso-PGF_{2α}. Overall, these data indicate that in obese children, increased lipid peroxidation may represent a link between increased weight in youth and atherogenesis.

Our small experimental group was a heterogeneous one, of mainly overweight, but also included lean children. Therefore, it was not surprising that no correlations were observed between anthropometric measures and pre-exercise program IsoPs in our volunteers.

However, given the ability of IsoPs to mediate oxidative stress themselves, the dramatic increase of post-exercise program IsoPs, especially in overweight children, opens the question of a paradoxal, exercise-mediated endothelial dysfunction, provided such elevated lipid oxidation levels would be repeatedly induced and/or sustained for longer time. Alternatively, such remarkably high IsoPs elevations may be required precisely for attaining protection from exercise-induced subsequent oxidative stress in healthy, growing children.

In human and animal models, 8-iso-PGF_{2α} has been shown to be capable of exerting important biological effects, including smooth muscle contraction, vasoconstriction, and vasodilation.^{36,37} Moreover, 8-iso-PGF_{2α} concentration has been shown to be a determinant of one such predominant effect over another.³⁷

It is, therefore, possible that repetitive exercise of adequate mode, intensity, volume, and frequency may be needed to cause IsoPs oscillatory variations including elevations high enough to modulate vascular tone. Because vascular tone modulation is essential to vascular integrity preservation, fine-tuning IsoPs concentrations through carefully designed exercise interventions may actually be a novel mechanism of early atherosclerosis prevention, starting in childhood.

Another new finding of our pilot study is the negative correlation between pre-exercise program urinary 8-iso-PGF_{2α} concentrations and positive mood scores. Our group mean baseline positive mood score is lower than expected in healthy children of this age according to our experience (data not shown) and when compared with values from the literature.²⁰

Sedentarism, low fitness, and/or overweight may be at least partly responsible for the lower level of enthusiasm these children approached the track summer camp with. Arachidonic (an n-6) fatty acid is a predominant constituent in the brain.³⁸ Substantial preclinical and clinical research supporting the role of arachidonic acid cascade in affective states was recently reviewed.³⁹

An elevated n-6:n-3 fatty acid ratio was found in and correlated with symptom severity of depression in patients as opposed to healthy volunteers.⁴⁰ Modification of neuronal cell membrane fluidity with consequent impact on neurotransmitter function were indicated as potential explanatory mechanisms for such effects.⁴¹

Nevertheless, nonsignificant differences in n-6:n-3 fatty acid ratio between depressed patients and controls were reported as well.⁴² Moreover, the role of arachidonic acid metabolites in mood and its disorders needs clarification.³⁹

Affective states, from those triggered by adverse childhood experiences⁴³ to adult depression,⁴⁴ are now linked to cardiovascular disease. Therefore, our preliminary new findings correlating lower positive mood to higher IsoPs in young, healthy children may suggest a possible candidate role of IsoPs for unifying etiologic pathways and mechanisms of depression and cardiovascular disease.

Another finding from our study was the negative correlation between post-exercise program F2-IsoPs and baseline body mass index, body mass index percentiles, waist circumference, waist circumference percentiles, and heart rate. It is possible that when compared with the lean children, the overweight and obese participants were able and/or willing to actively engage for a shorter time in a given exercise task whereas using the remainder for rest. Also, given the fact that children were allowed to take breaks at will, not only the duration of rest per break but also the frequency of such down time may have been more popular with the heavier and less fit children. A possibly shorter exercise duration per task may have corresponded to lower yield of mitochondrial respiration-generated reactive oxygen species^{6,30} and, therefore, inducing lower post-exercise IsoPs levels.

Our study's setting constitutes one of its strengths, because it reflects real-life situations, in which children eat according to their preferences and more importantly, within family budgetary boundaries. Moreover, the exercise program was organized and implemented by 2 professional physical education coaches and 1 certified athletics coach, therefore being representative of typical youth sports camps available in American communities.

Research limitations included one workout session cancellation during the second week of the exercise program resulting in intermittent workout schedule, inclement weather preventing additional data collection on the last day of camp, and small sample size driven by the subject noncompensatory nature of the study. At the same time, such a design is critical in providing real-life data of practical value to the clinician. Complex training of combined aerobic, anaerobic, and strength exercise, as opposed to each of the 3 taken separately, is both necessary for harmonious, overall growth and development and characteristic of activities youth engage in. Training schedules are rarely perfect, but rather subject to interruptions and cancellations. Also, exercise intensity dramatically varies within a given workout session. The effects of such real-life complex exercise programs need to be known before sound recommendations are to be made.

Children volunteering for our pilot study received no compensation, thus, at least partially explaining the low participation in this research. Moreover, not only was the sample small but also the children who did enroll were mostly overweight. Such facts may suggest clues regarding the low interest asymptomatic youth and their parents have in research studies on exercise and/or general healthy behavior with healthy volunteers. Because motivation drives and maintains human behavioral changes, these issues need to be explored in greater detail in contemporary sedentary and unfit youth.

CONCLUSION

Our pilot data show that even in healthy but sedentary, unfit, and/or overweight children on unrestricted diets, exercise programs as frequently recommended and encountered in American communities, in the absence of manifest injuries, may significantly increase in vivo lipid peroxidation. Given the associations between the latter and various pathologic conditions, our preliminary results warrant and can guide further research with larger sample size, additional time point measurements of these and other cardiometabolic risk factors to determine whether such an effect is indicative of normal adaptations to exercise in children or mediator of oxidative injury.

Taken altogether, our results and the divergent findings of others confirm the feasibility of IsoPs measurements and suggest the complexity of oxidative stress responses to exercise in youth. In this context, the role of nutrition and its interaction with exercise merit further exploration.

Until additional oxidative stress data in healthy youth become available, rather than the inertial “increased levels of exercise for all,” a selective approach may be a safer one. We suggest that young children, especially if unfit and/or overweight, be exposed to exercise in a gradual, enjoyable, noncompetitive manner. Low to moderate intensity activities should initially spark their interest, increase their exercise tolerance, and, if applicable, induce weight loss for sustained physical activity of higher volume and intensity to become part of their lifestyle.

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Figure 1.

Individual increase in concentrations of urinary 8-isoprostaglandin $F_{2\alpha}$, one of the F2-IsoPs, a marker of systemic oxidative stress, indexed to creatinine in 6 healthy children from pre-exercise program to post-exercise program time point. Group mean urinary F2-IsoPs increase is represented in bold ($p = .028$, Wilcoxon signed ranks test).

Table 1

Cardiometabolic Characteristics of Children Participating in This Study (n = 6)

Characteristic	Mean $\pm$ SD	Range	
		Minimum	Maximum
Age (yr)	8.8 $\pm$ 0.9	8	10
Height (m)	1.4 $\pm$ 0.1	1.4	1.5
Weight (kg)	37.1 $\pm$ 6.4	26.3	42.7
BMI (kg/m ²)	19.0 $\pm$ 3.4	14.4	23.4
BMI (%)	67.7 $\pm$ 37.1	10	97
WC (cm)	68.0 $\pm$ 7.9	57	76
WC (%)	67.7 $\pm$ 30.2	14	90
SBP (mm Hg)	104.0 $\pm$ 12.3	88	122
DBP (mm Hg)	63.0 $\pm$ 13.1	40	78
HR (bpm)	99.3 $\pm$ 18.0	80	120

SD, standard deviation; BMI, body mass index; BMI %, body mass index percentiles; WC, waist circumference; WC %, waist circumference percentiles; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate.