The Effects of Sugar Consumption on Physical Activity Performance in Children, aged 6-11

By

Suzanne Perkins

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Faculty Thesis Advisor: Terry Hartman, PhD, MPH, RD

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Introduction:

The Physical Activity Guidelines for Americans, created by the U.S. Department of Health and Human Services, highlights the importance of daily physical activity for all Americans. They recommend that children aged 6-17 engage in 60 minutes of moderate-to-vigorous activity daily. A combination of aerobic, muscle-strengthen, and bone-strengthening activities are encouraged to create balanced “health-promoting physical activity” (1). Research shows that as children age time spent doing physical activity decreases and that this decline can start as early as age 6 (2). Lack of physical activity has been more strongly associated to obesity in children, compared to total caloric intake or daily sugar intake (3).

The Dietary Guideline for Americans (DGA) recommends limiting added sugars to less than 10% of daily calories (4). The American Heart Association (AHA) recommends women consume no more than 100 calories daily from added sugar and men no more than 150 calories (5). This is equivalent of a 7.5oz sugar sweetened cola daily for women or a 12oz sugar sweetened cola daily for men. The DGA estimated that children 2-19 years old consumed 14% of their daily calories through added sugar. Children ages 6-11 had a mean daily intake of 69.5grams (278 calories) of added sugar (4). The AHA found children 2-19 years old consume 80grams daily of added sugar, absolute sugar intake was higher among boys compared to girls (87 versus 73grams) (5,6). Additionally, a cross-sectional study (n=8136) using National Health and Nutrition Examination Survey, NHANES, data found that all forms of dietary sugars, not just added sugars, contribute a large proportion of calories consumed by U.S. children (7). Added sugars increase energy intake, adiposity, and dyslipidemia which leads to an increased risk of developing dental caries, hypertension, cardiovascular disease, and obesity-related cancers later in life (5).

There have been many studies on amount of physical activity or added sugar consumption in children. However, little research has focused on the relationship between performance in physical activity and total sugar consumption. A large (n=10,207) cross sectional study of 9-10 year olds looked at the associations between sugar-sweetened beverage consumption, body composition and aerobic fitness. in 9-10 year olds. Sugar-sweetened beverage consumption was measured using the SportsLinx Lifestyle Survey. Body composition was assessed using BMI, waist circumference, hip circumference, subscapular and triceps skinfold. Aerobic fitness was based on performance on a 20m multistage-shuttle run. They found children who consumed sugar-sweetened beverage had lower body mass indexes and lower skin fold thickness, with minimal difference in aerobic fitness (8).

This article seeks to understand the association between percent calories from all forms of sugar and performance on five different physical fitness activities, using data from NHANES National Youth Fitness Survey, NNYFS (n=703), in children age 6-11 years old. Our over-arching question was do children who consume less total calories overall but a high percentage of calories from sugar have a different level of physical fitness compared to children who might consume more total calories but have a lower percentage of calories from sugar?

Methods:

Study Participants

The National Youth Fitness Survey, NNYFS, was the first national survey of physical activity and fitness in children and adolescents. In 2012, the survey was conducted to collect data on physical activity and fitness for U.S. children and adolescents aged 3-15 years. NNYFS used the same survey design as NHANES, The National Health and Nutrition Examination Survey, a multistage probability sample of the noninstitutionalized resident population of the United States (9). The NNYFS survey included a household interview and a physical activity and fitness examination in a mobile examination center, MEC. Protocol, ERB approval, and consent followed the procedures established for NHANES. Physical activity and fitness examinations were conducted in the MEC. Interviewers administered a computer-assisted 24-hour dietary recall, detailing types and amounts of food and beverages consumed in the 24-hour period prior to the interview in the MEC.

Analysis was limited to 6-11 year olds and excluded any participants who had: mobility limitations; been told by a doctors they have diabetes; taking insulin currently; or taking diabetic pills to lower blood sugar. Analysis was done on these participants because they were eligible to complete all five of the physical activities of interest: sum grip strength, average lower body strength, modified pull-up, plank hold, and aerobic fitness. Percent calories from sugar was calculated by first multiplying total grams of sugar by 4 to get the total calories from sugar. Then the total sugar calories was divided by overall total calories, consumed in the 24-hour period, and multiplied by 100 to get the percent calories from sugar.

Data collection

Grip strength was measured in kilograms using a dynamometer adjusted for participant hand size. Participants squeezed the dynamometer as hard as possible three times in each hand, alternating hands. Sum grip strength was calculated by adding together the largest reading from each hand. Lower body muscle strength was assessed through a hand-held dynamometer (HHD) to measure maximum isometric knee extension force, in pounds, in the sitting position. Participants pushed their legs as hard as possible against the HHD in three test of each leg, alternating legs. For analysis, an average maximum force was calculated for each leg and then the average of the left and right leg were averaged together to create an average lower body strength (ALBS). ALBS was then converted from pounds to kilograms, in order to be consistent across outcome variables. Modified pull-up was assessed using a horizontal bar positioned so that the participant could clasp the bar with an overhand grasp when lying flat on their back. Participants raised their bodies to the bar, keeping their heels on the ground. This movement was completed as many times as possible and the total number completed correctly was recorded. The plank hold exercise was used to assess core muscle strength and was measured by number of seconds the position was held. Participants used the front plank hold position, lying face down on a mat, resting on their forearms, and pushing off the floor to rise up onto their toes. This position was maintained as long as possible while keeping a straight back and not letting the hips rise or the stomach drop. Aerobic fitness was measured, in seconds, based on duration on the treadmill with increasing speed and incline. A treadmill designed specifically for exercise testing was used and participants were able to practice on the treadmill before the actual test began.

There were seven potential covariates of interest: Body mass index (BMI), age, race, household income, asthma status, wheezing during activity, and health conditions. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Age was the participant's age on the day of the examination in the MEC. Race was re-categorized into four groups: White, Black, Hispanic, Mexican American and other Hispanic each as a single race and other, including multiracial participants. Household income was self-reported as the annual household income reported as a value range in dollars. Asthma status was defined by whether the participant had ever been told by a doctor that they have asthma. Wheezing during activity was characterized by participant self-report that wheezing limited their usual activities. Health condition was self-reported and was re-categorized into Fair to Good and Very Good to Excellent. After previous exclusions, no participants reported a poor health condition (9).

Data Analysis

Descriptive statistics were used to describe the participants' demographic and health-related characteristics of interest. Multiple linear regression was used to evaluate an association between percent calories from sugar and the five physical activities; sum grip strength, average lower body strength, modified pull-up, plank hold, and aerobic fitness after controlling for important covariates. Regression models stratified by sex were planned *a priori*. Analysis was done in SAS using proc surveyreg in order to account for the complex weights of the NNYFS data.

Correlation and multiple regression analyses were conducted to examine the relationships between the five physical activities and percent calories from sugar and other potential predictors, stratified a priori for males and females. The other potential predictors were; BMI, age, race, household income, asthma status, wheezing during activity, and health condition. All of these predictors were included in each model. White was used for the reference category for race. The reference category for household income was $45,000-99,999. This category was selected because the average household income in the United States in 2012, $50, 502, fell within this category (10). Additionally, effect measure modification was analyzed for age, BMI, household income, and race.

Results:

Table 1 displays the distribution of demographics for the population of interest. Overall the population included a range of incomes and had good representation of the three major racial/ethnic groups. Females had consistently slightly lower means for all continuous variables including BMI, percent calories from sugar, sum grip strength, ALBS, modified pull-up, plank hold, and aerobic fitness.

Analysis was done to look at the distribution of demographics by quartiles of percent calories from sugar, Table 2. The quartiles ranged from a mean of 16.4% to 31.1%, percent calories from sugar. Across quartiles, age was inconsistent. Non-Hispanic White was consistently the largest race category across all quartiles, 34.7%, 38.1%, 31.7%, and 42.5% respectively. Non-Hispanic Black was the smallest category in the first, third, and fourth quartile; 22.3%, 22.2%, and 20.3% respectively. In the second quartile Hispanic was the smallest category, 26.7%. While gender was evenly split between males and female, there were slightly more females in the first, third, and fourth quartiles, 53.0%, 53.2%, 50.5% respectively. Across all quartiles $45,000-$99,999 was the largest category for annual household income. There was no discernable pattern across quartiles for any of the continuous variables.

When each variable of interest was evaluated by quartiles of percent sugar from calories stratified by gender the results revealed no new patterns or insights for age, race or household income. Percent calories from sugar did not differ significantly when stratified by gender. Results of these analyses are in Table 3. For Males, BMI decreased as percent calories from sugar increased. While for females, as percent calories from sugar increased, BMI trended towards an increase as well. Sum grip strength decreased for males across quartiles, while it was inconsistent for females. For males, the first through third quartiles saw a decrease in average lower body strength and modified pull-up and a slight increase in the fourth quartile over the third quartile. For females, average lower body strength and modified pull-up both had inconsistent increases and decreases across quartiles. Opposite effects were seen between males and females across quartiles for plank hold. Males saw a general decrease and females a general increase, with the exception of the third quartile. Aerobic fitness increased as percent calories from sugar increased in the first three quartiles and a slight decrease was seen in the fourth quartile. This trend was seen for both males and females.

Table 4 summarizes the regression analysis results for males for all five physical activities; sum grip strength, average lower body strength, modified pull-up, plank hold, and aerobic fitness. The model for sum grip strength was significant when all predictors were included with a R_2 of 0.69. Percent calories from sugar was negatively associated with sum grip strength (β= -0.77), but it was not statistically significant. The model for average lower body strength, ALBS, was significant when all predictors were included with a R_2 of 0.52. Percent calories from sugar was negatively associated with ALBS (β= -0.20), but it was not statistically significant. The model for modified pull-up was significant when all predictors were included with a R_2 of 0.27. Percent calories from sugar was negatively associated with modified pull-up (β= -0.12), but it was not statistically significant. The model for plank hold was significant when all predictors were included with a R_2 of 0.28. Percent calories from sugar was positively associated with plank hold (β= 0.87), but it was not statistically significant. The model for aerobic fitness was significant when all predictors were included with a R_2 of 0.33. Percent calories from sugar was negatively associated with aerobic fitness (β= -3.76), but it was not statistically significant. BMI was found to have statistical significance for aerobic fitness, controlling for all other factors. Aerobic fitness decreased by -14.67 seconds for each 1 unit increase in BMI. Age was found to have statistical significance for sum grip strength (β= 3.61) and ALBS (β= 2.21), controlling for all ot her variables. Modified pull-up was negatively associated with the 2nd quartile of percent calories from sugar (β= -0.90), it was statistically significant. Aerobic fitness was positively associated with the 3rd and 4th quartile of percent calories from sugar, (β= 76.45) and (β= 81.49) respectively, both were statically significant, controlling for all other factors. Effect measure modification was significant for household income and percent calories from sugar in sum grip strength, ALBS, and modified pull-up.

Table 5 summarizes the regression analysis results for females for all five physical activities; sum grip strength, average lower body strength, modified pull-up, plank hold, and aerobic fitness. The model for sum grip strength was significant when all predictors were included with a R^2 of 0.68. Percent calories from sugar was negatively associated with sum grip strength (β= -0.15), but it was not statistically significant. The model for average lower body strength, ALBS, was significant when all predictors were included with a R^2 of 0.45. Percent calories from sugar was positively associated with ALBS (β= 0.02), but it was not statistically significant. The model for modified pull-up was significant when all predictors were included with a R^2 of 0.21. Percent calories from sugar was negatively associated with modified pull-up (β= -0.10), but it was not statistically significant. The model for plank hold was significant when all predictors were included with a R^2 of 0.20. Percent calories from sugar was positively associated with plank hold (β= 0.08), but it was not statistically significant. The model for aerobic fitness was significant when all predictors were included with a R^2 of 0.39. Percent calories from sugar was negatively associated with aerobic fitness (β= -4.04), but it was not statistically significant. BMI was found to have statistical significance for sum grip strength, ALBS, modified pull-up, and aerobic fitness, controlling for all other factors. BMI was positively associated with sum grip strength (β= 1.00) and ALBS (β= 0.97). It was negatively associated with modified pull-up (β= -0.59) and aerobic fitness (β= -7.95). Age was found to have statistical significance for sum grip strength (β= 3.21) and aerobic fitness (β= -44.43), controlling for all other factors. Sum grip strength was positively associated with the 4^{th} quartile of percent calories from sugar, (β= 5.57), and was statically significant, controlling for all other factors. No effect measure modification was present in the variables assessed.

Discussion:

The association between quartiles of percent calories from sugar was inconsistent across all five physical activities and gender. Aerobic fitness showed an increase from the 1st-3rd quartiles and then a decrease in the 4th quartile, for males and females. This could indicate that increased available energy from sugar can be beneficial to aerobic fitness up to a certain point when it becomes detrimental. Sensitivity analysis was done on percent calories from fat to see if those who consumed more sugar calories had a poorer diet overall,. Overall, there was an inverse relationship between calories consumed from sugar and fat. Individuals who consumed the most calories from sugar consumed lower calories from fat compared to other quartiles suggesting sugar-sweetened beverages might be the main source of sugar consumption.

Regression analysis revealed no significant association between percent calories from sugar and physical activity performance. For males, age was a significant predictor of strength based exercises (sum grip strength and ALBS), but it was not a significant predictor for endurance based exercises (modified pull-up, plank hold, and aerobic fitness). Males generally performed better on physical activities, except for ALBS where females performed higher.

Effect measure modification was present for household income and percent calories from sugar and was shown to be a significant predictor for ALBS and modified pull-up. For females, BMI was a significant positive predictor for sum grip strength and ALBS and a significant negative predictor modified pull-up and aerobic fitness. Additionally, the 4th quartile of percent calories from sugar was positively associated with increased sum grip strength. This correlates with held assumptions that a larger individual will perform well in strength based exercise compared to endurance based exercises. While percent calories from sugar itself is not a significant predictor of physical activity performance it is an important covariate in understanding the overall health and fitness of an individual.

The difference in sugar consumption in males and females was present but not as pronounced as in the literature (5, 6). Males consumed an average of 26.7% calories from sugar and females 26.4%. However, males had a greater range of percent calories from sugar (68% male, 41.1% female). For both males and females, only 3% consumed 10% or less calories from sugar, the recommended level. This is inconsistent with previous studies that showed children aged 2-19 consumed 14% of their daily calories through added sugar (4). The reference category for this study had a higher mean for average daily consumption for percent calories of sugar (16.4%) than the recommended level of sugar, this could be leading to non-statistically significant results.

Limitation of this article include the self-reported dietary recall. Issues with recall and bias could affect which foods were reported and therefore skew the calculations of percent calories from sugar. Additionally, the cross-sectional nature of NNYFS data doesn't allow us to know if the 24-hour diet recall is reflective of a typical daily food consumption.

The strength of this article is that NNYFS is a nationally representative survey with a large sample size and standardized collection methods. The use of the MEC allowed for a controlled environment so that all physical measurements could be conducted under identical conditions. NNYFS calculated BMI using height and weight measurements taken in the MEC, this allowed for more accurate information. Additionally, the diversity of the five physical fitness activities allowed for a more rounded view of a child's fitness level.

The findings in the article should inform further research to look at quality of diet as a whole versus consumption of specific food groups. It would be beneficial to have a dietary recall longer than 24 hours in order to gain a better understanding of typical dietary patterns. Additionally, information such as did the child attend a party/ celebration, or participate in a sporting event during the time of the dietary recall could further help to understand dietary patterns and fitness. Future studies using NNYFS should consider using participation in organized sports as a covariate and controlling for increased SSB consumption from sports drinks. Stratified analysis by groups other than gender, such as race, socio-economic status, or rural versus urban, could also shed further light on the association between sugar consumption and physical fitness.

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Table 1: Distribution of Demographic Information and Physical Activity by Gender

Males

N:341 Percent: 48.51%

Age in Years	Percent (%)	Race	Percent (%)	Household Income	Percent (%)	Continuous Variables	N	Range	Mean (SD)[a]
6	19.4	Non-Hispanic White	37.0	$0-19,999	21.4	Body Mass Index (kg/m^2)	341	13.4- 40.0	19.1 (4.7)
7	18.5	Non-Hispanic Black	23.2	$20,000-44,999	25.5	Percent Calories from Sugar (Sugar kcal/ total kcal)	323	5.4-73.4	26.7 (8.4)
8	15.0	Hispanic	31.9	$45,000-99,999	34.0	Sum Grip Strength (kg)	335	15.8-76.8	31.9 (10.1)
9	15.5	Other Race (Inclduing Multi-Racial)	7.9	$100,000+	17.9	Average Lower Body Strength (kg)	323	3.2-51.2	18.2 (8.9)
10	16.7			Refuse to Answer	0.88	Modified Pull-up (total completed)	335	0.0-29.0	4.7 (4.7)
11	14.9			Don't Know	0.29	Plank Hold (seconds)	335	1.0-305.0	59.3 (40.9)
						Aerobic Fitness (seconds)	310	28.0-1024.0	666.0 (152.8)

Females

N: 362 Percent: 51.59%

Age in Years	Percent (%)	Race	Percent (%)	Household Income	Percent (%)	Continuous Variables	N	Range	Mean (SD)[a]
6	16.0	Non-Hispanic White	36.5	$0-19,999	23.6	Body Mass Index (kg/m^2)	362	12.2-38.8	18.7 (4.5)
7	17.1	Non-Hispanic Black	23.0	$20,000-44,999	27.8	Percent Calories from Sugar (Sugar kcal/ total kcal)	345	7.1-48.2	26.4 (8.0)
8	19.1	Hispanic	29.6	$45,000-99,999	21.9	Sum Grip Strength (kg)	352	11.5-61.7	30.8 (9.5)
9	13.5	Other Race (Inclduing Multi-Racial)	11.1	$100,000+	23.9	Average Lower Body Strength (kg)	351	3.2- 48.0	18.7 (7.9)
10	17.1			Refuse to Answer	1.9	Modified Pull-up (total completed)	355	0.0-25.0	3.9 (4.1)
11	17.1			Don't Know	0.8	Plank Hold (seconds)	358	1.0-245.0	57.8 (37.6)
						Aerobic Fitness (seconds)	340	73.0-1020.0	638.6 (123.3)

[a] Standard Deviation

Table 2: Analysis of Demographics and Physical Activity by Quartiles of Percent Calories from Sugar

	1st Quartile of Percent Calories from Sugar (Sugar kcal/ total kcal)	2nd Quartile of Percent Calories from Sugar (Sugar kcal/ total kcal)	3rd Quartile of Percent Calories from Sugar (Sugar kcal/ total kcal)	4th Quartile of Percent Calories from Sugar (Sugar kcal/ total kcal)
Percent Calories From Sugar	N=202 Mean (SD)[a]= 16.4 (3.4) Range= 5.4- 21.0	N=176 Mean (SD)[a]= 24.0 (1.7) Range =21.1- 26.7	N= 158 Mean (SD)[a] = 29.1 (1.5) Range= 26.8- 31.7	N= 167 Mean (SD)[a] = 37.1 (4.9) Range= 31.7- 73.4
Age in Years	**Percent (%)**	**Percent (%)**	**Percent (%)**	**Percent (%)**
6	14.4	18.2	26.6	12.6
7	17.8	17.6	15.8	19.8
8	16.8	16.5	17.1	18.0
9	15.4	16.0	12.0	14.4
10	23.3	13.6	13.9	15.6
11	12.4	18.2	14.4	19.8
Race	**Percent**	**Percent**	**Percent**	**Percent**
Non-Hispanic White	34.7	38.1	31.7	42.5
Non-Hispanic Black	22.3	27.3	22.2	20.3
Hispanic	31.2	26.7	34.8	30.5
Other Race (Inclduing Multi-Racial)	11.9	8.0	11.4	6.6
Gender	**Percent**	**Percent**	**Percent**	**Percent**
Male	47.0	50.6	46.8	49.7
Female	53.0	49.4	53.2	50.5
Income	**Percent**	**Percent**	**Percent**	**Percent**
$0-19,999	25.3	19.4	24.1	21.1
$20,000-44,999	25.3	28.0	24.7	28.9
$45,000-99,999	25.8	26.3	30.4	30.7
$100,000+	23.3	25.1	17.7	16.9
Refuse to Answer	0.5	0.6	2.53	-
Don't Know	0.9	0.6	0.6	2.4

Continuous Variables	N	Range	Mean (SD)[a]	N	Range	Mean (SD)[a]	N	Range	Mean (SD)[a]	N	Range	Mean (SD)[a]
Body Mass Index (kg/m^2)	202	12.6- 40.0	18.9 (4.5)	176	13.5-38.3	18.9 (4.6)	158	12.7- 32.4	18.6 (4.1)	167	12.9-38.8	19.1 (5.1)
Sum Grip Strength (kg)	196	13.4- 61.7	31.6 (9.3)	174	14.4-65.2	31.3 (9.1)	155	14.7-69.6	30.3 (10.8)	162	11.5- 76.8	32.0 (10.4)
Average Lower Body Strength (kg)	187	4.0- 41.8	17.6 (8.4)	173	3.60-39.84	19.1 (7.9)	151	3.2- 50.4	17.9 (8.9)	163	3.19- 51.19	19.3 (8.5)
Modified Pull-up (total completed)	194	0.0-29.0	4.2 (4.7)	175	0.0-22.0	4.9 (4.8)	156	0.0-20.0	3.7 (3.9)	165	0.0-18.0	4.2 (4.0)
Plank Hold (seconds)	199	2.0-228.0	60.8 (38.3)	175	1.0-245.0	58.4 (41.3)	153	2.0-305.0	55.3 (37.5)	166	1.0-206.0	59.1 (39.7)
Aerobic Fitness (seconds)	178	89.0-1021.0	634.3 (127.4)	167	46.0-1020.0	662.5 (131.6)	149	140.0-969.0	665.8 (135.6)	156	28.0- 1024.0	646.4 (158.8)

[a] Standard Deviation

Table 3: Quartiles of Percent Calories from Sugar by Demographics and Physical Activity

	Age in Years (%)						Race (%)				Household Income (%)				Continuous Variables Mean (SD)[a]					
Percent Calories From Sugar Quartiles Mean (SD)[a]	**6**	**7**	**8**	**9**	**10**	**11**	**White**	**Black**	**Hispanic**	**Other**	**0-19,999**	**20,000-44,000**	**45,000-99,000**	**Over 100,000**	**Body Mass Index (kg/m^2)**	**Sum Grip Strength (kg)**	**Average Lower Body Strength (kg)**	**Modified Pull-up (total completed)**	**Plank Hold (seconds)**	**Aerobic Fitness (seconds)**
Males																				
1st Quartile 15.5 (3.5)	21.2	22.2	27.5	34.0	40.4	23.5	31.0	27.9	22.0	37.0	30.1	28.7	19.8	39.4	19.6 (4.7)	33.0 (8.8)	18.3 (8.7)	5.1 (5.6)	65.0 (42.9)	653.1 (134.8)
2nd Quartile 23.7 (1.7)	30.3	31.8	21.6	26.4	19.3	25.5	23.8	34.2	22.0	29.6	23.3	28.7	25.0	26.2	19.0 (5.2)	31.1 (9.3)	18.1 (8.1)	5.1 (4.7)	55.6 (36.7)	679.2 (151.3)
3rd Quartile 29.2 (1.5)	30.3	20.6	19.6	17.0	15.8	25.5	15.9	20.3	27.5	29.6	20.6	21.8	25.9	16.4	18.5 (4.0)	31.6 (12.8)	17.7 (10.0)	4.2 (3.9)	60.7 (44.4)	682.0 (143.6)
4th Quartile 37.3 (5.8)	18.2	25.4	31.4	22.6	24.6	25.5	29.4	17.7	28.4	3.7	26.0	20.7	29.3	18.0	18.5 (4.0)	31.9 (30.5)	18.6 (9.1)	4.4 (4.2)	55.9 (39.4)	651.6 (178.0)
Females																				
1st Quartile 16.3 (3.3)	25.9	35.5	29.0	26.5	38.7	21.0	23.5	27.7	36.5	35.0	34.1	26.0	34.2	26.7	18.3 (4.1)	30.4 (9.5)	16.9 (8.1)	3.4 (3.7)	57.2 (33.6)	618.6 (119.4)
2nd Quartile 24.2 (1.6)	20.7	17.7	26.1	28.6	21.0	30.7	28.0	25.3	21.5	15.0	20.0	24.0	21.5	32.6	18.9 (3.9)	31.5 (8.8)	20.0 (7.7)	4.7 (4.8)	61.3 (45.5)	646.5 (107.8)
3rd Quartile 29.1 (1.5)	37.9	19.4	24.6	20.4	21.0	16.1	22.7	22.9	23.4	25.0	27.1	20.0	22.8	20.9	18.6 (4.2)	29.2 (8.5)	18.1 (7.9)	3.3 (3.8)	50.6 (29.7)	651.8 (127.5)
4th Quartile 37.8 (3.9)	15.5	27.4	20.3	24.5	19.4	32.3	25.8	24.1	18.7	25.0	18.8	30.0	21.5	19.8	19.1 (5.6)	32.0 (11.1)	20.0 (7.9)	4.1 (3.9)	62.3 (40.0)	641.2 (137.9)

[a] Standard Deviation

Table 4: Multiple Linear Regression Analysis Results for Physical Activity: Males[a]

Predictor Variables	Sum Grip Strength (kg)			Average Lower Body Strength (kg)			Modified Pull-Up (#)			Plank Hold (seconds)			Aerobic Fitness (seconds)		
	β	SE B	95% CI[b]	β	SE B	95% CI[b]	β	SE B	95% CI[b]	β	SE B	95% CI[b]	β	SE B	95% CI[b]
Percent Calories from Sugar (Sugar kcal/ total kcal)	-0.77	0.43	(-1.69, 0.15)	-0.20	0.31	(-0.87, 0.47)	-0.12	0.18	(-0.51, 0.26)	0.87	1.90	(-3.20, 4.94)	-3.76	5.78	(-16,.15, 8.63)
1st Quartile[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2nd Quartile	0.76	1.43	(-2.31, 3.82)	0.82	1.42	(-2.23, 3.87)	-0.90	0.90	(-2.82, 1.03)*	-8.84	8.55	(-27.17, 9.49)	33.76	32.12	(-35.13, 102.64)
3rd Quartile	2.10	1.89	(-1.96, 6.16)	-0.23	2.49	(-5.57, 5.10)	-2.98	1.32	(-5.81, -0.16)	-7.39	14.66	(-38.82, 24.04)	76.45	34.09	(3.33, 149.58)*
4th Quartile	2.21	3.12	(-4.49, 8.91)	-0.67	2.39	(-5.80, 4.47)	-3.92	2.02	(-8.25, 0.41)	-28.03	14.36	(-58.83, 2.77)	81.49	47.40	(-20.17, 183.15)
Body Mass Index (kg/m^2)	0.19	0.40	(-0.66, 1.05)	0.74	0.40	(-0.13, 1.61)	-0.30	0.13	(-0.59, -0.01)	-2.06	1.36	(-4.97, 0.86)	-13.44	4.28	(-22.62, -4.25)**
Age in Years	3.61	0.65	(22.22, 4.99)**	2.12	0.81	(0.38, 3.87)*	-0.05	0.53	(-1.20, 1.09)	7.96	5.27	(-3.34, 19.26)	3.18	13.08	(-24.88, 31.24)
Race															
Black	-0.74	3.97	(-9.26, 7.78)	2.89	2.17	(-1.77, 7.55)	-4.35	2.03	(-8.69, -0.00)*	-27.18	21.84	(-74.01, 19.66)	-110.34	65.65	(-251.14, 30.46)
Hispanic	-0.86	4.33	(-10.15, 8.42)	-3.81	3.05	(-10.34, 2.73)	-2.63	2.01	(-6.94, 1.68)	-30.42	27.13	(-88.62, 27.78)	-90.05	53.56	(-204.93, 24.82)
Other	-5.00	7.58	(-21.26, 11.26)	-18.19	13.34	(-46.79, 10.41)	4.90	8.34	(-12.98, 22.78)	-23.86	27.66	(-83.18, 35.45)	-79.27	82.92	(-257.11, 98.57)
White[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Household Income ($)															
0-19,999	-7.34	3.40	(-14.62, -0.06)**	-6.01	3.12	(-12.69, 0.68)	-1.73	1.96	(-5.93, 2.47)	13.42	18.49	(-26.24, 53.07)	-78.60	97.12	(-286.90, 129.70)
20,000-44,999	-4.91	2.62	(-10.52, 0.71)	-4.43	4.00	(-13.02, 4.16)	-3.25	2.18	(-7.94, 1.43)	-4.56	14.00	(-34.57, 25.46)	66.70	59.32	(-60.54, 193.94)
45,000-99,999[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100,000+	-5.63	4.08	(-14.37, 3.12)	-6.82	3.05	(-13.36, -0.28)*	-7.14	1.70	(-10.79, -3.49)**	-13.56	25.86	(-69.01, 41.90)	-67.38	79.52	(-237.94, 103.18)
Age in Years x Percent Calories from Sugar	0.01	0.02	(-0.04, 0.06)	0.02	0.03	(-0.04, 0.09)	0.03	0.02	(-0.01, 0.06)	0.06	0.21	(-0.38, 0.51)	-0.26	0.53	(-1.40, 0.88)
BMI x Percent Calories from Sugar	0.02	0.01	(-0.01, 0.05)	-0.01	0.01	(-0.04, 0.02)	0.00	0.01	(-0.02, 0.01)	-0.05	0.06	(-0.17, 0.08)	-0.04	0.16	(-0.37, 0.29)
Household Income x Percent Calories from Sugar															
0-19,999	0.36	0.12	(0.10, 0.62)*	0.29	0.11	(0.06, 0.52)*	0.08	0.07	(-0.06, 0.23)	-0.39	0.62	(-1.72, 0.95)	2.71	3.30	(-4.36, 9.78)
20,000-44,999	0.21	0.10	(-0.01, 0.43)	0.24	0.15	(-0.07, 0.56)	0.09	0.06	(-0.05, 0.22)	-0.07	0.50	(-1.15, 1.02)	-2.48	1.90	(-6.56, 1.61)
45,000-99,999[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100,000+	0.11	0.14	(-0.20, 0.42)	0.23	0.13	(-0.04, 0.51)	0.22	0.07	(0.06, 0.38)**	0.68	1.07	(-1.62, 2.97)	3.22	3.86	(-5.06, 11.50)
Race x Percent Calories from Sugar															
Black	0.05	0.16	(-0.30, 0.40)	0.00	0.09	(-0.20, 0.20)	0.15	0.07	(-0.00, 0.30)	0.88	0.73	(-0.68, 2.44)	3.73	2.46	(-1.54, 8.99)
Hispanic	-0.02	0.15	(-0.34, 0.30)	0.05	0.07	(-0.11, 0.21)	0.08	0.07	(-0.07, 0.23)	0.85	0.98	(-1.24, 2.94)	2.59	1.84	(-1.27, 6.54)
Other	0.14	0.26	(-0.41, 0.69)	0.61	0.49	(-0.44, 1.66)	-0.20	0.30	(-0.85, 0.45)	0.17	1.46	(-2.96, 3.31)	-1.25	3.05	(-7.78, 5.28)
White[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R^2 for Model	0.69			0.52			0.27			0.28			0.33		
P-value for the Model	<0.0001			<0.0001			<0.0001			<0.0001			<0.0001		
n	315			306			316			315			297		

[a] Controled for Asthma status, Health Condition, and Wheezing during activity

[b] Confidence Interval

[c] Control Group

* p-value < 0.05

** p-value < 0.01

Table 5: Multiple Linear Regression Analysis Results for Physical Activity: Females[a]

	Sum Grip Strength (kg)			Average Lower Body Strength (kg)			Modified Pull-Up (#)			Plank Hold (seconds)			Aerobic Fitness (seconds)		
Predictor Variables		SE B	95% CI[b]		SE B	95% CI[b]		SE B	95% CI[b]		SE B	95% CI[b]		SE B	95% CI[b]
Percent Calories from Sugar (Sugar kcal/ total kcal)	-0.15	0.30	(-0.79, 0/48)	0.02	0.23	(-0.47, 0.51)	-0.10	0.17	(-0.47, 0.27)	0.08	1.69	(-3.54, 3.70)	-4.04	3.46	(-11.47, 3.39)
1st Quartile[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2nd Quartile	2.08	1.38	(-0.88, 5.05)	1.79	1.31	(-1.03, 4.60)	1.03	1.57	(-2.34, 4.40)	1.68	12.95	(-26.09, 29.45)	19.97	20.16	(-23.27, 63.20)
3rd Quartile	2.70	2.05	(-1.71, 7.10)	1.09	1.96	(-3.11, 5.28)	-0.03	1.84	(-3.98, 3.92)	-3.15	13.26	(-31.60, 25.30)	13.21	35.03	(-61.91, 88.24)
4th Quartile	5.76	2.13	(1.20, 10.32)*	2.64	2.20	(-2.07, 7.36)	0.56	2.65	(-5.12, 6.23)	4.86	19.41	(-36.77, 46.49)	32.80	43.53	(-60.56, 126.16)
Body Mass Index (kg/m^2)	1.00	0.30	(0.35, 1.66)**	0.97	0.40	(0.12, 1.82)*	-0.59	0.16	(-0.94, -0.25)**	-3.14	2.92	(-9.41, 3.13)	-7.95	3.40	(-15.24, -0.66)*
Age in Years	3.21	0.75	(1.59, 4.82)**	0.96	0.73	(-0.60, 2.52)	0.40	0.41	(-0.48, 1.27)	8.38	7.09	(-6.82, 23.58)	-44.43	10.59	(-67.14, -21.73)**
Race															
Black	4.34	3.08	(-2.26, 10.94)	9.15	3.29	(2.17, 16.12)*	-0.11	1.06	(-2.38, 2.16)	-22.52	19.42	(-64.16, 19.12)	72.90	41.08	(-15.21, 161.01)
Hispanic	-5.06	4.13	(-13.93, 3.81)	-3.68	3.25	(-10.73, 3.37)	-1.50	1.88	(-5.53, 2.54)	-25.20	25.18	(-79.21, 28.81)	-30.28	57.14	(-152.94, 92.28)
Other	-3.57	4.14	(-12.46, 5.31)	-7.44	5.29	(-18.79, 3.90)	-2.21	1.69	(-5.83, 1.42)	-35.11	23.20	(-84.86, 14.65)	24.62	64.58	(-113.90, 163.14)
White[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Household Income ($)															
0-19,999	-0.52	2.20	(-5.25, 4.21)	0.81	3.54	(-6.77, 8.39)	-2.24	1.78	(-6.07, 1.59)	-28.17	16.10	(-62.69, 6.36)	-12.24	40.67	(-99.46, 74.99)
20,000-44,999	2.14	2.73	(-3.70, 7.99)	2.96	2.95	(-3.37, 9.29)	1.43	1.42	(-1.62, 4.48)	-9.95	15.09	(-42.32, 22.43)	1.11	65.47	(-139.31, 141.54)
45,000-99,999[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100,000+	-3.19	3.30	(-10.26, 3.89)	3.28	3.76	(-4.77, 11.34)	-2.36	1.44	(-5.45, 0.73)	-52.01	28.85	(-113.88, 9.86)	-4.19	48.03	(-107.21, 98.83)
Age in Years × Percent Calories from Sugar	0.01	0.02	(-0.05, 0.06)	0.02	0.02	(-0.02, 0.07)	-0.01	0.01	(-0.04, 0.02)	-0.13	0.27	(-0.71, 0.45)	0.67	0.41	(-0.21, 1.55)
BMI × Percent Calories from Sugar	-0.01	0.01	((-0.03, 0.01)	-0.01	0.01	(-0.04, 0.02)	0.01	0.01	(-0.00, 0.02)	0.00	0.10	(-0.21, 0.22)	-0.04	0.14	(-0.35, 0.27)
Household Income × Percent Calories from Sugar															
0-19,999	0.06	0.07	(-0.08, 0.20)	-0.11	0.11	(0-0.04, 0.02)	0.06	0.07	(-0.08, 0.20)	0.41	0.50	(-0.67, 1.49)	-0.68	1.77	(-4.47, 3.12)
20,000-44,999	-0.08	0.11	(-0.21, 0.15)	-0.14	0.10	(-0.36, 0.08)	-0.09	0.05	(-0.21, 0.03)	0.20	0.61	(-1.11, 1.52)	-1.19	2.41	(-6.36, 3.98)
45,000-99,999[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100,000+	0.10	0.11	(-0.14, 0.35)	-0.15	0.14	(-0.44, 0.14)	0.09	0.06	(-0.04, 0.21)	1.97	1.15	(-0.50, 4.44)	-0.03	1.71	(-3.70, 3.63)
Race × Percent Calories from Sugar															
Black	-0.08	0.11	(-0.32, 0.15)	-0.26	0.14	(-0.56, 0.04)	-0.02	0.04	(-0.11, 0.07)	0.70	0.73	(-0.86, 2.27)	-3.27	1.77	(-7.06, 0.52)
Hispanic	0.20	0.14	(-0.11, 0.51)	0.05	0.10	(-0.16, 0.26)	0.01	0.07	(-0.13, 0.16)	0.74	0.77	(-0.92, 2.40)	0.60	1.89	(-3.46, 4.66)
Other	0.13	0.17	(-0.23, 0.48)	0.19	0.17	(-0.18, 0.56)	0.04	0.07	(-0.11, 0.19)	1.06	1.15	(-1.39, 3.52)	-0.74	2.26	(-5.59, 4.11)
White[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R^2 for Model	0.68			0.45			0.21			0.20			0.39		
P-value for the Model	<0.0001			<0.0001			<0.0001			<0.0001			<0.0001		
n	325			325			330			330			318		

[a] Controled for Asthma status, Health Condition, and Wheezing during activity

[b] Confidence Interval

[c] Control Group

* p-value < 0.05

** p-value < 0.01