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# Fit to Play? Health-Related Fitness Levels of Youth Athletes: A Pilot Study

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## Abstract

Pfeifer, CE, Sacko, RS, Ortaglia, A, Monsma, EV, Beattie, PF, Goins, J, and Stodden, DF. Fit to play? Health-related fitness levels of youth athletes: A pilot study. *J Strength Cond Res* XX(X): 000–000, 2019—A recent National Strength and Conditioning Association position statement suggests that many youth are not prepared for the physical demands of sport. The purpose of this study was to compare health-related fitness (HRF) of youth athletes with normative findings from the general population. We recruited 136 athletes (63 male and 73 female athletes) aged 11–19 (16.01  $\pm$  1.35) years and collected HRF (body composition, cardiorespiratory endurance, musculoskeletal strength and endurance). Results were categorized based on FITNESSGRAM® standards and compared with Canadian youth general population normative data. Most male athletes were classified as “needs improvement” for cardiorespiratory and muscular endurance, and body mass index (BMI). Conversely, most female athletes were at or above the “healthy fitness zone” for all measures. Male athletes at both age groups (11–14, 15–19;  $p$  , 0.001) and female athletes aged 11–14 ( $p$  , 0.05) demonstrated lower cardiorespiratory endurance compared with Canadian general population. Female athletes (both age groups) demonstrated greater muscular strength, and male athletes (age, 15–19 years) demonstrated lower BMI than the Canadian general population. The results are concerning as male athletes demonstrated poorer HRF compared with the general population. Although most female athletes were within healthy ranges, a portion of them were still at risk. Considering the demands sport places on the body, evaluating HRF is paramount for performance and injury prevention but more importantly for overall health. Youth sport and strength coaches should evaluate and aim to enhance HRF, as participation in sport does not guarantee adequate HRF. Promoting long-term athletic development and life-long health should be a priority in youth.

**Key Words:** BMI, musculoskeletal fitness, adolescence, injury prevention

## Introduction

Athleticism is a term that implies high levels of health-related physical fitness (e.g., musculoskeletal fitness, cardiorespiratory fitness, and body composition) (51). Those who participate in sport generally are deemed “athletes” (51), and it is suggested that athletes, who typically participate in physical training and practice their sport, have more favorable physical fitness than nonathletes, even in youth (55). However, a recent position statement by the National Strength and Conditioning Association suggests that many youth are not prepared for the physical demands of sport (37). The demand for

higher levels of physical fitness is one part of athleticism that is consistent across competition levels from childhood into adolescence as strength, power, and endurance are important performance indicators (68,69,72). Thus, it is important to understand if youth sport “athletes” meet this increasing fitness demand, as inadequate levels of fitness may result in decreased performance, sport-related injury, and other unfavorable long-term health outcomes (i.e., obesity, high blood pressure, etc.) (56). Health-related fitness (HRF) has the specific aim of creating characteristics that promotes lifelong health (56,70), but it also has implications for preparedness for sport participation (37). The components of HRF include body composition, cardiorespiratory endurance, musculoskeletal fitness (muscular strength, endurance, and power), and flexibility (10,70). Body composition is the physical distribution of components of the body (e.g., fat mass, fat free mass, total body water, etc.) (70). An abnormal body composition is a risk factor for cardiovascular disease and diabetes (19,20,22,41), and it is associated with increased injury risk in sport (42,49). Cardiorespiratory endurance, as defined by Saltin (63), is the ability of an individual to perform large muscle, whole-body exercise at a moderate to high intensity for extended periods (56,63). Appropriate cardiorespiratory endurance is imperative for sport, as the majority of sports require some level of prolonged aerobic activity. Low cardiorespiratory endurance is a risk factor for injury in sport (11,43), as fatigue negatively impacts motor coordination and control, acutely predisposing an individual to injury (45). Furthermore, cardiorespiratory endurance is a hall-mark of physical fitness, demonstrating various health benefits in youth and adults (70). In youth, there are ties between cardiorespiratory endurance and multiple health outcomes including adiposity (7,12,27,50,75), blood pressure (18,40,60), blood lipid levels (3,29,60), glucose levels (32), and insulin sensitivity (29,32). However, although body composition and cardiorespiratory endurance are important, they do not tell the entire story about the health and fitness of an individual.

The Institute of Medicine has defined musculoskeletal fitness as, “a multidimensional construct comprising the integrated function of muscle strength, muscle endurance, and muscle power to enable the performance of work against one’s own body weight or external resistance” (56). Musculoskeletal fitness is important in sport to increase performance and aid in the reduction of injury (16,43). Furthermore, increasing musculoskeletal fitness promotes multiple health benefits, including body composition (5,24,25,38), blood glucose and insulin levels (5,66), blood pressure (25,47), blood lipid levels (25,77), and bone health (21,52).

The identification and evaluation of individuals with inadequate HRF in youth sport is important because it relates to an individual’s health, performance in sport, and potential for injury. Although it is suggested that individuals who participate in sport have more favorable HRF compared with the general population (55), there is no evidence that supports this contention in youth. Therefore, the purpose of this study was to evaluate the HRF in a sample of youth athletes aged 11–19 years from the south-eastern United States and compare with normative findings from general youth population data. Unfortunately, there are little data available on the HRF of youth sport in the United States, so we used FITNESSGRAM® normative standards and normative data from Canadian youth to provide a better understanding of HRF levels in youth sport. We hypothesized that the HRF of youth athletes will be more favorable than the general population youth.

## **Methods**

### **Experimental Approach to the Problem**

Data were collected before the beginning of each subject’s respective competitive season (fall sports, August to September; spring sports, January to February). Height (in centimeters), body mass (in kilograms), body mass index (BMI), body fat percentage, grip strength (in kilograms), standing long jump

(SLJ; in centimeters), and the FITNESSGRAM® PACER and curl-up were collected by individuals trained on each measure. Before testing, subjects performed a general self-selected warm-up (e.g., 10 minutes of light jogging paired with static and/or dynamic stretching). The PACER was tested on a separate day from other fitness tests to minimize global fatigue.

## **Subjects**

A total of 136 subjects (63 male and 73 female subjects) aged 11–19 (mean 6 SD;16.016 1.35) years were recruited from local public and private high schools (n 5 78) and local sports organizations (n 5 58). The ethnic breakdown of the sample was as follows: 81.6%white, 16.2% black, and 2.2% other. Subjects in the sample participated in the following sports at the high school interscholastic levels (both varsity and junior varsity): football (40 male), soccer (23 male and 39 female), volleyball (18 female), lacrosse (10 female), and other (6 female; sports including basketball and track and field). Exclusion criterion consisted of the report of a musculoskeletal injury within the past 6 months that limited participation or movement capability at the time of testing, lack of current medical clearance for participation in sport, and/or movement-related disorders. Subjects completed informed consent and were required to have parental consent before participating. The University of South Carolina Institutional Review Board and the participating school districts and organizations approved this study.

## **Procedures**

Valid and reliable HRF measures of musculoskeletal fitness (i.e., strength and endurance), cardiorespiratory endurance, and body composition (BMI and body fat percent) were assessed for all subjects. Standardized verbal instruction and demonstration of appropriate technique was provided for each fitness test.

The PACER is a multistage shuttle run, where individuals run 20 m back and forth to the FITNESSGRAM® CD's decreasing time interval cues. Subjects' PACER score was used to calculate an individual's aerobic capacity ( $\dot{V}O_{2\max}$ ) (78). The PACER-estimated  $\dot{V}O_{2\max}$  demonstrates strong validity ( $r \geq 0.87$ ) and reliability ( $r \geq 0.78$  to 0.93) in the age range tested (1,34–36,78). The curl-up is a muscular endurance task that required subjects to perform an abdominal curl with relaxed arms, causing their fingers to slide over 12.7 cm (standardized rubber measuring strip) to the cadence on the FITNESSGRAM® CD. We followed the FITNESSGRAM® procedure manual and materials for cadence, timing, and scoring of these 2 measures (78).

Grip strength was tested using a Jamar hand dynamometer that was adjusted according to hand size. Subjects held their arm by their side with elbow extended during this task and completed 3 trials for each hand (alternating, 20 seconds between trials), and the maximum of each hand was summed for an overall grip strength score (in kilograms) (74). Grip strength is a valid ( $r \geq 0.52$ –0.84) (23,44) and reliable ( $r \geq 0.71$ –0.90) measure of upper body and overall strength (4,6,62). Grip strength is suggested as a measure of muscular strength for youth, as noted from the Institute of Medicine report on Fitness Measures and Health Out-comes in Youth (56). Height was measured to the nearest 0.5 cm using a portable stadiometer (Shorrboard; Weigh and Measure, LLC; Olney, MD). Body mass index and body fat percentage were collected using a bioelectrical impedance scale (model SC-331S; Tanita Corporation, Arlington Heights, IL) (26).

## **Statistical Analyses**

Data were double entered and checked for consistency before analysis, and initial descriptive statistics (means and SDs) were calculated. The scores of FITNESSGRAM® measures were classified according to the 2015–2016 performance standards (e.g., healthy fitness zone, needs improvement, needs

improvement—health risk) by age and sex (78). The healthy fitness zone for the FITNESSGRAM® was used because they are criterion-referenced standards established to reflect that individuals classified in the “needs improvement” category are at potential risk for metabolic syndrome and future health issues. Those in the “needs improvement—health risk” category have a higher probable risk of the aforementioned health issues (57,78). Percentages of individuals in each fitness category were noted and used to gain a general understanding of fitness levels among male and female subjects. T-tests were also performed to compare subjects’ BMI and grip strength with Canadian population normative values by age and sex (74). An alpha of #0.05 was used to determine significance.

**Table 1**  
**Descriptive statistics.**

	Sex	<i>n</i>	Mean	$\pm SD$	<i>p</i>
Age, years	Male	61	15.87	1.44	0.37
	Female	68	15.65	1.26	
Body fat %	Male	63	17.70	7.40	0.00†
	Female	69	23.70	7.10	
BMI*	Male	63	24.46	5.15	0.00†
	Female	70	21.66	3.76	
Est. $\dot{V}O_2\text{max}\ddagger$	Male	34	41.26	6.36	0.47
	Female	58	42.43	6.64	
Curl-up	Male	36	23.39	13.97	0.00†
	Female	68	35.93	21.86	
Grip strength (kg)	Male	63	82.37	19.29	0.00†
	Female	72	57.20	8.90	
SLJ distance (cm)	Male	63	193.97	47.11	0.00†
	Female	61	153.71	34.49	

\*BMI = body mass index.

†*p* < 0.001 for differences between male and female athletes.

‡ $\dot{V}O_2\text{max}$  = (ml·kg<sup>-1</sup>·min<sup>-2</sup>).

**Table 2**  
**Male FITNESSGRAM® musculoskeletal and cardiorespiratory endurance percentages.**

Age, years	Curl-up		20 m PACER $\dot{V}O_2\text{max}$ (ml·kg <sup>-1</sup> ·min <sup>-2</sup> )		
	NI†	HFZ‡	NI†—health risk	NI†	HFZ‡
11	0	100	0	100	0
12	50	50	50	0	50
13	100	0	50	0	50
14	33.3	66.7	0	0	100
15	50	50	33.3	33.3	33.3
16	50	50	66.7	0	33.3
17	44.4	55.6	55.6	11.1	33.3
17+	0	100	0	0	100
% of total <i>n</i>	50.0	50.0	44.1	11.8	44.1

†NI = needs improvement: potential risk for metabolic syndrome; health risk: probable risk for metabolic syndrome.

‡HFZ = healthy fitness zone: protective effect for metabolic syndrome.

## Results

Sample descriptive statistics for the measures of HRF are presented in Table 1. HRF measures of BMI, PACER, and curl-up were classified according to the 2015–2016 FITNESSGRAM® Performance standards (Tables 2–5). More than half (50.8%; *n* = 31) of male subjects were classified as not meeting the healthy fitness zone for BMI, whereas only 21.5% (*n* = 14) of female subjects were below the healthy fitness zone. The majority of both male (70.5%; *n* = 43) and female (79.7%; *n* = 50) subjects were in the healthy fitness zone or “very lean” for body fat percentage. Male subjects’ abdominal muscular endurance (curl-ups) were split equally between the healthy fitness zone (50%; *n* = 17) and needing improvement (50%), whereas the majority (77.8%; *n* = 48) of their female counterparts were classified in the healthy fitness zone. For the estimated  $\dot{V}O_{2\max}$  from the PACER, most male subjects (55.9%; *n* = 19) were classified as not meeting the healthy fitness zone, whereas the majority of female subjects (63.2%; *n* = 36) were in the healthy fitness zone.

We compared the BMI, grip strength, and  $\dot{V}O_{2\max}$  of our sample with those in the study by Tremblay et al. (74) 2010 general population data on Canadian youth (Tables 6 and 7). Male athletes in the 11–14 (*t* = 526.627; *p* = 0.001) and 15–19 (*t* = 527.161; *p* = 0.001) age ranges and female athletes in the 11–14 age range (*t* = 523.177; *p* = 0.001) demonstrated a significantly lower  $\dot{V}O_{2\max}$  compared with Canadian general population data. Female athletes at both age groups had significantly higher grip strength than the Canadian normative data (11–14; *t* = 56.009; *p* = 0.001; 15–19; *t* = 54.066; *p* = 0.001). Furthermore, male athletes aged 15–19 years had significantly lower BMI than the Canadian general population youth (*t* = 51.983; *p* = 0.05).

## Discussion

The purpose of this study was to evaluate youth athlete’s HRF and compare these findings to general population normative data from the FITNESSGRAM® and Canadian youth normative data. We reject our blanket hypothesis statement of HRF of youth athletes being more favorable than the general population. Overall, the HRF for male athletes in this sample tended to be lower in comparison to normative data, whereas female athletes demonstrated mixed results. These data provide valuable insight for lifelong health and wellness of these individuals, as well as insights for sport performance and their injury risk potential.

**Table 3**  
Male FITNESSGRAM® body composition percentages.

Age, years	Body mass index				Body fat percentage			
	NI†—health risk	NI†	HFZ‡	Very lean	NI†—health risk	NI†	HFZ‡	Very lean
11	0	0	100	0	0	0	100	0
12	25	0	75	0	0	25	75	0
13	50	0	50	0	0	50	50	0
14	0	33.3	66.7	0	0	0	100	0
15	31.3	25	43.8	0	12.5	25	62.5	0
16	16.7	27.8	55.6	0	0	22.2	77.8	0
17	28.6	35.7	35.7	0	0	35.7	57.1	7.1
17+	0	100	0	0	0	0	100	0
% of total <i>n</i>	24.6	26.2	49.2	0.0	3.3	26.2	68.9	1.6

†NI = needs improvement: potential risk for metabolic syndrome; health risk: probable risk for metabolic syndrome.

‡HFZ = healthy fitness zone: protective effect for metabolic syndrome.

**Table 4**  
**Female FITNESSGRAM® musculoskeletal and cardiorespiratory endurance percentages.**

Age, years	Curl-up		20 m PACER $\dot{V}O_{2\max}$ (ml·kg <sup>-1</sup> ·min <sup>-2</sup> )		
	NI†	HFZ‡	NI†—health risk	NI†	HFZ‡
12	0	100	0	0	100
13	66.7	33.3	40	20	40
14	30.8	69.2	0	27.3	72.7
15	11.8	88.2	25	12.5	62.5
16	18.8	81.3	31.3	12.5	56.3
17	0	100	0	33.3	66.7
17+	33.3	66.7	33.3	0	66.7
% of total <i>n</i>	22.2	77.8	19.3	17.5	63.2

†NI = needs improvement: potential risk for metabolic syndrome; health risk: probable risk for metabolic syndrome.

‡HFZ = healthy fitness zone: protective effect for metabolic syndrome.

These data demonstrate a rather surprising lack of fitness before the competitive season in boys who are deemed “athletes,” as 3 of 4 fitness assessments had at least 50% of males needing improvement. Although we cannot comment on the athlete’s sport skills, they were not prepared for the competitive season evidenced by their HRF. This sample demonstrated poor HRF before their competitive season, which may be because of their lack of exposure to structured off-season training. Overall, the general lack of HRF on various levels demonstrates the need to address HRF at the beginning of a sport season to not only improve performance and reduce injury potential but also to reduce the potential of future negative health outcomes.

Interestingly, there were contradictory findings between the 2 assessments of body composition (BMI and body fat percentage), which prompt further comparison. Our data further demonstrates why BMI is a poor measure of body composition in a youth sport population because it does not take the type of mass into consideration (13). The BMI of the majority of male athletes (50.8%) was classified as “needs improvement” by FITNESSGRAM® standards, and 24.6% of these subjects were identified as having an immediate health risk based on their BMI. Body mass index in youth sport may be misleading because athletes may have higher lean mass than the general population, inflating their BMI (13,39,48,53). Therefore, we also evaluated body fat percentage because an unhealthy body composition predisposes these individuals for poor performance (59,65,67) and for an increased risk of injury (9,42,43,76). When evaluating body fat percentage, one-third (29.5%) of male athletes were at risk. The “needs improvement” classifications means that these individuals have potential increased risk for health issues later in life based on their body composition. Normative data suggests that approximately 28.2% of children aged 11–19 years are overweight or obese, whereas the data presented indicate that more than half of the male sample demonstrates an unhealthy body composition (by BMI) (74). Football athletes were the majority with poor body composition (both BMI and body fat per-cent), whereas soccer athletes demonstrated more favorable body composition. This may partially be the result of the nature of each sport; soccer requires running upward of 9.98 km per match, whereas football is distinguished by short bouts of activity followed by rest (2). This distinct difference in activity may result in differences in body composition, specifically favoring soccer players in body fat percent. In addition, the emphasis on increased strength and overall mass in football is quite different from soccer. Thus, an increase in mass may be viewed favorably in football, regardless of whether the body composition status is favourable from a health perspective (i.e., increased lean mass and decreased body fat percent). Furthermore, the seasonal nature of football (i.e., played only

in the fall) having a long off-season compared with other sports may explain the decline in HRF in many of these athletes, unless they participate in other sports and activities (8,31).

Surprisingly, almost half (44.1%) of male athlete's cardiorespiratory endurance ( $\dot{V}O_{2\max}$ ) classified them in the "health risk" category, which indicates that these youth do not demonstrate adequate endurance for sport participation and are at risk for future health issues (57). The athletes with poor cardiorespiratory endurance were split between football and soccer players. We would expect to see gross differences between the 2 based on their sport characteristics; however, a lack of structured off-season training may have resulted in decreased cardiorespiratory endurance across the board, as an individual's HRF may vary based on where they are in their respective sport's season (i.e., pre-, in-, off-season) (31). Male athletes demonstrated lower cardiorespiratory endurance compared with the Canadian normative youth data. This may suggest that athletes are not performing greater activity than the general population (i.e., non-athletes) to enhance their cardiorespiratory endurance. Thus, participation in only sport practices and competitions may not be adequate physical activity to enhance HRF. There is a critical need for adequate cardiorespiratory endurance because it is both an indication of future health and a marker for performance in almost every sport (14,43,57).

Half of male athletes demonstrated a need to improve their muscular endurance, and there was no difference between athletes' and the general population. Core stability relies on the muscles of the abdomen and hips and aids in the transfer of energy through the kinetic chain, amplifying the effects of a force (30). Furthermore, as male athletes' muscular strength is no different from the general population, this is a cause to revisit the afore-mentioned idea that athletes may not perform greater activity than the general population. The inability of an athlete to produce force and stabilize their core in dynamic, multijoint movements negatively affects their ability to control their extremities (79), and may decrease sport performance and predispose them to in-jury (14,33,64,79).

**Table 5**  
Female FITNESSGRAM® body composition percentages.

Age, years	Body mass index				Body fat percentage			
	NI†—health risk	NI†	HFZ‡	Very lean	NI†—health risk	NI†	HFZ‡	Very lean
12	0	0	100	0	0	0	100	0
13	16.7	33.3	50	0	0	50	50	0
14	0	0	92.9	9.1	0	0	78.6	21.4
15	11.1	11.1	77.8	0	11.8	23.5	64.7	0
16	11.8	17.6	70.6	0	0	17.6	82.4	0
17	0	14.3	85.7	0	0	14.3	71.4	14.3
17+	0	50	50	0	0	0	100	0
% of total <i>n</i>	7.7	13.9	76.9	1.5	3.1	17.2	73.4	6.3

†NI = needs improvement: potential risk for metabolic syndrome; health risk: probable risk for metabolic syndrome.

‡HFZ = healthy fitness zone: protective effect for metabolic syndrome.

Overall, musculoskeletal and cardiorespiratory systems of a large percentage of male athletes did not demonstrate healthy levels, although they participate in sport activities that inherently require an increased demand on both body systems for both performance and injury risk (37). These data also indicate that cardiorespiratory endurance is not being improved over time by sport practices and/or competitions and reveal the potential transient nature of muscular and cardiorespiratory endurance (15,17). Thus, sport coaches must invest in developing youth strength and endurance during the season and in the off-season (8,31,71), as both periods can be major influences on fitness and sport skills (28,42,57).



A portion of female athletes were in the “needs improvement” FITNESSGRAM® category for BMI (21.6%) and body fat per-centage (20.3%), although the majority were within or above the healthy fitness zone. Interestingly, female athletes demonstrated BMIs that were no different than the normative Canadian general youth population, which is potentially concerning (14,42,43,45,46,59,65,67). However, as previously mentioned, BMI may not be the best measure for body composition in an athletic population, and this result may be misleading (13).

The cardiorespiratory endurance of majority of female athletes was classified in the healthy fitness zone. However, one-third (36.8%) of female athletes were still classified as “needs improvement” for cardiorespiratory endurance, demonstrating a potential health risk (57). Female athletes also demonstrated lower cardiorespiratory endurance compared with the normative Canadian general youth population (11–14 year old). This is concerning as cardiorespiratory endurance is viewed at the core of physical fitness, is essential for sport (11,43), and is linked to multiple health outcomes (e.g., adiposity, blood pressure, and insulin sensitivity) (12,18,27,29,32,60,75). As previously mentioned, these individuals may not be performing more physical activity than nonathletes, and participation in only sport practices and competitions may not be adequate physical activity to enhance HRF.

Although most female athletes demonstrated adequate muscular endurance, a considerable portion (22%) of female athletes were classified as “needs improvement,” pointing to the risk for future health issues (57). Muscular endurance is key for injury prevention because fatigue may decrease an individual’s ability to coordinate and control their limbs. This is important for females because of their predisposition for knee valgus, compounded with decreased limb control may lead to anterior cruciate ligament injury (45,54). Female athletes in both age groups demonstrated higher muscular strength (via grip strength) compared with the normative Canadian data, which may be the result of sport competition increasing the need for muscular strength (37,58). Female athletes demonstrated more favorable HRF profiles when compared with male athletes, specifically because it related to normative data. This may be the result of the nature of the sports involved in the sample because most male athletes participated in football, whereas the majority of female athletes participated in soccer. Greater time in movement during practice and performances and the seasonal variations (i.e., long football off-season) in the sports may provide soccer athletes greater opportunity to enhance and sustain their HRF.

**Table 6**  
Male sport and Canadian general population health-related fitness.

	<i>n</i>	Mean	<i>SD</i>	<i>p</i>
Male 11–14 years old				
BMI*				
Tremblay et al. <sup>74</sup>	318	20.6	4.4	0.38
Pfeifer et al. <sup>54</sup>	12	22.1	5.9	
Grip (kg)				
Tremblay et al. <sup>74</sup>	316	51.0	17.0	0.08
Pfeifer et al. <sup>54</sup>	12	61.7	20.9	
$\dot{V}O_2\text{max}\S$				
Tremblay et al. <sup>74</sup>	307	54.9	3.4	0.00‡
Pfeifer et al. <sup>54</sup>	12	42.1	6.7	
Male 15–19 years old				
BMI*				
Tremblay et al. <sup>74</sup>	287	23.8	5.3	0.04‡
Pfeifer et al. <sup>54</sup>	49	22.3	4.7	
Grip (kg)				
Tremblay et al. <sup>74</sup>	286	85.0	18.0	0.23
Pfeifer et al. <sup>54</sup>	49	87.9	15.2	
$\dot{V}O_2\text{max}\S$				
Tremblay et al. <sup>74</sup>	307	50.8	5.8	0.00‡
Pfeifer et al. <sup>54</sup>	22	40.8	6.3	

\*BMI = body mass index.

‡*p* < 0.05.

‡*p* < 0.001.

§ $\dot{V}O_2\text{max}$  = (ml·kg<sup>-1</sup>·min<sup>-2</sup>).

**Table 7**  
Female sport and Canadian general population health-related fitness.

	<i>n</i>	Mean	<i>SD</i>	<i>p</i>
Female 11–14 years old				
BMI*				
Tremblay et al. <sup>74</sup>	302	20.4	3.8	0.42
Pfeifer et al. <sup>54</sup>	21	19.8	3.3	
Grip (kg)				
Tremblay et al. <sup>74</sup>	301	42.0	10.0	0.00‡
Pfeifer et al. <sup>54</sup>	20	54.6	8.9	
$\dot{V}O_2\text{max}\S$				
Tremblay et al. <sup>74</sup>	307	48.9	4.0	0.00‡
Pfeifer et al. <sup>54</sup>	18	43.6	6.6	
Female 15–19 years old				
BMI*				
Tremblay et al. <sup>74</sup>	280	23.1	4.6	0.54
Pfeifer et al. <sup>54</sup>	44	22.7	3.7	
Grip (kg)				
Tremblay et al. <sup>74</sup>	307	54.0	10.0	0.00‡
Pfeifer et al. <sup>54</sup>	47	59.3	7.9	
$\dot{V}O_2\text{max}\S$				
Tremblay et al. <sup>74</sup>	307	42.2	4.3	0.81
Pfeifer et al. <sup>54</sup>	41	41.9	6.7	

\*BMI = body mass index.

‡*p* < 0.001.

§ $\dot{V}O_2\text{Max}$  = (ml·kg<sup>-1</sup>·min<sup>-2</sup>).

We recognize this study is not without limitations. Because of the study being situated in one southeastern state in the United States and the voluntary nature of participation, there was a lack of

uniformity within the sample sizes, gender, and sport break-downs. An individual's environment (i.e., access to training facilities, coaches, training age) is a noted limitation to the engagement and development of strength, coordination, and overall fitness. Athletes from non-traditional school settings may have lacked access to strength and conditioning coaches and workout facilities compared with their public and private school counterparts. We recognize that the small sample size is a limitation for the analysis of HRF by age and gender (Tables 2–5); however, these provide an overview of the state of HRF in youth matched to the FITNESSGRAM® criterion-referenced standards.

These pilot data represent the foundation for the development of a large-scale study evaluating HRF in youth athletes. To enhance the understanding of the state of youth athlete HRF, future studies should aim for multiregional sampling of athletes with a nonathlete control group. Limiting future sampling to those sites with similar resources, and the collection of participation level (i.e., junior varsity vs. varsity) and training age may enhance the depth of data collected in future studies.

### **Practical Applications**

The findings from this study demonstrate many youth athletes in this sample, specifically boys, may be at an increased risk for negative health issues, injury, and decreased performance because of their poor HRF. These findings indicate that participation in sport practices and games may not necessarily promote improvement or maintenance of HRF. Strength and conditioning coaches may use this information to guide their decision-making processes for youth athletes because youth may require more attention to build a foundation of cardio-respiratory endurance and muscular strength and endurance. Evaluating HRF in youth sport is imperative not only to glean information regarding an individual's predisposition for future health issues (i.e., metabolic syndrome) but also to understand in what areas an individual might need improvement. Subsequently, addressing an individual's areas of need may improve their sport performance and decrease their injury potential. Promoting HRF, regardless of competitive level, may enhance an individual's long-term athletic development and enjoyment or engagement in sporting activities (37,46). Finally, regardless of sport participation youth HRF must be addressed because it has implications for the development of positive health trajectories across youth and into adulthood (61,72,73).

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