Hue et al Swimming Abilities in Afro-Caribbean Swimmers Anthropometric and Physiological Characteristics in Young Afro-Caribbean Swimmers: A Preliminary Study

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Anthropometric and Physiological Characteristics in Young Afro-Caribbean Swimmers: A Preliminary Study

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The authors investigated the anthropometric and physiological characteristics of young Guadeloupian competitive swimmers in relation to swimming performance and compared the abilities of these children with those of the young white swimmers reported in the literature. All 2004 competitive swimmers between 10 and 14 y old (126 children, 61 boys and 65 girls, 12.0 ± 1.3 y) from Guadeloupe underwent anthropometric measurements and physiological and performance testing. Six boys on the French national swimming team are referred to hereafter as the 2011 elite subgroup. Anthropometric parameters, a jump-and-reach test, glide, and estimated aerobic power (eVO_{2max}) were assessed in terms of swimming-performance analysis through a 400-m test. This study demonstrated that the Guadeloupian swimmers had more body fat than most age-matched white swimmers but had very poor hydrostatic lift; they had higher peak jump height and they swam as well as their white counterparts. The variability in 400-m performance between subjects was best described by glide, age, and eVO_{2max}. Compared with the group of boys with the same age, the 2011 elite subgroup was significantly better for arm span, peak jump height, glide, and 400-m and 15-m performances. Further research is needed to investigate motor organization and energy cost of swimming in Afro-Caribbean swimmers.

Keywords: performance prediction, detection, maximal aerobic power, girls

Athletes of West-Central-African origins (WCA), including African Americans and West Indians (ie, Afro-Caribbean), have long dominated international sprint and jump events.[1–4] Although the explanation for their disproportionate success remains unclear, differences in growth and physical performance have been demonstrated between black and white children,[5] with some studies showing better short-sprint performance in both male and female blacks than in their white counterparts.[1,6–8] Others have shown that bone density is higher[9,10] and fat percentage is lower in blacks,[1,11,12] and anthropometric characteristics have been suggested to explain the better sprint performance.[4] Jump and sprint performances are generally better in black than in white children,[13] certainly in relation to better explosive power as measured with the jump test.[1] It has thus been hypothesized that prepubertal Afro-Caribbeans are endowed to run faster.[1]

In contrast, blacks of WCA origins seem to be less advantaged in swimming. Although very few studies have examined swimming ability in WCA blacks, a 2009 epidemiological study of 1680 subjects in the United States demonstrated that race was associated with swimming ability, with African American children at a significant disadvantage,[14] and, more recently, a group of authors demonstrated that this could be explained by anthropometric factors.[3,4]

Although WCAs are underrepresented in swimming competition, Afro-Caribbean Guadeloupians have recently emerged as high-level swimmers, with some of them included on the French national swimming team. The purpose of this study was to investigate the anthropometric and physiological characteristics of young Guadeloupian competitive swimmers from 10 to 14 years old, including those currently on the national team, to analyze these parameters in relation with swimming performance and to compare the abilities of these children with those of young white swimmers in the literature.

Material and Methods

Subjects

All competitive swimmers between 10 and 14 years old (126 children, 61 boys and 65 girls, 12.0 ± 1.3 y) from Guadeloupe underwent anthropometric measurements and physiological and performance testing in 2004. The anthropometric and physiological data are presented in Tables 1 and 2. All subjects were fully informed of the study conditions, and their parents gave written consent in accordance with the regional ethics committee before participating. Among the 126 children, 6 boys (10–12 years old in 2004) were on the French national swimming team at the time of this writing. They are referred to hereafter as the 2011 elite subgroup. Our study meets the ethical standards defined by Harriss and Atkinson.[15]

\<<<<<<<<<<TABLE 1>>>>>>>>>>>\

\<<<<<<<<<<TABLE 2>>>>>>>>>>>\

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Anthropometry

Leg length (measured at the gluteal furrow) and arm span (measured from the tip of the middle finger of one hand to the other) were obtained with a polyester measuring tape and an anthropometer. After height and body-mass measurements, the percentage of fat body mass (%FBM) was estimated from the skinfold thickness, expressed in millimeters, of the sum of 4 skin areas (biceps, triceps, subscapula, and suprailiac) measured on the right side of the body with Harpenden skinfold calipers, following the method described by Durnin and Rahaman.[16] Sexual maturation was evaluated from the puberty stages of Tanner[17] by the physician in charge of the swimming league.

Buoyancy was evaluated by measuring hydrostatic lift (HL) as described by Chatard et al.[18] This was measured at the end of a maximal inspiration when the subjects were floating in the fetal position facing downward. Lead weights, varying from 0.1 kg to 1 kg, were successively applied to the back at the level of the shoulder blades. The final load necessary to maintain the subjects in a balanced position just under water was considered HL. This method has been shown to be highly reliable ($r = .98$ for 8 swimmers)[16] and is easy to use.

Jump-and-Reach Test

The jump-and-reach test was performed using an Ergojump (Jump-MD, Takeï, Japan). The subjects were asked to perform a countermovement jump (CMJ) as previously described.[1] The power output during the jump-and-reach test was determined by entering the jump-height and body-weight variables into the equation of Sayers et al,[19]

$$CMJ_{peakP}\ (W) = 51.9 \times CMJ\ height\ (cm) + body\ mass\ (kg) - 2007$$

where CMJ_{peakP} is the peak power obtained with the CMJ and CMJ height is the height attained.

A standardized 15-minute warm-up was performed by all subjects 10 minutes before the test. This warm-up was exclusively composed of lower limb stretching movements (knee flexors and extensors).

Performance

The day of the anthropometric measurements, the swimmers performed two 15-m sprints without diving, and the best performance was kept as their maximal swim speed. The best performance in a 400-m competitive event in a 50-m swimming pool at the time of the current season (ie, within the last 2 months) was recorded for each swimmer.

Glide

The passive-glide measure (ie, without any kicking phase) was the distance attained by the swimmer's head after a push on the swimming pool wall in the prone ventral hydrodynamic position at a depth between 0.5 m and 1 m.[20] Each swimmer performed the test 3 times to become familiar with it and to find the best gliding position. The best distance was retained.

Estimated Maximal Aerobic Power

The outdoor incremental test was the University of Montréal track test,[21] an indirect continuous multistage test that is valid and reliable for estimating indirect maximal aerobic power (eVO_{2max}) from maximal aerobic velocity. The subjects ran along markers placed every 20 m on a 400-m track and were paced by audible cues. The interval between cues decreased gradually (every 1 min), and the subjects thus had to increase their speed ($0.5\ km \cdot h^{-1} \cdot min^{-1}$) to keep pace with the cues.

Statistical Analysis

All values are expressed as mean ± SD. A 2-way (sex × age) ANOVA for unpaired populations was applied, with post hoc analysis if necessary. When statistical significance was observed, post hoc analysis was done. Pearson product–moment correlations describe the relationship between the individual anthropometric and physiological variables and 400-m performance.

Sex-specific and nonspecific multiple linear models were developed to identify the best combinations of multiple simultaneous determinants of the 400-m and 15-m sprint performances from the initial set of variables. A multipronged strategy was adopted for data selection after checking for assumptions. This consisted of examining the possible regression methods (backward, forward) to check for the consistency of the significant variables and for model optimization. The probabilities of F-to-enter and F-to-remove were .05 and .10, respectively. The adjusted r^2 values are provided in the results. The equations resulting from the regression analysis were applied to estimate 400-m performance and to relate it to the actual measured performance.

The boys in the 2011 elite subgroup were compared with the other boys age 10 to 12 years in 2004, through unpaired Student *t* tests performed on all anthropometric, physiological, and performance variables. Binary logistic-regression analysis was performed to determine the significant predictors of endpoint level of practice in 2011 (elite or not) from the following initially measured variables: height, leg length, arm span, weight, %FBM, eVO_{2max}, CMJ_{peakP}, power output, glide, HL, and 400-m-crawl performance. Because of missing data points, the analysis included 5 elite and 28 nonelite swimmers.

We used the Statistical Package for Social Sciences (SPSS), version 18.0. For all statistics, a significance level of $P < .05$ was preset.

Results

Anthropometry

As presented in Table 1, all the anthropometric data except %FBM changed with age. There were no differences in anthropometric data between boys and girls at any age except for %FBM, which was significantly greater for girls at each age and for the mean.

Physiology and Performance

eVO_{2max} was better in boys than girls ($P < .001$) and changed with age ($P < .04$). Mean CMJ and CMJ_{peakP} were greater in boys (sex effect: $P < .02$) and changed with age (age effect: $P < .001$ and $P < .001$, respectively, for CMJ and CMJ_{peakP}) (Table 2). The 400-m-crawl performance was better in boys (sex effect: $P < .04$) and changed with age ($P < .001$). The mean 15-m-sprint performance was better in boys than in girls (Table 2).

Performance Determinants

The variability in 400-m performance between subjects was best described by glide, age, and eVO_{2max} ($r^2 = .299$, $P < .01$). In girls, leg length, eVO_{2max}, and glide ($r^2 = .229$, $P < .01$) appeared as the best predictors. In boys, most of the variability was attributed to age and eVO_{2max} ($r^2 = .431$, $P < .01$) (Figure 1).

\<<<<<<<<<<FIGURE 1>>>>>>>>>>>\

The 2011 Elite Subgroup

Compared with the group of boys with the same age (10–12 y, n = 33), the 2011 elite subgroup did not present any significant difference in age, height, leg length, weight, %FBM, eVO_{2max}, or HL (Tables 3 and 4). However, some parameters were significantly better (Tables 3 and 4) in the high-level swimmers, such as arm span ($P < .05$), CMJ_{peakP} ($P < .05$), glide ($P < .02$), and 400-m ($P < .03$) and 15-m ($P < .001$) performances.

\<<<<<<<<<<TABLE 3>>>>>>>>>>>\
\<<<<<<<<<<TABLE 4>>>>>>>>>>>\

Logistic regression identified 4 variables predictive of the skill level 7 years later (elite and nonelite). The equation based on CMJ_{peakP}, glide, HL, and 400-m performance was able to allocate 100% of the swimmers of this population to their exact endpoint group.

Discussion

This study investigated the anthropometric and physiological characteristics of young Guadeloupian children in relation to their competitive swimming performances and compared their swimming abilities with those usually noted in young white swimmers.

This study is the first to investigate the anthropometric characteristics of Guadeloupian children (ie, of African origin) involved in swimming competition. Our male swimmers showed greater height and CMJ_{peakP} but similar FBM at 11[1] and 14 years than boys of the same origins but not involved in sports (personal data). They were in the same range for height (148–170 vs 147–173 cm) and weight (40–60 vs 38–62 kg) as white male swimmers of similar age[22–27] but could certainly be considered fatter (15.6–20.6 vs 11–17.7%FBM). Although few studies have reported HL, it seemed to be lower in our swimmers (1 vs 2 kg),[27] which is surprising given the higher %FBM. This low HL added to high %FBM has previously been observed in monofin swimmers,[28] probably in relation to ethnic characteristics: Higher bone density has been demonstrated in blacks,[9,10] with a higher leg-to-trunk ratio[4] resulting in greater lower limb muscle mass[4] and lower spirometric volumes.[29] Taken together, these parameters would be ~~a~~ negative elements in children's swimming ability.[25]

Until quite recently, the explanation for why the fastest runners are black and the fastest swimmers are white was thought to lie with physics[3,4] and, more specifically, with center of mass, which is 3% higher in blacks than in whites, giving them an advantage for running but a disadvantage for swimming.[4] Although we measured our swimmers' leg length, we were unable to find similar data for young white swimmers in the literature to make comparisons. However, as noted, the observation that our swimmers had higher %FBM but lower HL than white swimmers of the same age suggests that they had a higher leg-to-trunk ratio.

There are few studies of swimming girls, but the anthropometric values of our girls seemed to be in the range reported by others.[30]

Many of the studies in the literature did not use the same protocol (direct vs indirect methods) to assess VO_{2max}, so it is difficult to discuss the VO_2 of our swimmers in comparison with that obtained in whites. However, the values of indirect VO_{2max} for the boys followed the regressions based on 33 experimental studies in athletic children in the same age range established by Falgairette et al[31] from direct protocols. The maximal aerobic velocity also showed the same range noted by Berthoin et al[32] from an indirect protocol. For the girls, the values were slightly lower than those observed in the same literature for VO_{2max} (12 experimental studies) and maximal aerobic velocity, particularly in the prepubertal age range. The differences observed for the girls could be attributed to higher weight and FBM.

Numerous studies have explored CMJ data in children, and the values obtained in our children (39.1–50.8 cm) are the highest values noted for CMJ performance at the same age, both in swimmers (23–27 cm for Bencke et al[22] in 10.5- to 12-year-old children) and nonswimmers (24–30 cm for Bencke et al[22] in gymnasts of the same age and 25.2 and 29.1 cm in white and black 12-y-old Tunisian football players).[33] This observation is regularly noted in the literature in comparisons of blacks of WCA origin[33] with other ethnic groups and, more important, in comparisons of Guadeloupian black children with white ones.[1] This may be due to greater maximal length strength[AUQ1],[34,35] possibly because of a different distribution of muscle-fiber types.[37] This suggests that our swimmers are endowed for sports event of short duration, as suggested for people of African origin.[6–8,37] However, this seems to contradict our finding that the 400-m swim performance was not lower than that noted in the current literature.

Parameters Involved in 400-m Performance

The 400-m distance is a valid test to evaluate maximal aerobic power in swimmers[38] and is regularly used in the literature. The performance during the 400-m swim could be favorably compared with the times noted in the literature for the same age and the same sex (399–335 s for 400-m in boys 11–14 y and 374–367 s for 400-m in girls 12.5–13.5 y).[23,24,26,27,39] In contrast, the results of the 2011 elite subgroup were better than those noted in the literature (ie, a mean of 330 s for the 400-m in 10- to 12-y-old boys).

Performance was poorly but significantly correlated with glide, age, and eVO_{2max}, indicating that the older children with better glide and better eVO_{2max} demonstrated better performance in the 400-m swimming trial. These results agree with the literature, which shows a correlation with direct or indirect VO_{2max} in young swimmers.[23,24,26,39] We measured indirect VO_{2max} with a running test known to show higher results with longer leg length and greater running economy, and these 2 factors are well known to improve with age. It was therefore not surprising that 400-m performance was also related to age, as older swimmers normally swim with better efficiency than do younger ones.[25] Lätt et al[26] demonstrated that 400-m performance increases with age according to increases in body height and arm span and improvement in VO_2, as well as in relation to technical factors.

The implication of the glide in 400-m performance emphasizes the importance of underwater resistance in swimming. Glide's effect on swimming performance has been studied during short swimming durations and consecutive to the start and grab phases[40,41] or across passive drag.[18] The following has been demonstrated: Swimmers with longer glides usually have the most effective hydrodynamic position to avoid a high loss of velocity during the glide,[40,41] and a good glide associated with low passive drag should be considered a good indicator of general aptitude for swimming.[18] It is not certain, however, that the swimmers with better passive drag (ie, better glides) are more economical during active drag, because 400-m swimming performance in a 25-m pool means 15 glides, which could amount to substantial energy conservation for swimmers with a better glide. Sanders and Byatt-Smith[42] demonstrated that starting aquatic propulsion too early (ie, opposite the glide) raises the energy cost of swimming, and Vantorre et al[40,41] suggested that a longer gliding phase (ie, after the start phase and after each "flip turn") is more economical because the swimmers do not act to move forward and remain in a hydrodynamic position. Moreover, Chatard et al[18] showed a correlation with passive drag and swimming performance.

When boys and girls were separated, the factors implicated in the variability of 400-m performance were age and eVO_{2max} in boys (r^2 = 0.431, P < .01) and leg length, eVO_{2max}, and glide in girls (r^2 = .229, P < .01). The finding that age was not correlated in girls and was replaced by an anthropometric parameter (ie, leg length) may be explained by different maturation rates in boys and girls of the same age, with girls attaining final maturation (ie, reflected by the Tanner stage) earlier.

Girls Versus Boys

We did not see a sex × age effect, but some parameters demonstrated a sex effect: The girls were significantly fatter, had lower eVO_{2max} and CMJ_{peakP}, and demonstrated lower performance for both the 400-m and 15-m trials. The results on body fat and VO_{2max} were reported for older boys and girls involved in swimming activity (ie, 13–15 y old),[38] as well as for school children.[32] This sexual dimorphism is notable in puberty, which is associated for girls with significantly lower hemoglobin values and higher fat mass due to hormonal effects.[43]

Although we found no significant sex × age difference in 400-m performance, the girls increased their 400-m speed up to 13 years old and then stagnated, whereas the 400-m speed in boys continued to rise. Our results agree with findings that the most consistent rapid rise in swimming speed occurs from 11 to 13 years in boys[44] and girls.[39] However, although a slow increase in swimming speed is noted at 13 to 14 years followed by a second acceleration from 14 to 16 years of age,[44] which we noted in our girls, our boys demonstrated a stagnation at 12 and 13 and an acceleration at 14, certainly in relation to greater maturation and thus more muscle power at 14 than at 12 and 13 years old. This interpretation is consistent with the increase in Tanner stage in our boys at 14 years compared with 12 and 13. The significantly better 15-m performance in boys was consistent with greater muscle development, as reflected by the greater CMJ_{peakP}.

The 2011 Elite Subgroup

Costa et al[45] demonstrated that performance is not stable in young white swimmers until about 16 years of age, and therefore predictions of future performance are not really robust until data at 16 years are available. Nevertheless, it was very interesting to note that 3 of the 4 variables predictive of skill level were significantly better in the 2011 elite subgroup 7 years later (ie, CMJ_{peakP}, glide, and 400-m performance), which suggests that future elite swimmers are discriminated by CMJ_{peakP}, glide, HL, and 400-m performance and had better CMJ_{peakP}, glide, and 400-m. As CMJ_{peakP} was better in the 2011 elite group and may be linked to the glide (ie, swimmers with better leg power push harder on the wall, thereby having the best glide result), we investigated the glide:CMJ_{peakP} ratio. We found that the ratio did not differ between the 2011 elite subgroup and their counterparts (ie, 2.44 ± 1.28 vs 2.87 ± 1.27 in elite vs their counterparts for the [glide/CMJ_{peakP} × 1000] ratio; arbitrary units). This indicates that the better glide noted in the 2011 elite subgroup was not due to the better CMJ_{peakP} but certainly to more effective hydrodynamic characteristics.

However, the better CMJ_{peakP} denoted higher explosivity in the 2011 elite subgroup, which was confirmed by the better 15-m performance. This latter was not a discriminating factor between the elite and nonelite swimmers in our study, and it is not a key factor of 400-m performance, as long-distance characteristics differ from those of sprint events.[46]

Perspective

This study demonstrated that (1) although the Guadeloupian swimmers were fatter than most white swimmers of the same age, they had very poor HL, certainly in relation with ethnic characteristics; (2) they had better CMJ_{peakP}, also certainly in relation with ethnic characteristics; and (3) they performed as well as their white counterparts at the same age. The top 2 swimmers of Afro-Caribbean origin selected for the French team for both international and Olympic competition (ie, Julien Sicot and Malia Metella) were both sprinters, but only 1 of the 6 young swimmers of the current study is now a sprinter. This means that our young swimmers with great explosivity and poor HL, who were discriminated by important parameters implicated in long-distance swimming (400-m performance, a reflection of aerobic power) and glide, did not succeed in sprint events at an international level but in longer ones.

Further research is needed to investigate the motor organization and energy cost of swimming in Afro-Caribbean swimmers, because they clearly are different from those noted in whites.

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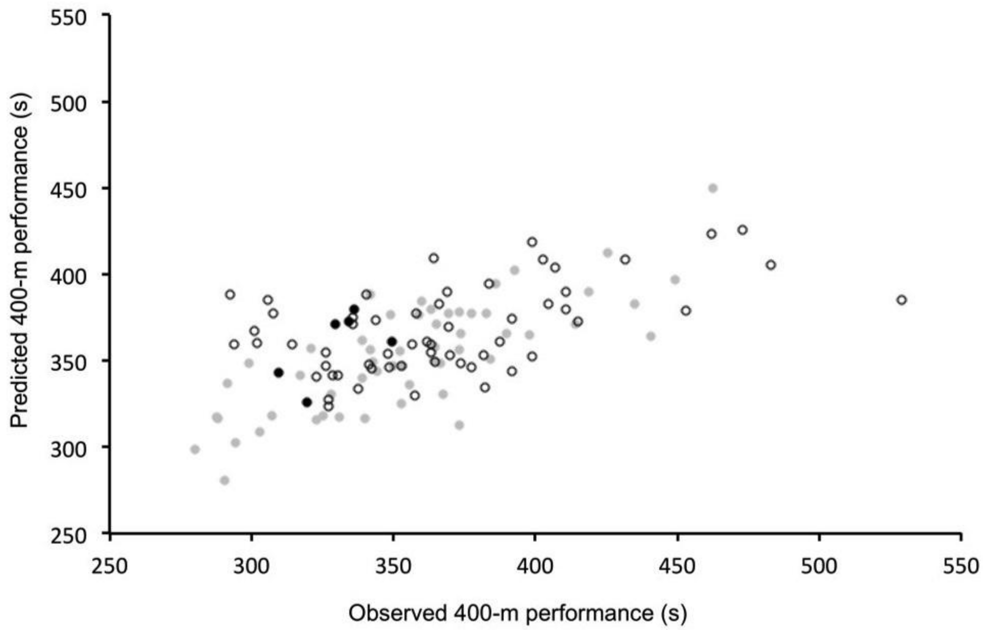

Figure 1 — Observed and predicted sex-specific 400-m performance in future high-level performers (black circles) and in other boys (gray circles) and girls (white circles).

Table 1 Anthropometric Differences Between Boys and Girls Over Time

	Age, y	n	Tanner stage	Height, cm*	Leg length, cm*	Arm span, cm*	Weight, kg*	Body fat, %
Boys	10	9	1–2	148.1 ± 12.6	70.5 ± 5.3	156.0 ± 13.8	39.9 ± 11.2	17.5 ± 5.0
	11	14	1–2	152.3 ± 5.9	71.1 ± 5.5	156.1 ± 9.5	41.3 ± 8.1	20.6 ± 4.4
	12	16	1–2	155.9 ± 6.2[a,b]	76.9 ± 4.3[a,b]	165.1 ± 11.2[b]	45.1 ± 8.9	15.6 ± 3.5
	13	12	1–3	169.7 ± 5.5[a,b,c]	79.7 ± 4.9[a,b]	177.3 ± 7.4[a,b,c]	51.3 ± 7.5	16.6 ± 5.3
	14	10	2–4	170.4 ± 9.3[a,b,c]	82.2 ± 5.4[a,b,c]	175.7 ± 13.3[a,b,c]	59.5 ± 12.4	19.9 ± 8.0
mean				159.0 ± 11.6	76.1 ± 6.6	166.1 ± 13.7	46.8 ± 11.3	17.9 ± 5.5
Girls	10	12	1–2	144.8 ± 7.1	68.7 ± 4.9	152.2 ± 10.1	39.3 ± 6.7	**29.6 ± 4.7**
	11	17	1–3	154.9 ± 7.4[a]	74.7 ± 7.3[a]	160.1 ± 9.8	43.2 ± 7.4	**24 9 ± 4.4**
	12	19	2–4	158.4 ± 4.6[a]	75.2 ± 4.3[a]	166.7 ± 7.6[a]	46.6 ± 8.0[a]	**25.3 ± 6.1**
	13	8	3–5	163.1 ± 5.4[a,b]	81.1 ± 5.1[a,b,c]	171.4 ± 10.1[a]	54.1 ± 4.8	**28.9 ± 4.8**
	14	9	3–5	163.7 ± 6.3[a,b,c]	77.8 ± 5.3[a]	170.3 ± 8.3[a,b]	55.9 ± 10.2	**27.7 ± 3.2**
mean				156.8 ± 8.4	75.3 ± 6.4	165.0 ± 10.4	47.0 ± 9.3	**26.6 ± 5.2**

Note: Bold indicates sex effect: different from boys at the same age ($P < .001$).

*Age effect ($P < .001$): a, different from 10 y; b, different from 11 y; c, different from 12 y ($P < .05$).

Table 2 Physiological and Performance Results

	Age, y	n	eVO_{2max}, mL · min^{-1} · kg^{-1}*	MAV, km · h^{-1}	CMJ, cm*	CMJ_{peakP}, W*	HL, kg	Glide, m*	400-m, s	15-m, s
Boys	10	9	51.3 ± 3.9	9.4 ± 2.1	43.2 ± 9.3	2079 ± 549	1.1 ± 0.6	7.7 ± 1.0	389 ± 47	10.7 ± 0.7
	11	14	50.6 ± 3.0	9.7 ± 1.6	45.4 ± 6.6	2367 ± 559	1.2 ± 0.8	6.9 ± 1.1	371 ± 30	10.3 ± 0.6
	12	16	52.3 ± 5.1	11.3 ± 2.3	47.7 ± 5.2	2672 ± 511[a]	1.1 ± 0.5	7.7 ± 1.3	348 ± 39[a]	10.0 ± 0.9
	13	12	54.8 ± 4.6[b]	12.9 ± 2.4[a,b]	48.0 ± 7.9	2995 ± 504[a,b]	1.0 ± 0.7	7.2 ± 1.0	347 ± 34[a]	10.0 ± 0.7
	14	10	57.0 ± 4.6[a,b,c]	13.8 ± 3.0[a,b,c]	50.8 ± 7.2	3588 ± 699[a,b,c]	0.8 ± 0.5	8.6 ± 1.1[b,d]	310 ± 33[a,b,c,d]	9.7 ± 0.6
mean			**45.4 ± 4.5**	**5.7± 1.7**	39.1 ± 5.1	1948 ± 457	1.2 ± 0.9	7.5 ±1.3	397 ± 74	**11.8 ± 1.2**
Girls	10	12	47.8 ± 4.1	8.6 ± 2.2	**41.0 ± 4.1**	2243 ± 275	1.0 ± 0.6	7.2 ± 1.3	381 ± 39	10.6 ± 0.8
	11	17	**49.1 ± 2.4[a]**	**8.8 ± 1.5[a]**	**42.2 ± 4.7**	2393 ± 400[a]	1.3 ± 0.7	8.6 ± 1.4[b]	352 ± 41	10.6 ± 1.2
	12	19	**48.8 ± 2.4**	**8.3 ± 1.8[a]**	48.1 ± 5.4	3019 ± 282[a,b,c]	1.3 ± 0.4	7.2 ± 2.3	348 ± 31	**10.9 ± 0.3**
	13	8	**48.7 ± 3.8**	**10.5 ± 1.8[a]**	**42.2 ± 7.0**	**2690 ± 226[a,b,d]**	**1.5 ± 0.8**	9.8 ± 0.3[a,b]	**356 ± 23**	10.4 ± 0.6
	14	9								
mean			**48.1 ± 3.6**	**8.5 ± 2.1**	**42.2 ± 5.6**	**2397 ± 466**	1.3 ± 0.7	8.0 ± 1.5	**367 ± 48**	**10.9 ± 1.0**

Abbreviations: eVO_{2max} indicates estimated aerobic power; MAV, maximal aerobic velocity; CMJ, countermovement jump; CMJ_{peakP}, CMJ peak power; HL, hydrostatic lift. Note: Bold indicates sex effect: different from boys at the same age ($P < .001$).

*Age effect ($P < .001$). a, different from 10 y; b, different from 11 y; c, different from 12 y; d, different from 13 y ($P < .05$).

Table 3 Anthropometric Differences Between Elite and Nonelite Swimmers

	n	Age, y	Height, cm	Leg length, cm	Arm span, cm	Weight, kg	Body-fat mass, %
Elite	6	11.5 ± 0.8	158.1 ± 12.4	74.2 ± 6.2	168.6 ± 14.8	46.9 ± 10.6	18.7 ± 1.2
Nonelite	33	11.1 ± 0.3	151.8 ± 9.6	73.2 ± 5.7	158.1 ± 10.6*	41.6 ± 9.0	17.6 ± 5.1

*$P < .05$.

Table 4 Physiological and Performance Results in Elite Versus Nonelite Swimmers

	n	eVO_{2max}, mL · min^{-1} · kg^{-1}	CMJ_{peakP}, W	HL, kg	Glide, m	400-m, s	15-m, s
Elite	6	51.9 ± 4.3	2793 ± 597	1.1 ± 0.4	9.3 ± 0.6	330 ± 16	9.3 ± 0.6
Nonelite	33	45.0 ± 6.5	2357 ± 556*	1.1 ± 0.6	7.2 ± 1.1*	374 ± 40*	10.5 ± 0.7*

Abbreviations: eVO_{2max} indicates estimated aerobic power; CMJ_{peakP}, countermovement peak power; HL, hydrostatic lift.

*$P < .05$.