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Body Composition of Cold-Water Swimmers: The San Francisco Polar Bear Swim Study

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Abstract: *Objectives*: To assess the body composition of recreational cold-water swimmers, to determine if cold-water swimmers have an increased % body fat when compared to average Americans, and to examine the relationships between body composition and total swim distance and time in the water per swim.

Methods: Following 3 months of swimming regularly in cold water in the San Francisco Bay (water temperature range: 9.6° C [49.3° F] to 12.6° C [54.7° F]) during the winter months, body mass index (BMI), % body fat (assessed by circumference technique), and surface/volume ratio were measured in 88 subjects (70 men and 18 women). The total cumulative swim distance was recorded by each subject and each subject estimated his or her average time in the water per swim.

Results: For all subjects, averages were as follows: total swim distance in 3-month period (miles[km]): 50.3 [81.0] ± 17.6 [28.3] (range 40 [64.4] – 154 [247.8]), average estimated time in the water per swim (minutes): 32.5 ± 7.9 (range 17 -60), age (years): 52.3 ± 10.1 (range: 24-76), BMI (kg/ m^2): 25.8 ± 3.4 (range:19.0-37.1), % body fat: 22.6 ± 6.7 (range: 6.9-42.4), surface/volume ratio(m^2/L): .0259 ± .0023 (range: .0200-.0311). Compared to corresponding American 50th percentile values, the % fat of men was modestly lower (Median of the difference =-1.6%; P=0.007); the % fat of women was modestly higher, but not statistically different (Median of the difference =1.7%; P<0.1). There was a marginal non-linear correlation between % fat and average estimated time in the water per swim (Coef.=0.007; P=0.048). No body composition variable correlated with total swim distance (P>0.1 for all variables).

Conclusion: Our results suggest that recreational cold-water swimmers do not have an increased % body fat when compared to average Americans, and individuals with a wide variety of body types are able to swim recreationally in cold water. The marginal correlation between % fat and average estimated time in the water suggests that leaner swimmers voluntarily limit time in cold water.

Keywords: Swimming, body composition, exercise, physiology, hypothermia.

INTRODUCTION

Swimming in cold water is increasing in popularity and has been a topic of interest in both the medical literature and the popular media [1-6]. Although traditionally cold water has been considered the domain of elite athletes who are protected by an increased % body fat [7, 8], few studies have systematically examined the body composition of a large group of recreational cold-water swimmers.

The San Francisco Bay is home to a group of swimmers who swim year-round without wetsuits or swim aids [2, 5]. With the cooperation of this group, our goals were to assess the body composition of recreational cold-water swimmers, to determine if cold-water swimmers have an increased % body fat when compared to average Americans, and to examine the relationships between body composition and the outcomes of a recreational cold-water swim event.

METHODS

Between December 21, 2010 and March 21, 2011, 106 swimmers completed the annual San Francisco Dolphin Club Polar Bear Swim. In this event, swimmers were required to swim a minimum total of 40 cumulative miles (64.4 km) spread over a 90-day period, in the San Francisco Bay, without wetsuits or swim aids. Participants could exceed the 40-mile minimum, with honors going to those who accumulated the greatest number of miles. Swimmers swam at an individual pace and self-recorded their daily mileage on a public recording chart. Study subjects were also asked to comment briefly on their swim habits and experience and to estimate their average time in the water per swim. Warm showers and saunas were available to all participants both before and after swimming. Although wetsuits were prohibited, insulating neoprene caps were permitted.

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Within 15 days of the completion of the Polar Bear event, 88 swimmers consented to % fat, body mass index (BMI), and surface/volume ratio measurements using previously described methods [2, 9-13]. Calculations of BMI, % fat, and surface/volume ratio are summarized in Table **1**.

Table 1. Calculation of Body Mass Index, % Fat, and Surface/Volume Ratio

Body Mass Index (BMI) [9]
(1) Body Mass Index (BMI) (kg/m^2) = W/H^2, where W is weight (kg) and H is height (m).
% Fat [10,11]
(2) % Fat (men) = 86.010 X log(Ab – N) – 70.041 X log(H) + 30.30, where Ab is abdominal circumference (cm), N is neck circumference (cm), and H is height (cm).
(2b) % Fat (women) = 163.205 X log(Wa + Hi –N) – 97.684 X log(H) – 104.912, where Wa is waist circumference (cm), Hi is hip circumference (cm), N is neck circumference (cm), and H is height (cm).
Surface/Volume Ratio [2, 12, 13]
(3) Surface/volume ratio (m^2/L) = surface area/body volume
(3b) Surface area = $W^{0.425}$ X $H^{0.725}$ X 0.007184
(3c) Body volume = 0.01W[%fat/0.9 kg/L + 100-%fat/1.1 kg/L], where W is weight (kg) and H is height (cm).

For simplicity, % fat was estimated using a circumference-based technique; utilizing this method, % fat was calculated from height and circumference measurements of the neck and abdomen for men, and height and circumference measurements of the neck, waist, and hip for women [10, 11]. Surface/volume ratio was calculated as described previously [2, 12], using a traditional assessment of body surface area [13]. Theoretical normal values for surface/volume ratio were calculated using ranges of American 50th percentile % fat values (ages 30-79 yrs)[9] (men: 19.7-24.1 %, women: 22.6-30.6 %), American height averages [14] (men: 1.789 m, women: 1.648 m), and theoretical weights of 70 kg for men and 59.4 kg for women.

For descriptive statistics, means ± standard deviations are presented unless otherwise specified. Spearman correlations, Wilcoxon tests, and linear regression were used to examine the relationships between variables. Logarithmic transformation of non-normally distributed variables was done prior to linear regression. A paired non-parametric test (Wilcoxon signed rank sum test) was used to compare each subject's measured % fat to the corresponding age and sex-specific American 50th percentile fat value [9]. The California Pacific Medical Center institutional review board approved the study.

RESULTS

During the Polar Bear Swim period the water temperature of the San Francisco Bay ranged between 9.6° C (49.3° F) and 12.6° C (54.7° F). No subject was seriously injured while participating. The average age of participants was 52.3 ± 10.1 years (range: 24-76 years), and 27 subjects (31%) were 60 years of age or older. A wide variety of swim backgrounds were reported and 4 subjects had previously completed English Channel swims. The average distance achieved during the 90-day swim period was 50.3 ± 17.6 miles (81.0 ± 28.3 km), (range 40 – 154 miles [64.4-247.8 km]). The average estimated time in the water per swim was 32.5 ± 7.9 minutes (range 17.0 – 60.0 minutes).

Biophysical characteristics and age of the subjects are summarized in Table **2**. The average BMI both of the group overall (25.8 ± 3.4 kg/m^2), and of men (26.4 ± 3.4 kg/m^2), was in the overweight, but not obese category [9]. The average BMI of women (23.7 ± 2.8 kg/m^2) was in the normal category [9]. The highest recorded BMI in women was 29.6 kg/m^2. Thus, no woman was obese by BMI criteria (BMI ≥30 kg/m^2) [9]. No subject was underweight by BMI criteria (BMI<18.5 kg/m^2) [9].

Mean % fat values are reported in Table **2**. Median % fat values (Median [25th, 75th percentiles]) were as follows: total subjects (22.6 [17.9, 26.9]), men (20.4 [17.0, 24.9]), women (29.8 [27.2, 33.4]). The percent of subjects with measured % fat greater than their corresponding American 50th percentile values were as follows: total subjects (43.1% [N=38]), men (38.6% [N=27]), women (61.1% [N=11]).

Based on the results of a paired non-parametric test, men in our study were modestly leaner when each subject's % fat was compared to his corresponding American 50th percentile value [9] (Wilcoxon signed rank sum test; Median of the difference =-1.6%; P=0.007). There was no significant difference when each subject's % fat value was compared to the corresponding American 50th percentile value [9] in either the group overall (Median of the difference = -1.0 %; P=0.083), or in women (Median of the difference = 1.7 %; P>0.1).

There was a highly significant correlation between BMI and % fat in both men (Spearman; r=0.85; P<0.001) and women (Spearman; r=0.89; P<0.001). BMI correlated inversely and strongly with surface/volume ratio in the group overall (Spearman; r=-0.97; P<0.001), and in both men (Spearman; r=-0.97; P<0.001) and women (Spearman; r=-0.97; P<0.001). The average surface/volume ratio values of both men and women were outside of theoretical normal ranges (Table **2**); these smaller average values suggest a modest increase in the overall size of our subjects when compared to theoretical normal values.

There was a marginal non-linear correlation between % fat and estimated average time in the water per swim (Linear regression with log transformation of swim time; Coef.=0.007; P=0.048). Other variables (age, sex, BMI, and surface/volume ratio) did not correlate with the average estimated time in the water per swim (P>0.1 for all variables). No variable (age, sex, % fat, BMI, and surface/volume ratio) correlated with total distance achieved in the 90-day period (P>0.1 for all variables).

DISCUSSION

Several key points are apparent from our study. Wide ranges of values for BMI, surface/volume ratio, and % fat were observed, indicating that swimmers of different body types were able to participate. While traditionally cold-water swimmers have had an increased % fat [7, 8], swimmers in our study did not have to be overweight to swim in the conditions and water temperatures of the Polar Bear event we describe. Age did not appear to be a barrier to swimming; the average age of swimmers was in the middle-aged

Table 2. Characteristics of Recreational Cold-Water Swimmers

	Age (Years)[†]	BMI (kg/ m^2)	% Fat	Surface/Volume, (m^2/L)
Total (n=88)	52.3 ± 10.1 (24-76)	25.8 ± 3.4 (19.0-37.1)	22.6 ± 6.7 (6.9-42.4)	.0259 ± .0023 (.0200-.0311)
Men (n=70)	52.3 ±10.1 (24-76)	26.4 ± 3.4 (20.7-37.1)	20.8 ± 5.6 (6.9-34.6)[*]	.0255 ± .0022 (.0200-.0311)
Women (n=18)	51.9 ±10.1 (33-68)	23.7 ± 2.8 (19.0-29.6)	29.8 ± 6.0 (20.0-42.4)	.0272 ± .0022 (.0232-.0311)

Mean with standard deviation presented with range in parenthesis.

Classification for BMI (kg/ m^2) [9]: <18.5: underweight,
18.5-24.9: normal
25.0-29.9: overweight
≥30: obese

Range of American 50th percentile values for % body fat (ages 30-79) [9]:
Men: 19.7-24.1
Women: 22.6-30.4

Theoretical normal surface/volume ratio (m^2/L) ranges (using range of American 50th percentile values for % body fat (ages 30-79)) [9] (see text for additional outline of calculations):
Men: .0283 - .0280
Women: .0291 - .0286

[*]When each subject's % fat was compared to the corresponding age and sex-specific American 50th percentile value [9], men were modestly leaner (Median of the difference =-1.6%; P=0.007); there was no significant difference in either the group overall (Median of the difference = -1.0 %; P=0.083), or in women (Median of the difference = 1.7 %; P>0.1).

[†]Age 60 years or older: N=27 (31%).

category, and more than 30 % of subjects were 60 years or older. Lastly, the majority of swimmers were not elite athletes. Although 4 subjects had previously completed English Channel swims, a typical subject in our study swam recreationally, was in his or her 50s, and did not have national or international competition experience.

Further examination of the body composition data from our study reveals a number of complex findings. Like the majority of Americans, the average BMI of our total subjects was in the overweight, but not obese category [9]. However, although BMI was increased, in general % fat did not appear to be elevated in our subjects when compared to accepted American % fat ranges [9, 10, 15].

More specifically, women in our study had a normal average BMI, and % fat values that were only modestly (and not significantly), above their corresponding American 50th percentile values [9]. Although the relatively small number of women limits our conclusions, these results suggest that women swimmers in our study were generally similar in body composition to average American women.

Men in our study had an elevated average BMI, and % fat values that were modestly below their corresponding American 50th percentile values [9]. Accordingly, men in our study appeared to be modestly leaner than average American men, and the elevations in BMI we found may reflect modest increases in overall size and muscle mass rather than a simple increase in adiposity. However, we are cautious in this interpretation given the standard error and limitations of % fat measurements [9-11] and the small size of the % fat differences we observed.

Thus, based on these data, our subjects appeared to be grossly similar to, and men perhaps modestly larger and leaner than, average Americans. Regardless of the interpretation of body composition results, on average, subjects in our study were not obese by either BMI or % fat criteria [9, 10, 15].

Increased % fat has been associated with decreased cooling and increased survival in cold water [1, 7, 8, 16-19]. Although % fat values in our study were not generally elevated, average % fat values in our study were also not substantially decreased, and no subject was underweight by BMI criteria (BMI<18.5 kg/m^2) [9]. Thus, while most swimmers were not obese, neither were they on average excessively lean, with average % fat values suggesting some beneficial adipose insulation in the group overall.

Increased overall body size (as reflected by increases in BMI and decreases in surface/volume ratio) like increased % fat, has been associated with decreased cooling and increased survival or performance in cold water [2, 4, 12, 16-19]. Surface/volume ratio has been used previously to assess overall size and general body morphology, with larger individuals having smaller ratios [2, 12, 17-19].

The elevated BMI and decreased surface/volume ratio values in our study suggest elevations in overall body size that may have been beneficial for swimming in cold water. However, although the BMI and surface/volume ratio averages in our study were different from normal or theoretical normal values, they were generally consistent with the values of the majority of Americans who typically have an elevated BMI and weight [9, 14]. A substantial size benefit compared to average Americans is therefore unlikely.

A high and inverse correlation between BMI and surface/volume ratio was reported in a prior study of cold-water swimmers [2]. The strong and inverse correlation between surface/volume ratio and BMI in our current study further suggests that these variables similarly reflect body size and morphology, and might be used interchangeably to reflect size or morphology in future studies.

Despite the potentially protective aspects of % fat and size, no body composition variable correlated with total distance achieved in the 90-day swim period. The lack of correlation may relate to the relatively short immersion times reported overall by our swimmers. Additionally, thinner and smaller individuals may have compensated for lack of insulation by limiting time in the water during each swim and by utilizing multiple short swims throughout the 90-day period.

The marginal correlation between average estimated time in the water per swim and % fat in our study also suggests that leaner individuals limited their cold water exposure.

Although marginal, this correlation appears to support a prior study that reported that swimmers with less subcutaneous fat voluntarily spent less time in cold water than those with thicker fat layers [1].

Although prior studies suggest a generalized net heat loss while exercising in cold water [2, 8, 16-18] some fit swimmers in our study may have generated heat while swimming rigorously [16]. Such heat production has limits [8, 16-18], but may have been temporarily advantageous in the conditions and relatively short immersion times we describe. Access to warm showers and saunas also may have contributed to the success of some individuals, but all individuals, even those with increased size, faced time limits that depended on the water temperature and conditions on any given day [1, 4, 8, 16-19].

Review of prior work [8, 16-19] suggests that on the basis of gross body composition, our subjects overall were not substantially protected from immersion hypothermia when compared to average Americans. Perhaps contrary to common perception, repeated exposure to cold water has not been shown conclusively to confer a substantial ability to conserve core heat [8, 17, 18]. Rather, as outlined above, body composition variables, particularly % fat and overall body size, are key determinants of core cooling rate in cold water [1, 2, 4, 8, 16-19]. Thus, with measured body composition variables that were grossly similar to average Americans, our subjects as a group would not be expected to have substantially better direct physical protection from core hypothermia.

Where our subjects likely had an advantage was in acclimatization to cold shock. Cold shock refers to the physiologic responses that occur immediately on immersion in cold water, including hyperventilation, tachycardia, decreased breath-holding ability, and a general decrease in swim performance [16, 20-23]. Following repeated exposure to cold water, however, individuals can acclimatize and have less hyperventilation and tachycardia and a general improvement in swim performance [16, 22, 23]. Our subjects, who swam regularly in cold water during the winter months, were likely acclimatized. Thus, they would be expected to be less affected by cold shock and therefore more likely to have a limited, but better-than-average swim performance in cold water.

The circumference-based technique we used to estimate % fat is less commonly used in research and may be less accurate than other methods, and is a potential limitation of our study. Subjects were not tracked past the 90-day swim period, the exact time in the water with each swim was not recorded, and other biophysical parameters, such as potentially beneficial brown fat, were not assessed. An increase in brown fat has been associated with cold exposure [24-27], and future studies may show a correlation between brown fat percentage and time spent swimming in cold water. Further longitudinal tracking may determine the overall health implications of swimming regularly in cold water.

CONCLUSIONS

In summary, our results suggest that recreational cold-water swimmers do not have an increased % fat when compared to average Americans, and individuals with a wide variety of body types are able to swim recreationally in cold water. Because body composition was grossly similar to that of average Americans, our subjects as a group likely did not have substantially better direct physical protection from core hypothermia, but may have had limited better swim performance as the result of acclimatization. Although marginal, the correlation between average time in the water per swim and % fat suggests that leaner swimmers voluntarily limit time in cold water. All swimmers, regardless of body composition, remain at risk for hypothermia with prolonged exposure to cold water.

CONFLICT OF INTEREST

Dr. Thomas J. Nuckton is a member of the San Francisco Dolphin Club and was a subject in this study. Neither Dr. Thomas J. Nuckton nor Dr. Michael A. Kohn has a financial conflict of interest that relates to this study.

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