# A comparison of shoulder muscular performance and lean mass between elite and recreational swimmers
## Implications for talent identification and development

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## Abstract

This study compared the shoulder muscular performance and lean mass between elite and recreational swimmers.

Thirty elite swimmers (mean age ± standard deviation = 23.1 ± 3.5 years) and 21 recreational swimmers (mean age ± standard deviation = 20.8 ± 2.1 years) participated in the study. Maximum muscle strength and time to maximum muscle strength of shoulder flexor, extensor, abductor, and adductor muscles were measured using a handheld dynamometer. Lean mass of the arms and body (excluding the head) were measured using dual-energy x-ray absorptiometry (DXA).

Results revealed that compared with recreational swimmers, elite swimmers had higher maximum muscle strength of the shoulder flexor, extensor, abductor, and adductor muscles (all $P < .001$). The time to reach maximum muscle strength of all shoulder muscles showed no significant difference between the 2 groups ($P > .05$). The lean mass values in the left arm ($P = .037$), right arm ($P < .001$), and whole body ($P = .014$) were higher in elite swimmers than recreational swimmers.

Elite swimmers had greater shoulder maximum muscle strength compared with recreational swimmers though the time taken to reach maximum muscle strength was similar between the 2 groups. Elite swimmers also showed a higher lean mass in both arms and their entire body when compared with recreational swimmers. The results may be useful for recreational swimmers who intend to advance to professional level, and for talent identification and early development of elite swimmers.

**Abbreviations:** ANCOVA = analysis of covariance, DXA = dual-energy x-ray absorptiometry, IPAQ = International Physical Activity Questionnaire, MANCOVA = multivariate analysis of covariance.

**Keywords:** amateur swimmers, muscle mass, professional swimmers, strength

## 1. Introduction

Swimming is one of the most popular sports around the world and there are many local and international competitions, ranging from recreational to elite levels. However, what discriminates between elite swimmers and non-elite swimmers? Can a recreational swimmer achieve elite-level performance after receiving a certain period of training? Previous studies tried to answer these questions from an anthropometric point of view.[1–4] For example, both

Ackland[1] and Sekulic et al[3] have suggested that swimmers with tall stature and long limbs have better potential to become elite swimmers across all distances, especially in short distance swimming, because they have better mechanical advantage in the development of propulsive force; while swimmers with shorter, stockier body builds have higher potential to be elite long-distance swimmers and are more suited to breaststroke. In addition, swimmers with higher skin-folds (more subcutaneous fat) may be more suitable for high-level long-distance open-water events. This is likely due to reduced drag from smaller body size and a more streamlined position.[4] Barbosa et al[2] have also found that transverse surface area of trunk discriminates young talented swimmers from the rest. However, to the best of our knowledge, no study has used physical characteristics—muscle strength and lean mass—to differentiate elite and non-elite (recreational) swimmers.

It is well known that both lean mass and muscle strength of the upper limbs are important for the development of propulsive force and hence attaining faster swimming speed.[5–7] They can be improved through resistance or power training.[8] It is plausible that elite swimmers may achieve a higher lean mass and greater muscle strength than recreational swimmers after training. That is, trainability of the muscular system might differentiate elite and non-elite (recreational) swimmers. However, no study has investigated the difference in muscular performance and lean mass of elite and recreational swimmers thus far. The aim of this study was to compare the shoulder muscular performance and lean mass between elite and recreational swimmers. By identifying differences between high-level and lower-level

performers, the physical (muscular) characteristics of elite competitive swimmers could be addressed. Therefore, results of this study may assist talent identification and development in competitive swimming.

## 2. Methods

### 2.1. Participants

This was a cross-sectional and exploratory study. Between December 2017 and January 2018 (an off-season period), elite swimmers were recruited from the Hong Kong Swimming National Squad and Hong Kong Swimming Regional Squad, and recreational swimmers were recruited from the University of Hong Kong Swimming Team and local swimming clubs by convenience sampling. They were screened by a physiotherapist and a trained student researcher to determine their eligibility to join the study. The inclusion criteria were: aged between 18 and 35 years; had a minimum of 3 years of swimming experience; received training weekly; and participated in international/national/regional (elite swimmers) or local swimming competitions (recreational swimmers). The exclusion criteria were: significant cervical, shoulder, or upper limb disorder that required medical attention in the past year; significant musculoskeletal, neurological, or metabolic disorders; metal implant; pregnant (for women participants); muscle fatigue on the day of the assessment; participated in sports regularly other than swimming (e.g., triathletes); received regular high-intensity resistance training (body building) in the past 3 months; or used creatine or any other dietary supplement.

Ethical approval was obtained from the University of Hong Kong/Hospital Authority Hong Kong West Cluster's Institutional Review Board. Written informed consent was obtained from each participant before data collection. All procedures were performed in accordance with the Declaration of Helsinki.

### 2.2. Measures

Data collection was performed by a physiotherapist and a trained student researcher who were not blinded to the participants' group allocation. It took place in the Physical Activity Laboratory and dual-energy x-ray absorptiometry (DXA) Laboratory of the University of Hong Kong.

### 2.3. Demographic information

Demographic data, training, and medical history were obtained from each participant via face-to-face interview. Then, each participant was invited to complete an International Physical Activity Questionnaire (IPAQ, short form) to document his or her habitual physical activity level.

### 2.4. Maximum isometric muscle strength and time to maximum isometric muscle strength of shoulder muscles

Maximum isometric muscle strength and time to reach maximum isometric muscle strength of shoulder flexors, extensors, abductors, and adductors on the dominant side of the body were measured using a hand-held dynamometer following standardized procedures.[9] In brief, the trunk was stabilized, and the arm exerted a maximum force in a specific direction. The assessor added resistance to the arm to counter the participant's force until the participant's maximal muscular effort was

overcome and the shoulder joint gave way (i.e., a break test) to evaluate the maximum isometric muscle strength and time to reach maximum isometric muscle strength (Fig. 1).[10] The 4 major shoulder muscle groups—shoulder flexors, extensors, abductors, and adductors—were selected as previous research showed that different phases of a swim stroke (e.g., catch phase, pull phase, and recovery phase) activate these muscle groups at different times.[7,11] A hand-held dynamometer was used because it is a valid and reliable tool for testing muscular performance in adults.[10,12] A familiarization trial was included followed by 3 testing trials. Then, the average maximum isometric muscle strength value and time to maximum isometric muscle strength value of the 3 testing trials of each muscle was documented and used for analysis.

### 2.5. DXA-derived lean mass

Each participant underwent a whole-body scan using a Horizon A DXA scanner (Hologic Inc., Bedford, MA) as the test is valid and reliable for quantifying body composition (e.g., lean mass and fat mass) in adults.[13] The scan was performed by a licensed technician following standardized procedures as stated in the Horizon A DXA scanner manual.[14] In brief, participants were instructed to stay in supine lying with hips internal rotated for 3 minutes. The lean mass values of both arms and whole body (less head) were determined using the region of interest program of the DXA scanner and used as outcome measures. The percentage of body fat was also reported as a demographic data.

### 2.6. Statistical analysis

SPSS 24.0 software (IBM, Armonk, NY) was used for the statistical analysis. Descriptive statistics was generated to describe the demographic and outcome variables. Normality of data was checked by Kolmogorov–Smirnov tests and histograms. Demographic data of elite swimmers and recreational swimmers were compared using independent $t$ test (continuous data) and chi-squared test (categorical data). To avoid an inflation of type I error and account for the possible confounding effect of age and other demographic variables, 3 separate multivariate analysis of covariance (MANCOVA) were performed to compare the maximum isometric muscle strength of shoulder flexors, extensors, abductors, and adductors; time to reach maximum isometric muscle strength in the shoulder flexors, extensors, abductors, and adductors; and upper limb lean mass measures between the 2 groups. In addition, a one-way analysis of covariance (ANCOVA) was used to compare the total body lean mass outcome between groups. A two-tailed significant level of 0.05 was adopted for all of the statistical tests.

## 3. Results

Thirty elite swimmers and 21 recreational swimmers were screened. All of them were eligible to participate in the study. Since age differed between the 2 groups, this demographic variable was treated as a covariate in the multivariate and univariate analyses. All participant characteristics are presented in Table 1. Elite swimmers had more swimming experience ($P < .001$), spent more time in training ($P < .001$), and trained more frequently ($P < .001$) than recreational swimmers. However, their IPAQ-derived total physical activity level, percentage of body fat, body mass index, weight, and height were similar to their recreational counterparts ($P > .05$).
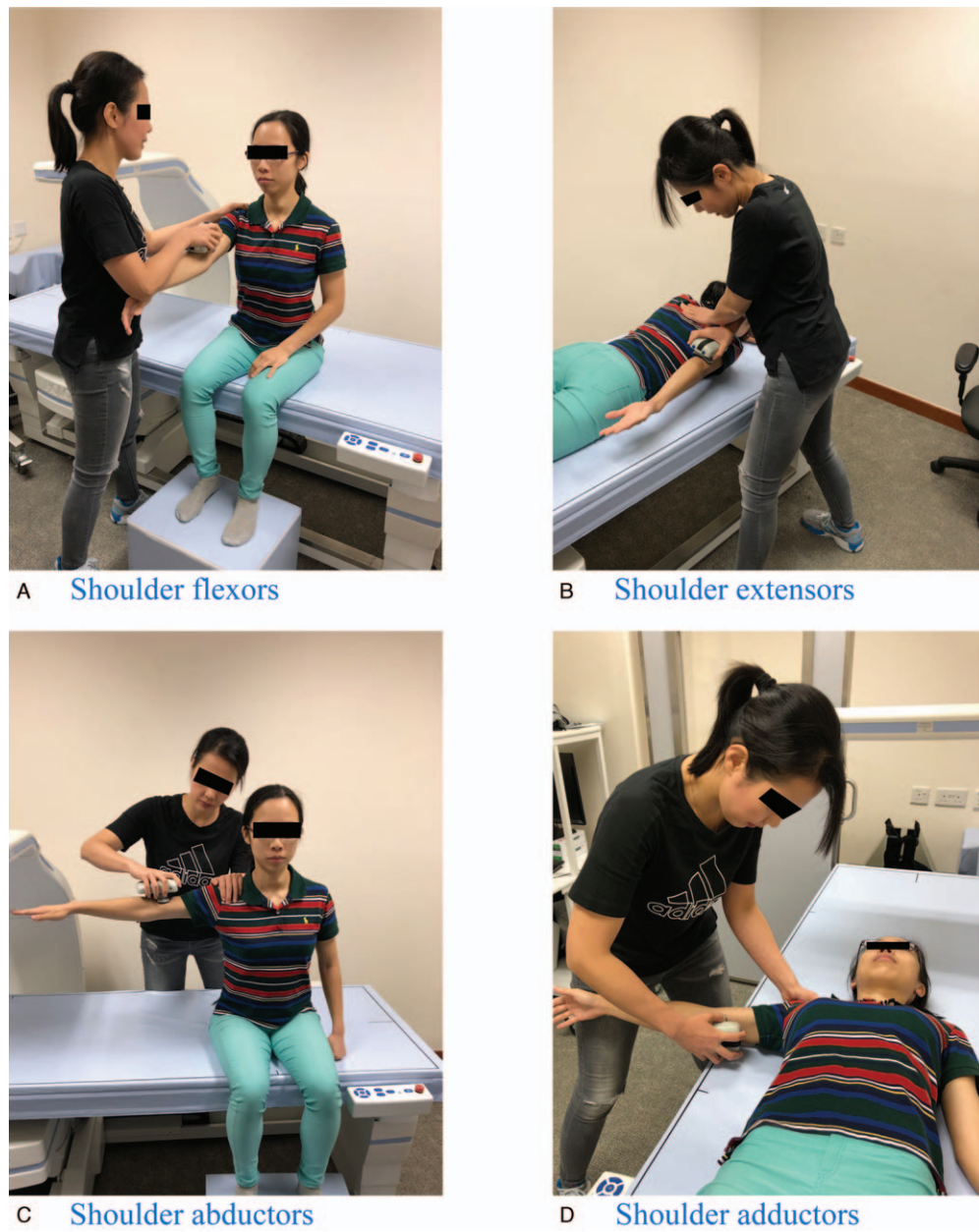
**Figure 1.** Shoulder muscles' maximum isometric muscle strength and time to maximum isometric muscle strength tests.

**Table 1**

**Participant characteristics.**

|  | Elite swimmers (n=30) | Recreational swimmers (n=21) | P |
|---|---|---|---|
| Age, y | 23.10±3.49 | 20.76±2.10 | .009* |
| Body weight, kg | 66.06±13.52 | 61.70±8.35 | .196 |
| Height, cm | 173.05±10.85 | 170.46±9.01 | .372 |
| Sex (n) | 18 males and 12 females | 12 males and 9 females | .533 |
| Body mass index, kg/m$^2$ | 21.84±2.38 | 21.18±1.86 | .293 |
| Total body fat (%) | 24.75±4.51 | 24.30±5.22 | .661 |
| Training time, h/wk | 10.97±2.82 | 2.26±0.80 | <.001* |
| Training frequency, times/wk | 4.80±1.52 | 1.67±0.58 | <.001* |
| Swimming experience, y | 16.23±2.97 | 10.45±2.41 | <.001* |
| IPAQ total physical activity level, MET, min/wk | 7558.52±3291.07 | 6046.02±3919.06 | .142 |

Means±standard deviations are presented unless specified otherwise.

IPAQ = International Physical Activity Questionnaire (short form), MET = metabolic equivalent.

* $P < .05$.

**Table 2**

Comparison of outcome measures between elite and recreational swimmers.

| | Elite swimmers (n = 30) | Recreational swimmers (n = 21) | *P* |
|---|---|---|---|
| Maximum isometric muscle strength (N) | | | |
| Shoulder flexors | 107.13 ± 10.29 | 93.10 ± 6.14 | <.001[*] |
| Shoulder extensors | 112.57 ± 10.67 | 93.33 ± 6.48 | <.001[*] |
| Shoulder abductors | 117.33 ± 8.45 | 93.05 ± 6.14 | <.001[*] |
| Shoulder adductors | 123.90 ± 11.15 | 96.52 ± 6.11 | <.001[*] |
| Time to maximum isometric muscle strength, s | | | |
| Shoulder flexors | 0.64 ± 0.04 | 0.65 ± 0.04 | .914 |
| Shoulder extensors | 0.74 ± 0.04 | 0.74 ± 0.04 | .519 |
| Shoulder abductors | 0.49 ± 0.04 | 0.47 ± 0.03 | .052 |
| Shoulder adductors | 0.66 ± 0.05 | 0.64 ± 0.04 | .113 |
| DXA-derived lean mass, g | | | |
| Left arm | 2872.49 ± 921.57 | 2372.07 ± 688.05 | .037[*] |
| Right arm | 2925.97 ± 912.00 | 2590.96 ± 770.41 | <.001[*] |
| Total body (less head) | 45,768.04 ± 11,140.23 | 40,168.40 ± 118,08.60 | .014[*] |

Means ± standard deviations are presented unless specified otherwise.
DXA = dual-energy x-ray absorptiometry.
[*] $P < .05$.

Multivariate analysis results showed that the maximum isometric muscle strength values of all shoulder muscles were higher in the elite swimmer group than the recreational swimmer group (all $P < .001$). As for the time to reach maximum isometric muscle strength in the shoulder muscles, results revealed no significant between-group differences (all $P > .05$). For the lean mass measures, elite swimmers had higher lean mass in their left arm ($P = .037$), right arm ($P < .001$), and the entire body excluding the head ($P = .014$) (Table 2).

## 4. Discussion

To the best of our knowledge, this was the first study to compare the muscular performance and lean mass between elite and recreational swimmers. We found that elite swimmers had a higher maximum isometric muscle strength in shoulder flexors, extensors, abductors, and adductors than recreational swimmers. The higher maximum strength of shoulder musculatures in elite swimmers may be explained by both "nature" and "nurture."

Nature—It is well known that elite swimmers possess a natural advantage in swimming performance due to some inherent traits such as higher hand grip strength.[15] Our results supplement pervious findings that higher shoulder flexor, extensor, abductor, and adductor muscle strength may be some inherent physical capacity of the elite swimmers. Further correlational study should be carried out to confirm the relationship between shoulder muscle strength and swimming performance.

Nurture—Our elite swimmers had an average of 8.8 hours of extra training time per week, 3 extra training sessions per week, and a surplus of 6 years of swimming experience compared with their recreational counterparts. So, it is logical that elite swimmers had better peripheral muscular adaptations[11] and higher shoulder muscle strength than the less-trained recreational swimmers. Indeed, previous studies have shown that well-trained swimmers have superior dynamic and static muscle strength than untrained subjects,[16] and higher upper-body muscle strength is related to faster swimming speed.[5–7] We suggested that further study may standardize the training volume of elite and recreational swimmers, compare and quantify swimming speed between elite and recreational

swimmers, and explore how swimming performance is related to shoulder muscle strength.

Regarding the time to reach maximum strength in the shoulder musculatures, our results revealed that elite swimmers were not better than the recreational swimmers. This finding was not entirely surprising as previous studies have demonstrated that both elite[17] and recreational swimmers[18,19] have above the norm muscle power.[18] The difference in muscle power or time to maximum muscle strength between elite and recreational swimmers may be very small. Future study may measure muscular performance under water to determine the possible difference in time to reach peak shoulder strength between elite and recreational swimmers.

Our results also revealed that lean mass values of total body and bilateral upper limbs were higher in elite swimmers than that of the recreational swimmers. These findings could be partly explained by the longer training period and higher training frequency of the elite swimmers and are generally in line with previous studies showing that elite competitive swimmers have higher lean mass than non-athletes,[20] and lean mass increased significantly after intensive swimming training in elite male swimmers.[21] The higher lean mass in the elite swimmers may mean that they had higher propulsive force and better swimming performance.[18] Further study is necessary to examine the relationships between regional and total body lean mass and swimming performance among the elite swimmers.

This study has some inherent limitations. The major one is that we did not differentiate sprinters from endurance swimmers who may demonstrate different skeletal muscle adaptions due to specific training regimes.[11] In addition, the participants' swimming strokes, distances, and techniques were not taken into account when analyzing the data. All these factors may have confounded the results.[6,22] Moreover, only the isometric muscle strength of shoulder muscles was measured in this study. Further study may include dynamic muscle strength tests (e.g., isokinetic dynamometry) as swimming is dynamic in nature, and measure the strength of some other important muscle groups for swimming (e.g., elbow extensors and knee flexors and extensors).[11,23] The shoulder dynamic stabilizer—rotator cuff—muscle strength should also be investigated.[24] Another limitation of the present study was the cross-sectional study design—it

cannot be used to establish a causal relationship between different levels of competitive swimming and muscular performance and lean mass of the athletes. The better shoulder muscle strength and higher lean mass in the elite swimmers may be due to heredity or training as explained previously. Moreover, we found that elite swimmers had similar IPAQ-derived total physical activity level compared to recreational swimmers though they spent more time in training per week and trained more frequently. This may be because IPAQ (short form) is not sensitive enough to quantify sport-specific physical activity level of athletes.[25] Finally, regarding the external validity of the study, our results cannot be generalized to athletes of other aquatic sports. Nevertheless, our results may inform coaches to select swimmers to talent-development squads and to design specific training regimes for talented swimmers to improve their performance.

## 5. Conclusions

Elite swimmers demonstrated higher maximum isometric strength in 4 major shoulder muscle groups (i.e., shoulder flexors, extensors, abductors, and adductors) and had more lean mass in their arms and whole body (excluding the head). However, the time taken to reach maximum isometric strength in the shoulder muscles was similar between the elite and recreational swimmers. Findings of the present study may assist talent identification and development in competitive swimming.

## Acknowledgments

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