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ANTHROPOMETRICAL AND PHYSIOLOGICAL PROFILE OF CHINESE ELITE SPORT CLIMBERS

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Abstract

Introduction: Significant ethnic differences exist in anthropometrical characteristics and body composition between normative Chinese and western populations. Elite climbers relative to age-matched general populations in Europe and North America are generally characterized smaller body size and a low percentage of body fat (%BF) compared to normative data. The variable of a positive arm span to height ratio (ie Ape Index) is often suggested to be advantageous for climbing performance, but has never been reported in Chinese climbers.

Aim: To thoroughly examine anthropometrical and physiological characteristics of adult Chinese competition sport climbers, eleven male (30.2±6.3 yrs) and ten female (32.2±5.5 yrs) competition sport climbers from Hong Kong, China, were examined. The mean self-reported on-sight climbing ability was Fr.7a+ (6c to 7c+) and Fr.7a (6b to 7c) respectively.

Methods: Anthropometrical characteristics examined were: height, mass, body mass index (BMI), %BF, Ape Index, biiliocristal and biacromial breadths. Physiological variables gathered were: resting heart rate and blood pressure, leg span, handgrip strength, bone mineral density and aerobic capacity. Selected variables were compared with age- and sex-matched Chinese population and western elite climbers previously reported.

Conclusion: In comparison to national Chinese statistics, these Chinese climbers had a lower body mass, BMI, %BF, and resting heart rate; similar stature, handgrip strength and resting blood pressure; and a higher bone mineral density and aerobic capacity. Relative to studies on western elite climbers, the Chinese climbers had a smaller body size and lower aerobic capacity; while BMI, %BF, handgrip strength/body mass ratio, and leg span were similar. In addition, both genders possessed an Ape Index >1.

***Keywords**: anthropometry, chinese, climbing, ape index, somatotyping, competition climbing*

Introduction

Sport climbing participation has grown significantly since the 1980's as its popularity spread globally.

A wealth of scientific studies on climbers exists and are primarily focused on climbing injuries, followed by studies on the physiological responses during climbing and anthropometrical data [1-7]. Such studies are generally authored by Europeans or North Americans, and report data mostly on adult male climbers. There is a dearth of research specifically on Chinese climbers of any ability level or gender.

Most climbers participate in a few types of climbing styles. Goddard and Neumann [8] suggested that specific anthropometrical characteristics of rock climbers are prerequisite to optimal performance, though these were not clearly stated for each climbing subdiscipline. More recent climbing studies suggest slightly different anthropometrical variables for these styles [3-5]; and have found age, experience and height correlated positively to elite bouldering performance [4]. Also, strength endurance correlates strongly with red point performance in sport climbing [9]. Sheel [10] further suggested that optimisation of bodily physiological function including aerobic and anaerobic capacity may be more, or at least equally, important when assessing performance variables for competition sport climbers, including anthropometric characteristics.

In 1989, first annual international world cup climbing competition was held in China. The event sparked national interest in the sport that then resulted in many new climbing walls being erected throughout China to meet the growing demand of novice and competition climbers. As climbing was a new competition sport to China, sport science analysis of variables needed by Chinese climbers to improve performance was desirable. It is known that there are significant ethnic differences in anthropometrical characteristics and body composition between Chinese and western populations. Chinese tend to be smaller in body size and have less body fat compared to their western counterparts. The well-described specific physical and physiological characteristics of western climbers, which provided directional information for the attainment of a high standard of the sport, may not be an appropriate reference for Chinese climbers. Moreover, these variables may have changed for all climbers since the 1980's as climbing grades have increased, and competition routes have changed.

Materials and methods

The purpose of this study was to evaluate the anthropometric and physiological characteristics of elite Chinese male and female sport climbers in order to provide evidence-based references for competition climbing. Anthropometrical characteristics examined were: height, mass, body mass index (BMI), percentage body fat (%BF), arm span, biiliocristal and biacromial breadths. Physiological variables included resting heart rate and blood pressure, leg span, handgrip strength, bone mineral density and aerobic capacity. Selected variables were compared with age- and sex-matched norms of Chinese population published in the Report of National Physical Fitness Surveillance (RNPFS) [11] and in previous study of Wong et al. [12]. Selected previous data of western elite climbers were also used as references.

Participants

Eleven adult male and ten female climbers in Hong Kong, China, who had trained for a mean period of 9.7±2.9 years and 10.5±4.7 years respectively, volunteered to participate in this study. They all performed at a national competition level. Their physical characteristics are stated in Table 1. The self-reported preseason climbing training volume of male participants was recorded as 3.6±3.5 $hr \cdot d^{-1}$ and 3.6±2.1 $d \cdot wk^{-1}$, and the females trained 3.6±2.5 $hr \cdot d^{-1}$ and 3.2±1.1 $d \cdot wk^{-1}$. The respective ranges of self-reported on-sight and redpoint climbing ability of the male participants were Fr.6c to 7c+ (mean = 7a+) and Fr.7b to 8c (mean = 8a), and Fr.6b to 7c (mean = 7a) and Fr.6c+ to 8a+ (mean = 7c) for the females. Informed written consent was obtained from all participants. The study protocols were performed in accordance with the 1961 Declaration of Helsinki and were approved by the Committee on the Use of Human and Animal Subjects in Teaching and Research of Hong Kong Baptist University.

Measurements

Anthropometrical and physiological assessments were performed in controlled laboratory conditions with a temperature of 22°C and relative humidity of 70%. The participants were requested to refrain from eating at least two hours prior to testing, and from participation in strenuous physical activity for at least one day before physical testing. All anthropometrical measurements were performed in compliance with established procedures and were taken by the same investigator. Standing height was measured to the nearest 0.5 cm with the participant barefoot and with their back against a wall-mounted stadiometer. Body weight was measured to the nearest 0.1 kg using a TANITA electronic BIA scale (TBF410, Tokyo, Japan). Arm span was measured in a standing position against a wall with the arms abducted horizontally at the height of the shoulders. The distance measured by an anthropometric tape to the nearest 0.5 cm was from the tip of one middle finger to that of another [13]. Ape index was defined as the ratio of arm span to body height [14]. Leg span was determined with the climber, who was laid flat in a supine position, with the two feet placed as far apart as possible while the knees remained straight. The distance between the medial calcaneus of both legs was measured to the nearest 0.5 cm [15]. Biiliocristal breadth was the distance between the most lateral points on the iliac tubercles. Biacromial breadth was the distance between the most lateral points on the acromion processes. The two breadths were measured in a standing position with arms relax at both sides. Lafayette anthropometer was used to measure to the nearest 2 mm [16].

Skinfold thickness was measured using Harpenden Skinfold Caliper (Lafayette Instrument, US) to the nearest 0.2 mm. The four sites measured on the right side of the participant were triceps, biceps, subscapular and iliac crest according to Durnin and Womersley [17]. The average value of three trials was then applied to the body density (Db) prediction equations [17] which were age and gender specific. The estimation of %BF from the predicted body density was according to the equation of %BF = (4.97/Db)-4.52 for male participants and %BF= (4.76/Db)-4.28 for female participants [18].

Calcaneal bone mineral density (BMD) was measured using the LUNAR Achilles-plus Solo bone Densitometer (WI, US), according to the manufacture's protocol. Both a Z-score and a T-score were determined for each measurement [19], and compared to age and gender specific normative values. A low Z-score indicated an etiology other than age-related bone loss. The T-score was used to compare the BMD of the participant with the mean value for young adults of the same gender and race; it is used for the diagnosis of low bone mass or osteoporosis.

Grip strength was measured using an adjustable handgrip dynamometer (Takei Scientific Instruments, Japan), with the subject standing, elbow flexed to 90°, and upper arm in a vertical position. Participant was given three trials for maximum isometric grip strength. The highest reading to the nearest 0.5 kg was the result.

Resting heart rate and blood pressure were measured by an arm-type oscillometric TM-2655 device (A&D Company Ltd, Tokyo, Japan) after sitting on a chair quietly for at least five minutes. Aerobic fitness was assessed using Astrand-Ryhming 6-min submaximal cycle ergometer test. The testing protocol was described previously [20]. All tests were performed on a Monark cycle ergometer (828E, Sweden). Heart rates were monitored using Polar heart rate monitor (S625, Polar Electro, Finland). The predicted $\dot{V}O_2max$ was determined using Astrand and Ryhming (1954) protocol [21].

Table 1. *Physical characteristics of the Chinese male and female climbers*

	Male climbers (n=11)	Norms	Female climbers (n=10)	Norms
Age (years)	30.2±6.3 (21.0 – 40.0)		32.2±5.5 (25.0 – 41.0)	
Weight (kg)	58.4±5.6 (50.6 – 70.2)	66.7* (n=10,313)	48.7±3.5 (43.2 – 55.5)	53.9* (n= 10,421)
Height (cm)	172.7±6.2 (162 – 181)	169.3* (n=10,316)	158.6±4.6 (147.5 – 163.5)	157.8* (n=10,422)
Body mass index (BMI)	19.6±0.9 (17.7 – 21.4)	23.3* (n=10,313)	19.4±1.0 (18.3 – 20.8)	21.6* (n= 10,421)
Percent body fat (%)	11.0±3.2 (5.8 – 17.2)	20.0%±7.3 ^ (n=47)	27.3±3.4 (22.9 – 33.5)	25.5%±6.0^ (n=47)

Values are Mean±SD (Range)* Median value reported in the RNPFS, 2007 [11]^ Mean value reported in the study of Wong et al. [12]

Table 2. *Anthropometric characteristics of the Chinese male and female climbers*

	Male climbers (n=11)	Female climbers (n=10)
Arm span (cm)	181.1±8.0 (170 – 195)	166.5±11.7 (152 – 196)
Ape index	1.05±0.03 (0.99 – 1.08)	1.05±0.06 (1.00 – 1.22)
Biiliocristal breadth (cm)	26.5±1.1 (24.8 – 28.2)	26.2±1.7 (24.0 – 28.6)
Biacromial breadth (cm)	35.1±1.9 (32.2 – 38.6)	29.1±1.7 (26.4 – 31.8)
Biiliocristal / biacromial ratio	0.76±0.03 (0.71 – 0.80)	0.90±0.04 (0.84 – 0.96)
Leg span (cm)	142 ±11 (118 – 161)	135 ±13 (107 – 148)

Values are Mean± SD (Range)

Table 3. *Physiological characteristics of the Chinese male and female climbers*

		Male climbers (n=11)	Norms	Female climbers (n=10)	Norms
Resting heart rate (b min-1)		67.4±9.4 (49 – 77)	78 b* (n=10,278)	69.6±7.5 (56 – 83)	78* (n= 10,387)
Resting blood pressure (mmHg)	Systolic	120.3±21.3 (105 – 137)	118* (n=10,251)	107.5±12.3 (92 – 126)	106* (n=10,345)
	Diastolic	70.6±9.8 (59-87)	78* (n=10,246)	64.8±8.4 (53 – 77)	70* (n=10,342)
Handgrip strength (kg)	Right	48.1±9.5 (35.0 – 68.0)	47.6* (n=10,314)	23.4±4.1 (17.0 – 31.0)	28.1* (n=10,420)
	Left	46.3±8.6 (37.0 – 61.0)		24.1±5.3 (16.0 – 34.0)	
Handgrip strength / body mass ratio		0.81±0.17 (0.63 – 1.19)		0.49±0.09 (0.35 – 0.59)	
Bone mineral density	T-score	0.1±1.25 (-1.80 – 2.50)		1.7±2.21 (-0.90 – 5.60)	
	Z-score	0.7±1.19 (-1.80 – 2.90)		2.1±2.23 (-0.50 – 6.10)	
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})		44.1±3.8 (38.9 – 50.4)	38.4±7.3 ^ (n=47)	37.1±6.5 (27.5 – 49.4)	27.3±5.1^ (n=47)

Values are Mean±SD (Range)*Median value reported in the RNPFS, 2007 [11]^Mean value reported in the study of Wong et al. [12]

Data analysis

Standard descriptive statistics (means, standard deviation, range) were used to present the characteristics of the participants for all variables. The descriptive statistics for male and female participants were reported separately. After the data were tested to fulfil the criteria of normal distribution, One sample *t*-test was applied to examine the difference in selected variables between the mean values of the present study and: (i) that of the age group of 30-39 yrs from the local Chinese population [12] and; (ii) the median values of the age group of 30-35 yrs of Chinese population published in the RNPFS [11]. All tests for statistical significance were standardized at an alpha level of $P<0.05$.

Results

Physical characteristics of the Chinese male and female climbers are shown in Table 1. It was noted that the body height of the male and female climbers were close to the median values in the RNPFS while their body weight and body mass index were lower than the corresponding median values. In comparison to the %BF of local population, the value of the male climbers was lower ($P<0.05$) while the difference in female climbers was not significant ($P>0.05$).

Table 2 shows the anthropometric characteristics of the Chinese climbers. Selected physiological data of the climbers are in Table 3. In comparison to the median values of resting heart rate in the RNPFS, lower values were found in both the male and female climbers. Systolic blood pressure of the male and female climbers were close to the median values while diastolic pressure were lower than median values with statistical significant difference found in the male climbers. For the handgrip strength, the values of the male and female climbers were close to and lower than the corresponding median values, respectively. In comparison to the $\dot{V}O_2$max of local population, the values of both the male and female climbers were higher ($P<0.05$).

Discussion

Western elite adult sport climbers are generally characterized by a small stature and low BMI compared to normative values [1,3,13,22]. Similar characteristics were found in Chinese climbers as well. According to the norms of corresponding age groups in the RNPFS [11], the body height and weight of both male and female climbers in the present study were at the 75th and 25th percentile, respectively. The BMIs of male and female climbers were at 10th and 25th percentile, respectively, and were close to the category of under-weight. The lower body weight and BMI of the climbers maybe partly attributed to the lower fat content in body. In comparison to the corresponding age groups of the local population [12], %BF was lower in the Chinese male climbers. The attribution of low fat content of the climbers was further supported by lean skinfold meansurements of the triceps and subscapular of both male and female climbers with which the skinfold thicknesses were only at 25th percentile of related norms in RNPFS [11]. These findings were in agreement with previous notion that western elite climbers were characterized by small body size and low %BF [1,3]. However a lean body mass alone will not improve any climbing performance and is no substitute for an appropriate programme of sport specific training and diet. Eating disorders and anorexia are reported among elite climbers [5]; such excessive leanness may additionally have possible implications in the fairness of competition as found in similar lean sports [23], and obviously on health. There are currently no weight or BMI restrictions in climbing competitions internationally though this is being reviewed by the UIAA [Schöffl 2010, personal communication].

Comparing the physical characteristics of the Chinese climbers with those of western climbers reported previously in corresponding age groups, the body weight and height were less in both the Chinese male and female climbers while the difference in BMI, approximately 20, and %BF were not apparent [1]. Watts [24] further suggested that taller climbers may benefit from an obvious advantage in being able to reach handholds more readily than shorter climbers. However, he also suggested these taller climbers would likely weigh more and the longer moment in their arms would drive their torso's centre of gravity relatively far from the wall thereby creating biomechanical disadvantages during climbing. Michailov et al. [4] discovered that taller climbers had disadvantage in a bouldering world cup held in 2007 probably due to the competition routes' properties. However, this theory has not been tested and competition walls have changed over the decades and may favour slightly different body types.

Amongst the climbing community, it is believed that a positive Ape Index is an advantageous variable for climbing performance, though such evidence is seldom reported [5]. Giles et al. [2] suggested that a positive Ape Index (arm span / body height) greater than 1 was usually found in elite western climbers and this facilitated an obvious reach advantage during climbing activity. This view was further endorsed by Magiera and Ryguła [25]. Rimoin et al. [26] reported that black people tended to have longer limbs compared with Asians, and that Asians with a short stature tended to have arm span less than their body height [27]. However, the Ape Index of Chinese elite climbers had never been reported. In this study, the Ape Index of both male and female participants was greater than 1, suggesting this is an advantageous variable in elite competition climbing.

"*Climber's back*" is a term used to describe an inwardly placed shoulder girdle hump that results from an increased thoracic kyphosis and lumbar lordosis, and shortened pectoralis muscles. This postural adaptation was strongly correlated to male elite climbers who climbed ≥ UIAA grade 10 [28], and it may also contribute to a finding of a positive Ape index. In the present study, we observed several cases of this postural adaptation in males. The attribution of Ape Index of > 1 to the postural adaptation from the climbing training in Chinese climbers awaits further study.

Watts [14] found that biiliocristal/biacromial ratio in young climbers (n=90 aged 13.5±3.0 years) was generally higher compared to both normative and athletic controls (0.86 vs 0.74) and the climbers also had a narrower biacromial breadth relative to biiliocristal breadth. The narrow shoulder structure in combination with an enhanced Ape Index inferred the longer absolute arm length (ie longer 'levers') in the climbers compared to controls. This ectomorph somatotype finding combined with long arms may have implications for reaching distance that is more important than variable of Ape Index alone for elite performance. To our knowledge, the biiliocristal/biacromial ratio of elite adult climbers has not been reported. Successful adolescent athletes aged 12 to 18 years normally exhibit a similar somatotype to sport specific adult elites [5]. Therefore, the data on our Chinese climbers was respectively compared with those of Watts [14]; the biiliocristal/biacromial ratio of the Chinese climbers appeared to be lower in the male (0.76 vs 0.87) and similar in female (0.9 vs 0.86) while the Ape index of both male and female Chinese climbers (Male: 1.05 vs 1.02, Female: 1.05 vs 1.01) tended to be higher. It is possible the differences in the biiliocristal/biacromial ratio and Ape Index between the two studies could be attributable to the discrepancies in maturity level and/or in ethnicity of climbers. Nevertheless, the Chinese elite climbers possessed an enhanced Ape Index, and this is very likely a favourable variable for elite performance of climbing [25] especially as Asians with a short stature tend to have arm span less than their body height [27]. However, the anthropometric characteristic of climbers and physiological responses under condition is different in each study [5,7].

Climbers must transfer and support their body mass during complex horizontal and vertical movements primarily by their fingertip grip strength, engagement of the upper limb muscle groups, and forces exerted through lower extremities. The variable of a repeatedly high hand/fingertip strength to fatigue (notably isometric strength, especially when supporting one's body mass) is a key performance variable in climbing [29,30]. However, elite climbers in previous reports did not show significant higher absolute handgrip strength in comparison to the sex- and age-matched population norms, but they possessed higher handgrip strength relative to body weight [22,31]. Similar characteristics in handgrip strength were also observed in the present study. By comparing with the norms in RNPFS [11], male and female climbers were at 75th and 25th percentile, respectively. Moreover, the handgrip strength of both gender in Chinese appeared to be lower than those reported in western elite climbers (Male: >50 kg, Female: >32 kg) [2,30]. However, when the handgrip strength was expressed relative to body weight, the ratio in the Chinese male and female climbers appeared to be similar to that of their western counterparts (Male: 0.79, Female: 0.49) [2,13,30]. Such findings indicated that the low body mass of the Chinese climbers may help compensate for their lower handgrip muscular strength in comparison to those of western climbers, in performing the movement against body mass vertically during climbing.

Leg span is a climbing-specific flexibility test. This measures hip abduction which is essential for the bridging movement performed in climbing [15]. In comparison to the limited previous data, the leg span of the Chinese male elite climbers (142±11 cm) was similar to that of western with varied abilities climbers (139±4 cm) [15]. Previous female data was not available for comparison. All this data reflected the better flexibility of Chinese climbers in hip abduction, perhaps because Chinese may have proportionally shorter legs compared to Western climbers and may therefore share a similar leg span with them.

Regarding to the calcaneal bone mineral density (BMD), the Z- and T-score in the present study demonstrated the healthy BMD profiles of Chinese elite climbers with marked higher scores found in the female climbers. A study using mice by Mori et al. [32] indicated that voluntary climbing exercise increased bone volume and transient osteogenic potential of their bone marrow. Vicente-Rodriguez et al. [33] also reported the effort of muscles development and greater force would increase BMD. During climbing, the body's mass acts as the resistance that is lifted and supported. The healthy profiles in BMD in the Chinese climbers were in agreement with the previous studies on climbers [1,3] and resistance-trained counterparts [34]. It was suggested the mechanical stimulation to the bones secondary to the intense muscular contractions enhanced osteogenesis.

In comparison to the norms in RNPFS [11], the resting heart rate of both Chinese male and female elite climbers was at 25th percentile. The systolic and diastolic blood pressures of both genders were at the 75th and 50th percentile, respectively. The healthy resting heart rate and blood pressure profile of the Chinese climbers was concomitant with higher $\dot{V}O_2max$ in comparison to that of local populations [12]. However, the predicted $\dot{V}O_2max$ of the Chinese climbers were lower in comparison to that of western high-level sports climbers reported recently (Male: 53.6±3.7 ml·kg^{-1}·min^{-1}; Female = 49.2±3.5 ml·kg^{-1}·min^{-1}) [1]. The lower values might be partly attributed to the varied testing mode as a sub-maximal cycling exercise test was used in the present study while the $\dot{V}O_2$max of the western climbers were directly measured on a vertical climbing ergometer, where arms and legs were actively climbing until fatigue, and this testing increased in velocity during a sport climbing specific test. This latter test may have resulted in untypically high climbing $\dot{V}O_2$max values. In normal case, the $\dot{V}O_2$max of climbing (averaged 24.9-27.4 ml·kg^{-1}·min^{-1}) was lower than cycling or running treadmill exercises (averaged 50.5-54.8 ml·kg^{-1}·min^{-1}) [35,36]. Nevertheless, metabolic data on adults climbing non-stop 'to climbing fatigue' averaged 32-37 ml·kg^{-1}·min^{-1} suggesting the Chinese climbers have a sufficient cardiovascular fitness for climbing [29], and aerobic adaptations to regular climbing training less.

In conclusion, Chinese elite sport climbers presented general anthropometric and physiological characteristics similar to western elite climbers. This included lower values for: body mass, body mass index, percent body fat, and resting heart rate; similar stature, hand grip strength and resting blood pressure; and higher bone mineral density and aerobic capacity in comparison to the corresponding age group of general population. Relative to western elite climbers, the Chinese climbers were shorter in stature and possessed a lower aerobic capacity while BMI, %BF, ratio of handgrip strength and body mass, and leg span were similar. Similar to western counterparts, they also possessed of the long-arm body figure with marked high biiliocristal / biacromial ratio and Ape index of > 1 found in female and in both genders, respectively.

Limitations

There is limited number of subjects and no anaerobic capacity was investigated due to limitation of equipments in this study. Moreover, the relationship between Ape Index and Biiliocristal/Biacromial Breadths for climbing is worth for future investigations. Youth and female climbers are still seldom to be explored in the field. Measurement and analysis the case of "climber back" maybe determine the relationship on climbing ability.

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A – Study Design
B – Data Collection
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D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection