

Anthropometric, Strength, Endurance and Flexibility Characteristics of Male Elite Ice Climbers and Sport Climbers

Anthropometrische, Kraft-, Ausdauer- und Flexibilitätsmerkmale männlicher Elite-Eiskletterer und Sportkletterer

Summary

- › **Objective:** Purpose of this study was to compare elite male ice climbers and sport climbers for their anthropometry, muscular strength, endurance, and flexibility. Although there is a certain overlap between these two activities, sport climbing, which recently became an Olympic discipline, has been studied significantly more than the ice climbing. Hence, the second aim was to indirectly determine whether sport climbing training processes and nutrition can be beneficial for the ice climbing athletes.
- › **Methods:** 23 male ice climbers of the Ice Climbing World Cup 2010 in Saas Fee (Switzerland) who all reached the final round were compared to 23 elite male sport climbers, which refers to "on sight" climbing grade of VII+/6b (UIAA/French) or higher. Measurements included anthropometry, three different tests for flexibility, two for strength and two for endurance.
- › **Results:** Ice climbers have more fat in the trunk region (Fat%-T), have significantly less handgrip strength in both hands, as well as strength to mass ratio (SMR) of the dominant hand. In the test "foot raise", ice climbers showed significantly less flexibility.
- › **Conclusion:** Results indicate that ice climbers have not only higher body fat percentage, probably as an adaption to cold environment but also lower strength and flexibility than sport climbers. With such data, we can conclude that sport climbing training protocols for development of strength, endurance and flexibility can be potentially beneficial to ice climbers.

Zusammenfassung

- › **Ziel:** Ziel dieser Studie war es, männliche Elite-Eiskletterer und Sportkletterer hinsichtlich ihrer Anthropometrie, Muskelkraft, Ausdauer und Flexibilität zu vergleichen. Das zweite Ziel war zu bestimmen, ob Trainingsprozesse und Ernährung auf der Grundlage von Untersuchungen an Sportkletterern auch für Eiskletterer von Vorteil sein können.
- › **Methoden:** 23 männliche Eiskletterer des Ice Climbing World Cup 2010 in Saas Fee (Schweiz), die alle in die Finalrunde kamen, wurden mit 23 männlichen Elite-Sportkletterern verglichen, die „on sight“ einen Klettergrad von VII+/6b (UIAA/French) oder höher aufwiesen. Die Messungen umfassten die Anthropometrie, drei verschiedene Tests für Flexibilität, zwei für Kraft und zwei für Ausdauer.
- › **Ergebnisse:** Eiskletterer haben mehr Fett im Rumpfbereich (Fat%-T), signifikant weniger Handgriffkraft in beiden Händen sowie Kraft-zu-Masse-Verhältnis (SMR) der dominanten Hand. Eiskletterer zeigten deutlich weniger Flexibilität im Hüftbereich.
- › **Schlussfolgerung:** Die Ergebnisse zeigen, dass Eiskletterer nicht nur einen höheren Körperfettanteil haben, wahrscheinlich als Anpassung an eine kalte Umgebung, sondern auch eine geringere Kraft und Flexibilität als Sportkletterer. Sportkletter-Trainingsprotokolle können zur Entwicklung von Kraft, Ausdauer und Flexibilität für Eiskletterer potenziell von Vorteil sein.

KEY WORDS:

Training Processes, Nutrition, Handgrip Strength, Measurements, Training Protocol

SCHLÜSSELWÖRTER:

Trainingsprozess, Ernährung, Handkraft, Messungen, Trainingsprotokoll

Introduction

Ice climbing has a very long history in traditional alpinism. The first ice climbing contest was organized in 1912 on Brenva Glacier in Courmayeur, Italy. However, in 2002 the first World Cup competitions under UIAA rules took place. Nowadays many countries have held national competitions (15).

Ice climbing in nature mainly occurs on frozen water, while competitive ice climbing also implies dry-tooling (climbing with ice tools on rock or wooden constructions). The nature of competitive

ice climbing mainly corresponds to mix climbing (climbing with ice tools and crampons on ice, rock or wooden constructions).

Competitive ice climbing has two disciplines, lead and speed. In both categories ice climbers (IC) use ice tools and crampons for progression. In speed the goal is to climb a 15-20m high ice wall as fast as possible. Lead climbing has time limitation and the goal is to reach the highest point of a technically demanding route. >

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Table 1

Anthropometric characteristics of two groups. BMI=body mass index, BMR=basal metabolic rate, RL/A=right leg/arm, LL/A=left leg/arm, T=trunk, FFM=fat free mass, TBW=total body water, LL=leg length, *=Statistically significant different from sport climbers ($p<0.05$).

VARIABLE	ICE CLIMBERS (N=23)			SPORT CLIMBERS (N=23)		
	MEAN (SD)	MEDIAN	RANGE	MEAN (SD)	MEDIAN	RANGE
Height (cm)	176.17 (7.4)	175	172-204	180.8 (5.6)	181	170-191
Arm span (cm)	184.8 (8)	184	172-204	186.6 (6.8)	186	169-196.5
Ape index	1.05 (0.03)	1,04	1.01-1.15	1.03 (0.02)	1,03	0.99-1.07
Length-LL (cm)	95.4 (4)	95	90-107	96.8 (5.3)	96	86-106
Length to thumb-LL (cm)	115 (3.3)	115	111-123	116 (6.2)	117	105-126
Mass (kg)	70.4 (7)	69,7	61.1-92	70.4 (6.6)	69,6	58.7-83.3
BMI	22.7 (1.4)	22,3	20-25.6	21.5 (1.8)	21,7	17.9-24.9
BMR (kcal)	1855.3 (197.7)	1828	1615-2441	1897.3 (160.6)	1882	1603-2178
Fat (kg)	6.6 (2.1)	6,6	2.7-11.9	4.7 (1.9)	4	2.6-9.1
Fat%	9.4 (2.9)*	9,2	3.9-15.4	6.5 (2.3)	5,6	3.8-11.3
Fat%-RL	10.3 (2.1)	10,1	6.1-14.2	8.4 (2.5)	8,9	3.5-12.7
Fat%-LL	10.2 (2.4)	9,8	5.7-14.2	8.4 (2.2)	8,2	4.6-13.0
Fat%-RA	6.6 (2.1)	6,6	2.3-10.1	5.5 (2.5)	6	1.5-9.4
Fat%-LA	6.6 (2.6)	6,6	1.6-11.8	5.1 (2.6)	5,5	1.3-9.9
Fat%-T	9.5 (3.9)*	9,4	3.0-17.2	5.5 (3.0)	4,2	3.0-11.7
FFM (kg)	63.8 (6.7)	62,7	55.7-84.0	65.7 (5.5)	65,2	65.1-75.0
TBW (kg)	46.7 (4.9)	45,9	40.8-61.5	48.1 (4.0)	47,8	41.1-54.9

Ice climbing has specialized movements which require a high level of flexibility and muscle strength from athletes, such as “figure four” (Figure 1) and “figure nine”. These figures are useful for moving into another or longer reach during ice climbing. The easiest way to go into a “figure four” is by sticking both tools into ice or rock, then one has to hike both feet up and drop one leg over the opposite hand. After this, the climber has to tighten his abs and suck weight over his wrist, and extend free arm as much as needed to reach the next hold. “Figure nine” are done in the same way as figure fours, but imply using the hand and leg from the same part of the body (20).

Despite significant progress in ice climbing, there are still no scientific data that strictly refer to these athletes. Previous papers were related only to the sport/rock climbers (SC) (4, 6, 10, 11, 14, 18, 17), alpinists and mountain climbers (1, 2) or the injuries of IC (8, 13, 12). Therefore, IC, considering organization of training process, anthropometric characteristics and nutrition, had only information based on data of sport/rock climbers. The first aim of this paper was to compare elite ice and rock climbers, their anthropometry, muscular strength, endurance and flexibility. The second aim was to determine whether organization of training process and nutrition based upon researches on SC can be beneficial to IC too.

Methods

Participants

A total of 57 male volunteers participated in the study. Mean age of ice climbers (IC) was 26.7 ± 5.9 and sport climbers (SC) 27.9 ± 3.9 years. All IC included in the study passed the qualification round for the Ice Climbing World Cup, while the second group consisted of elite SC. At the Ice Climbing World Cup 2010 in Saas Fee (Switzerland) we measured all together thirty four IC and excluded eleven who did not pass the qualification round. So the final number of IC in the study was 23. The

second group consisted of 23 SC all members of Mountaineering Association of Serbia who self-reported minimum climbing capability for “on sight” at climbing grade $>VII+/6b$ (UIAA/French). This level of difficulty was taken as high-level sport climbing performance (19). “On-sight” means that the climber ascends the route on the first try without falls and without prior viewing or information about the route (16).

Procedures

The subjects were instructed to rest well one day before the testing. Immediately before testing subjects warmed up. The test procedures were designed that the pre-measuring did not affect the following measurements. The subjects were allowed to rest shortly between tests; the rest involved walking to the following testing location or an explanation of the following test. The schedule of the most demanding tests provided the subjects with enough time to rest in between. Rest periods between handgrip tests (different hands) lasted 45 seconds, while the rest periods for tests performed on the same limb lasted 90 seconds (5, 6). All participants had the same testing sequence. The tests described below are listed in the same order in which they were performed:

Height

Subjects were measured in upright position with their back against the wall, barefoot and with the head in Frankfurt position. Measurement was done to the nearest 0.1cm using stadiometer Seca.

Arm Span

Arm span was measured in standing position with arms abducted horizontally. The greatest tip to tip distance between extended fingers was recorded in centimeters (17). The ratio of arm span to height (“ape index”) was calculated as arm span divided by height (21, 22).

Table 2

Strength, endurance and flexibility characteristics of two groups. HG=handgrip; HG E=handgrip endurance; d=dominant hand; LH=left hand; RH=right hand; P=pincer strength; SMR=strength to mass ratio; SME=shoulder muscle endurance. *=Statistically significant different from sport climbers (p<0.05).

VARIABLE	ICE CLIMBERS (N=23)			SPORT CIMBERS (N=23)		
	MEAN (SD)	MEDIAN	RANGE	MEAN (SD)	MEDIAN	RANGE
Foot raise (cm)	68.1 (5.7)	68	58-78	76.3 (7.4)	76	63-91
Hip flexion(°)	94.5 (9.8)	90	72-112	92.5 (13.2)	87	66-115
Hip abduction(°)	90.9 (9.8)	90	72-112	94.4 (7.5)	95	80-111
HG-LH(N)	442.2 (95.96)*	440,47	262.92-623.70	575.0 (83.25)	558,75	4457.77-772.65
HG-RH (N)	495.4 (95.55)	516,8	316.27-714.87	588.69 (77.85)	580,69	464.61-801.88
HG E(70%)-d (s)	30.3 (12.0)	31,2	10.3-54.3	33.1 (10.6)	34,2	11.12-55.06
Pd (N)	97.4 (25.0)	93,34	55.72-141.69	97.6 (20.02)	93,49	72.50-147.22
SMR-d (N/kg)	7.05 (1.08)	6,96	5.13-9.60	8.5 (1.0)	8,6	6.43-11.05
SME (s)	51.84 (20.04)	48	Jul 91	58.7 (15.0)	58,9	18.40-87.20

Leg Length

The subjects are in supine position with their legs flat on the mat. With their feet shoulder width apart, the length of a subject's right leg was measured from the anterior superior iliac spine to the apex of the medial malleolus and, with the foot plantar flexed as much as possible, the measurement extended to the tip of the big toe (5, 6). Measurement was performed with anthropometric meter to the nearest 0.5cm.

Body Composition

The subjects were measured using Bioimpedance scale Tanita BC 418 MA in upright position with electrodes on their hands and under their feet. They have been measured in athletic mode, on room temperature and with dry hands and feet. Tanita's body resistance calculation involves: body fat mass and %, segmental body fat mass and % (left, right arm and foot, trunk), basal metabolic rate (BMR), fat free mass (FFM), segmental FFM (left, right hand and foot, trunk), total body water (TBW), body mass index (BMI) and body mass. Measurement was done to the nearest 0.1 kg for body mass, fat mass, FFM and TBW, 0.1% for fat %, 1kcal – BMR and 0.1kg/m² – BMI.

Foot Raise

A subject had to stand facing a wall with his toes touching a line positioned 23cm from the wall. Both of the subject's hands had to be placed on the wall at shoulder height. Standing on his left foot, the subject was instructed to place the toe of his right foot as high up the wall as possible without allowing it to move laterally (5,6). The height the subjects raised their foot to was measured with a wall meter to the nearest 0.5 cm. Measurements were only taken for the right leg (5, 6).

Hip Flexion

Subjects were in the supine position with their legs flat on the mat and with their feet shoulder width apart. Their arms were bent in elbows and shoulders and their hands were positioned under the head. The subjects were instructed to lift their left foot by flexing their hip as much as possible, while avoiding flexing legs in knees or moving their right leg. The center of the goniometer body was placed over the greater trochanter, while Achilles' tendon was used for measuring the angle. Each subject underwent three trials and the best results were taken as final (19). Measurement was taken from wall goniometer to the nearest 1°.

Hip Abduction

The subjects were in the same position as the one they have to take for hip flexion, but this time with simphisis pubis positioned at dead center of the floor goniometer. Subjects were instructed to perform the best abduction of left leg they can, while their right leg remained in the initial position and with the knee stretched. Each subject underwent three trials and the best results were taken as final (22). Measurement was done to the nearest 1°.

Handgrip Strength

A handgrip electronic dynamometer (Uno-Lux NS) was used. It was adjusted so that the grip was 4.5cm wide. The subjects stood upright with their feet slightly apart and elbows bent at 90°. The subjects were instructed to squeeze the dynamometer gradually and with maximal force for at least 2s without moving the arm. One practice trial was followed by two tests on both hands (5,6). Measurements were taken alternately between the left and the right hand. The best score for each hand was taken as the final result, and the measurement was done to the nearest 0.01N.

Handgrip Endurance

After a 2-minute rest period, the subjects had to grip and hold cross bars of electronic dynamometer in the same way they did when measuring hand strength, but now they had to hold on to the bars for as long as they could. During the test, a subject was provided with an opportunity to follow his progress on a monitor in real time. Besides the time and the endurance indicators, the monitor also displayed two lines showing 60% and 70% of maximal handgrip strength, in order for the subjects to be aware of the force they need to use during testing. Time was measured only for force exceeding 70%; when the force drops under 60% the time counter stops. Measurement was done only on one's dominant hand and with 2-minute rests between two attempts. The measurement was done to the nearest 0.01N.

Pincer Strength

After a 2-minute break the subject had to grip cross bars of electronic dynamometer between his thumb and forefinger and squeeze with maximum strength for 2 seconds (5, 6). Best of the two results was taken as the final result; the subjects were allowed to take 2-minute rests between two attempts. Measurement was done only for dominant hand and to the nearest 0.01N.

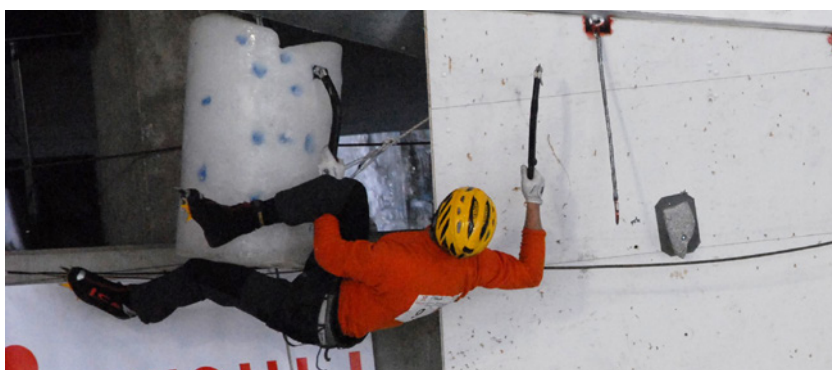


Figure 1

Ice climber is doing „figure tour“ at Ice Climbing World Cup (ICWC) 2010, Saas Fee, Switzerland. Photo: Prof. T. Küpper.

Static Endurance of Arm and Shoulder Muscles

A subject stood with his back to the wall; with his pelvis, back and head touching the wall. The feet were slightly separated and distanced from the wall by the length of the subject's foot. Knees were stretched. The subject lifted 5kg weights with an overhand grip, pulls them to his chest and extends his arms at shoulder height straight in front of himself. When the subject was no longer able to hold the position and started to bend his arms or legs, the test was finished. The test was also finished if he allowed one of his arms to drop more than 5cm, even if he was able to lift it again. This test was performed two times and the better of two results was taken the final result.

Statistical Analysis

All statistical analyses were performed using SPSS software. Descriptive statistics included mean, standard deviation (SD), median and range for all variables. The differences between different groups were tested with analysis of variance test (ANOVA test). Statistical significance was set at $p < 0.05$.

Results

Table 1 presents anthropometric data of the groups. There is no significant difference between IC and SC in variables such as height, arm span, ape index, mass, BMI and BMR. Also, there is no difference between groups in variables FFM, TBW and "%Fat" in extremities (RL, LL, RA, LA). IC have more fat% in their body (9.4 ± 2.9), comparing to SC (6.5 ± 2.3), and more fat in the trunk region (Fat%-T, IC 9.5 ± 3.9 vs. SC 5.5 ± 3.0).

Table 2 presents the results for the variables foot rise, hip flexion, hip abduction, handgrip strength, handgrip endurance, pincer strength, strength to mass ratio (SMR), static endurance of arm and shoulder muscle. IC show significant less handgrip strength in both hands, as well as SMR of the dominant hand (IC 7.05 ± 1.08 vs. SC 8.5 ± 1.0 N/kg). Considering the results of the test "foot rise", IC show significant less flexibility (IC 68.1 ± 5.7 vs. SC 76.3 ± 7.4 cm). All other measurements of muscular strength and endurance, and flexibility did not show significant differences between IC and SC.

Discussion

Over the past twenty years competitive ice climbing experienced an increase in popularity, while the existing climbing standards greatly improved. The Ice Climbing World Cup was organized every year over the past 15 years and each time it was bigger and more popular than the year before. Though and

to our best knowledge, there are no previous papers focusing anthropometry of IC – only about ICs injuries (8, 12, 13).

The results of the study show that there are significant differences between the two groups of climbers regarding body fat, flexibility, absolute and relative muscle strength (SMR). IC have higher %fat, weaker flexibility, and less absolute and relative muscle strength compared to SC.

If we compare segmental analyzes of body fat distribution between IC and SC, the results show that a significant difference between the two groups exists only for fat percentage content in the trunk, while the fat percentage in the arms and legs are the same. Similar to other authors we could demonstrate that SC

are athletes with small to moderate height and with very low percent of body fat (4, 6, 9, 11, 12, 13, 17, 18).

Based on data available we could deduce that a higher percentage of body fat has a negative impact on performance and ranking in a sport which implies lifting one's weight against the force of gravity (18). An elevated value of fat percentage in the trunk at IC might be a consequence of not only prolonged stay in the cold environment but also need for resilient body structure in rough alpine terrain and mountaineering in general. Most of IC have background in mountaineering.

There was a significant difference between the groups shown in the indirect measurement of flexibility, using foot rise test. IC has weaker results, although it was expected that due to the ice climbing technique requiring low holding of the heel as a front point, figure "four" and "nine" they would be better than SC. Considering that IC have a lot of possibility for steady leg position on the ice during ascent, there might be no need for extremely high foot rise while ice climbing. Also, it can be a consequence that sport climbing as ongoing Olympic sport is much more competitive and on a higher level than ice climbing and its athletes.

Considering handgrip strength, IC showed significant weaker results than SC. Muscles of the forearm and hand are stronger in elite sport climbers. Except for a reason mention in the previous paragraph, this could be due to ergonomically shaped ice axes that are easier to hold than tiny crimps in rock climbing.

During ice climbing, forearm muscles often produce maximal or submaximal force with periods of rest. In the case of the handgrip endurance test, we measured time for strength exceeding 70% of previously measured maximal handgrip strength for the dominant hand. The previous papers (3, 7, 16) implied that a grip strength exceeding 70% of maximal force closes all the blood vessels and prompts anaerobic activity of muscles. In this test IC did not show any significant differences in comparison to the SC, which may be due to the fact that both groups have extremely high endurance of forearm muscles.

During ice climbing, climbers use tools which have ergonomic shape and resting hooks. The first hook is placed at the bottom, while the second one is placed at 1/3 of handhold height. The second one is often used by climbers in the following way: the index finger is put over it for rest or better grip. Consequently, Pincer strength test is particularly interesting if we want to determine and compare muscle tension in index finger of ICs and SCs. There was no significant difference between groups and we can conclude that the test may not be specific enough.

Testing for shoulder muscle endurance can make a significant contribution in an attempt to determine anaerobic capacity of bigger muscle groups. We did not find any differences between the two groups. Therefore, we can conclude that this testing may not be specific enough for climbers.

Limitation of the Study

Body composition of subjects we measured by bioimpedance scale. Tanita BC 418 MA model was used. Even though the scale is one of the top models of leading brand on the market and all recommended manufacturer procedures were followed some inaccuracy due to the software database limitation could be shown in measurement.

Conclusion

Although most of the anthropometric data were the same between the two observed groups, they also indicate that IC have more body fat, less flexibility and muscle strength than SC. With such data, we can conclude that there is a certain but overall subordinate difference between IC and SC and that sport climbing training protocols for strength development, endurance and flexibility can be potentially useful for IC too. ■

Conflict of Interest

The authors have no conflict of interest.

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