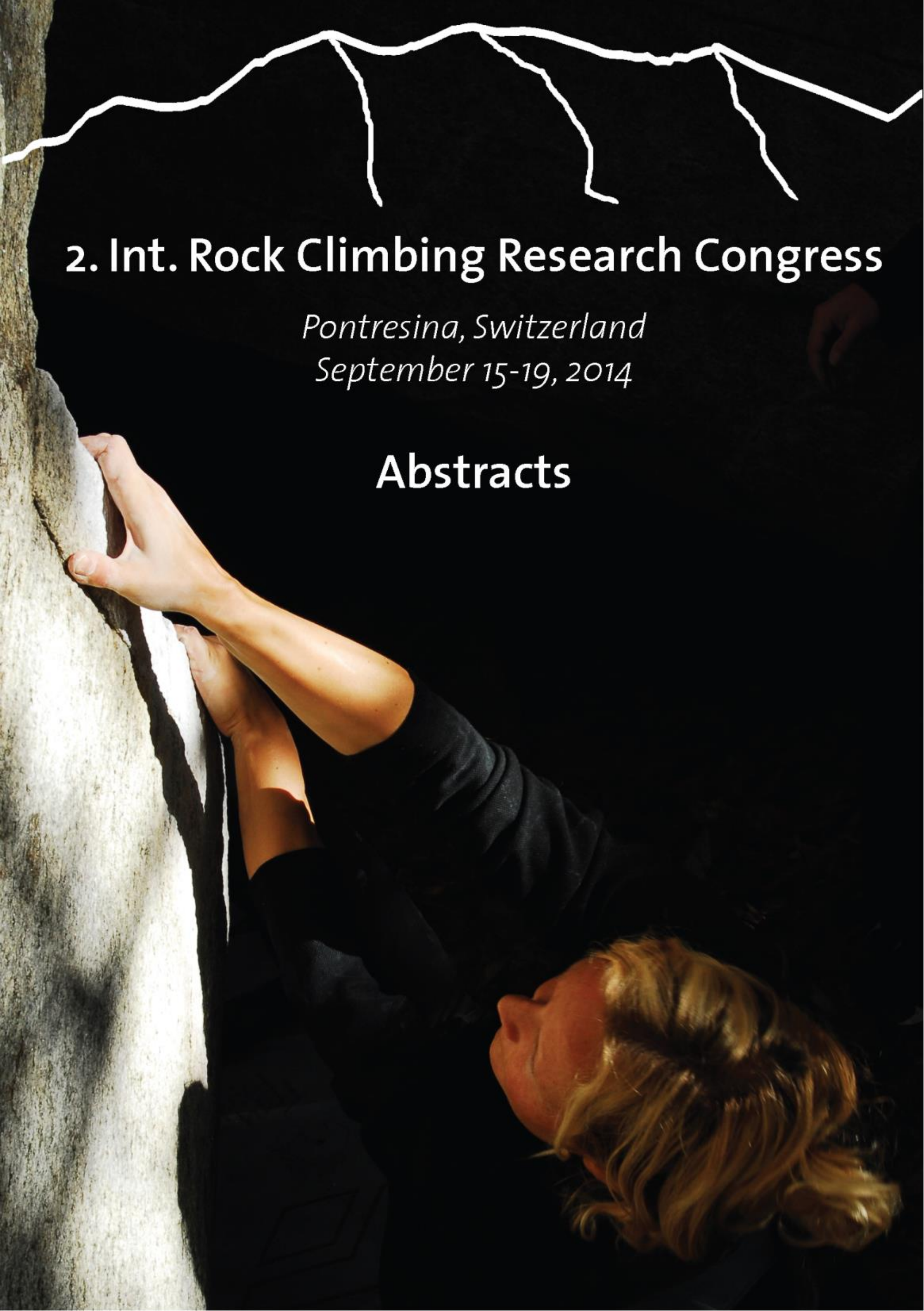
2. Int. Rock Climbing Research Congress

Pontresina, Switzerland
September 15-19, 2014

Abstracts



Program Overview

Monday, September 15, 2104

13h00	**Conference start** **Welcome notes**
13h10	**Keynote Biomechanics** ***L. Vigouroux*, Prehensile capabilities of rock-climbers**
14h10	**Oral Session 1** *L. Donath*, Effects of climbing-wall inclination on trunk muscle activation during various static climbing positions: Implications for therapeutic climbing *F.Mally*, Surface electromyography measurements of stabilizing ventral muscles in therapeutic climbing *S.Fryer*, Forearm muscle tissue re-oxygenation kinetics in male sport rock climbers
15h10	Coffee break
15h30	**Oral Session 2** *J.Balas*, Finger flexors strength measurement using electronic scales in sport climbers & The effect of arm and grip position during finger flexor strength measurement in sport climbers *M. Fanchini*, Internal responsiveness of two methods for assessing maximal strength and peak rate of force development in lead rock climbers *P.Wolf*, Interaction forces in climbing: Cost-efficient complementation of a 6dof instrumentation
16h30	**Special: Expedition I** ***R. Schäli*, Recent adventures**
17h30	Information on Mountaineering
19h00	**Conference Dinner**

Tuesday, September 16, 2014

08h30	**Keynote Material** ***T. Fuss*, Climbing equipment and friction**
09h30	**Oral Session 3** *K. Raine,* Benefits of 3D topos for information sharing and planning in rock climbing *S. Beekmeyer,* Discovering climbing in artificial structures using digital design and fabrication technology
10h15	Coffee break
10h45	**Oral Session 4** *M. Spoerri*, A new program to calculate a climber's fall *D. Orth*, Hold design supports transfer of fluidity in climbing skill *L. Seifert*, Full-body movement pattern recognition in climbing *L. Seifert*, Movement phase detection in climbing
12h05	Lunch break
13h00	**Forum Session Grading** led by *N. Draper* Consensus on climbing ability grouping
13h30	**Oral Session 5** *P. Watts*, Geometric Entropy During Rock Climbing – Lead vs Top-Rope Ascents *K. Phillips*, Body position and technique effects on displacement in the dyno maneuver in rock climbing *A. Amca*, Relationship between climbing specific grip techniques, hold depth and maximal finger force capacity of rock climbers
14h30	Preparation Mountaineering

Wednesday, September 17, 2014

	Mountaineering or Climbing

Thursday, September 18, 2014

08h30	**Keynote Training I** ***P. Matros*, Impact of feedback provided by a trainer**
09h30	**Oral Session 6** *G. Gonzales*, A preliminary analysis of motivation and goal orientation in rock climbers *V. España-Romero*, Anthropometry, physical fitness and psychological profile of adolescent rock climbers from South of Spain: predictors of performance
10h15	Coffee break
10h45	**Oral Session 7** *B. Smith*, Human Factors in Avalanche Decision Making Among Mountaineers in Scotland *M. Panackova*, Physiological demands of indoor wall climbing for children *D. Giles*, Current understanding in climbing psychophysiology research
11h45	Lunch break
12h30	Climbing Morteratsch
19h00	**Special: Expedition II** ***U. Hefti*, Swiss Himlung Expedition**
20h00	**Conference Dinner**

Friday, September 19, 2014

08h30	**H.P. Bircher Memorial Lecture** ***V. Schöffl*, Finger injuries in rock climbing**
09h30	**Oral Session 8** *K. Bonetti*, Talus fractures in climbers *T. Bayer*, Epiphyseal stress fractures of adolescent climbing athletes – a 3.0T MRI evaluation
10h15	Coffee break
10h45	**Oral Session 9** *M. Kilgas*, Static Stretching does not impair sport specific measures of upper-limb force and power in rock climbing *F. Bourassa-Moreau*, Computer connected force platform performance assessment and training tool for rock climbing *L. Roland*, Postural adaptations in female elite rock climbers: the Climber‘s Back *M. Schneeberger*, Results of conservative treatment of closed finger flexor tendon pulley rupture with a pulley protection ring
12h25	**Farewell**

Effects of climbing-wall inclination on trunk muscle activation during various static climbing positions: Implications for therapeutic climbing

L. Donath[1], C. Grzybowski[2], H. Wagner[2]

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***Summary* – Holding climbing positions statically at specified handhold setups and at different wall inclinations might be useful during therapeutic climbing in order to work on patients' trunk posture and strength. However, electromyographical data are needed to better understand underlaying neuromuscular and postural demands in response to such mechanical alterations. Our data suggest that a negative climbing-wall inclination of at least 12° results in significant muscle activity changes of trunk muscles during various static climbing positions compared to the vertical wall. These data might have impact on how to employ wall-inclination and climbing positions to progressivly plan and conduct therapeutical climbing".**

INTRODUCTION

Climbing serves as a promising sort of physical therapy in patients with various orthopedical and neurological conditions. Results from previous intervention studies already revealed positive effects of climbing training on selected psychological and physiological outcomes (e.g. pain perception, quality of life, functional outcomes), particularly in patients with low back pain [1]. A lack of evidence, however, has to be stated concerning fundamental neurophysiological investigations that examine neurophysiological demands in relation to climbing positions and wall-inclinations. These data are needed to provide goal-oriented exercise training regimes. Thus, the purpose of the present study was to investigate to what extend muscle activation of the trunk is linked to the wall inclination and the climbing and handhold position, respectively. We aimed at assessing which angles lead to relevant changes of trunk muscle activity during various static climbing positions.

MATERIAL AND METHODS

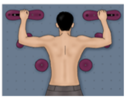
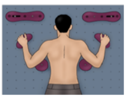
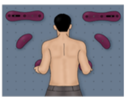
Thirteen healthy adults without climbing experience were asked to hold three static climbing positions (base position, lifting a hand, lifting a foot) at three different handhold setups and six wall inclination angles (0°, 4°, 8°, 12°, 15°, 18°) for 5 seconds each. Bilateral muscle activity of the erector spinae, multifidus, latissimus dorsi, external oblique, internal oblique and the rectus abdominis was measured using surface electromyography.

The EMG data was analysed for each muscle and climbing condition separately.

RESULTS

Compared to the vertical wall, the muscle activity starts to differ significantly ($p \leq 0.05$) from 12° onwards. This inclination angle particularly affects the activity of all muscles when lifting a hand ($p \leq 0.05$). The oblique muscles did not show any or little effects when lifting a foot or being in the base position, while all other muscles demonstrate a continuous increase. An overview is provided in table 1.

Table 1 Handhold setups and climbing positions for each muscle. Angles that were statistically different compared to the vertical wall are presented ($p<0.05$).

	left				right		
position	**base position**	**lifting hand**	**lifting foot**	**muscle**	**base position**	**lifting hand**	**lifting foot**
	≥ 12	≥ 12	≥ 12	erector spinae	≥ 12	≥ 12	≥ 12
	≥ 12	≥ 12	≥ 12	multifidus	≥ 12	≥ 12	≥ 12
	18	≥ 12	n.s.	latissimus	18	≥ 15	≥ 12
	n.s.	≥ 12	12 / 18	external oblique	n.s.	≥ 12	≥ 15 [1]
	n.s.	≥ 12	n.s.	internal oblique	n.s.	18	n.s.
	12 / 18	≥ 12	≥ 12	rectus abdominis	12 / 18	≥ 12	n.s.
	≥ 12	≥ 12	≥ 12	erector spinae	≥ 12	≥ 12	≥ 12
	≥ 12	≥ 12	≥ 12	multifidus	≥ 15	≥ 12	≥ 12
	≥ 12	≥ 12	≥ 8	latissimus	≥ 15	≥ 15	≥ 12
	n.s.	≥ 12	12 / 18	external oblique	n.s.	≥ 12	n.s.
	n.s.	≥ 12	n.s.	internal oblique	n.s.	18	≥ 15
	≥ 12	≥ 12	≥ 12	rectus abdominis	n.s.	≥ 12	≥ 15
	≥ 15	≥ 12	≥ 12	erector spinae	≥ 15	≥ 12	≥ 12
	18	≥ 12	≥ 12	multifidus	n.s.	≥ 12	≥ 12
	≥ 12	≥ 12	n.s.	latissimus	≥ 15	18	≥ 12
	≥ 15	≥ 12	≥ 15	external oblique	18	≥ 12	n.s.
	n.s.	≥ 12	n.s.	internal oblique	18	≥ 12	≥ 12
	≥ 12	≥ 12	≥ 12	rectus abdominis	≥ 12	≥ 12	≥ 12

CONCLUSION

Inclinable climbing walls serve as promising means to increase trunk muscle activity. Climbing walls used for therapy should offer variable inclination angles. To increase the activation of oblique muscles, lifting hands seem to be required. Further research should concentrate on the development and evaluation of climbing exercises and training interventions for specific patients, e.g. people with scoliosis.

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Surface electromyography measurements of stabilizing ventral muscles in therapeutic climbing

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[2]*RMIT University, School of Aerospace, Mechanical and Manufacturing Engineering, Melbourne, Australia*

***Summary* – With three subjects taking part in the study the muscle activation of four ventral surface muscles was investigated during therapeutic climbing. All subjects repeatedly performed one specific therapeutic climbing exercise while muscle activation was measured with a wireless surface electromyography system. It was investigated whether an asymmetric activation occurs in order to remain holding onto the climbing wall or not. Although showing high individual differences a cross-activation could actually be observed for each subject.**

INTRODUCTION

The positive effects of climbing in therapy can and have already been observed within different fields of rehabilitation. Promising progress has already been achieved in orthopaedics, as well as geriatrics and neurology [1][2][3]. Its overall effect on strength and core stability has been of interest before [4] and is within this study as well. As in [5] it was questioned whether a cross-activation of specific muscles can be observed when increasing instability during climbing.

METHODS

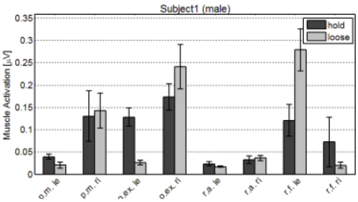
Three subjects (2 male, 1 female, age: 25±1years, height: 175±5cm, weight: 67±8kg, no muskosceletal injuries at time of measurements) participated in this study. The therapeutic climbing exercise of choice was a commonly used exercise in order to train core muscle strength. Starting with a symmetrical position whereby the subject's back was facing a 15° overhanging climbing wall. After a few seconds the subjects were asked to loosen one hand and remain close to the wall without falling off. Repeatedly and slowly loosening of the left hand lead to a quasi-static performance of symmetrical and asymmetrical load distribution. During the trials activation of the muscles pectoralis major, obliquus externus abdominis, rectus abdominis and rectus femoris was bilaterally captured at 1000Hz using a wireless surface electromyography (EMG) system (MYON 320, myon AG, Schwarzenberg, CH).

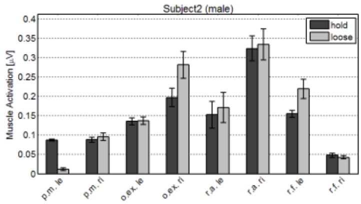
DATA TREATMENT

Raw EMG data of the trunk muscles were filtered with a 4th order Butterworth filter at a cut-off frequency of 30Hz in order to decrease heart muscle artefacts [6]. After that data were rectified and smoothed using a root mean square running average filter with a window width of 300ms. Two phases – "holding with both hands" and "loosen left hand" – were defined from the activation of the left pectoralis major muscle. Three trials per subject were randomly chosen and a mean value of muscle activation was calculated for 100ms of both phases per trial. Hence a mean value out of 300ms per phase and subject was calculated.

RESULTS

Figure 1 below shows the mean activation (and standard deviation) of all measured muscles compared between both phases of the exercise and treated separately for each subject.





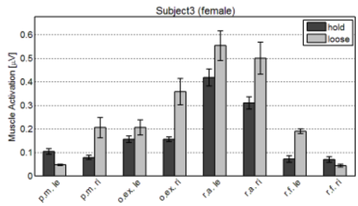


Figure 1 Mean activation of all muscles of all three subjects compared between the two phases; "hold" refers to the subjects symmetrically holding on to the wall; "loose" describes the phase where the left hand got detached from the wall.

DISCUSSION

Despite individual differences within distinctness a cross-activation could be observed for all subjects while taking the left hand off the wall. However, it is not entirely clear yet why single muscle groups also show asymmetrical activation during actual symmetrical load distribution. Also correlations and further predictions are hard to be done based on the low number of subjects. Planning of similar studies with a larger number of subjects has been going on already.

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Forearm muscle tissue re-oxygenation kinetics in male sport rock climbers

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***Summary* – The current study quantified muscle tissue oxygenation kinetics during and after a sustained isometric contraction at 40% of MVC. Oxygen saturation was assessed in the flexor digitorum profundus (FDP) and flexor carpi radialis (FCR). Elite climbers used significantly more O2 during the contraction, and had a significantly faster time to half recovery than the intermediate and advanced climbers, as well as the control group. Elite climbers appear to have an increased ability for oxyhaemoglobin to off-load O2 into the muscle during exercise, and may have an enhanced PCr-resynthesis during recovery[1].**

INTRODUCTION

Previous research into the performance of rock climbing has focused on de-oxygenation and re-oxygenation kinetics during open crimp contractions to failure [2, 3]. However, no known study has attempted to determine oxygenation kinetics during both the contraction and subsequent recovery period. An assessment of re-oxygenation during recovery in multiple ability groups of rock climbers may provide insight into some of the underlying physiological mechanisms which enable elite performers to sustain intense isometric contractions for prolonged periods of time. As Near Infrared Spectroscopy (NIRS) has previously been correlated to PCr recovery [1], this area is of particular interest. Therefore, the aim of this study was assess MVC, maximal de-oxygenation, and re-oxygenation time to half recovery after a sustained contraction to failure in different ability groups of rock climbers.

METHOD

Thirty-eight participants were categorized into 4 ability groups as defined by Draper et al., [4] (intermediate (n=9), advanced (n=10), elite (n=10) and control (n=9)). A climbing specific handgrip ergometer was developed to accurately measure force (newtons), and regulate ±5% error during the contraction.

Participants were asked to apply 40% of MVC to the climbing hold until volitional fatigue occurred. During both contraction and recovery (passive, 5min), NIRS was used to assess muscle tissue oxygenation kinetics.

RESULTS

Table 1 Mean (SD) tissue de-oxygenation (%) Δ, and time to half recovery (s) post sustained contraction in the FDP and FCR of intermediate, advanced and elite climbers as well as non-climbers.

	% (Δ) de-oxygenation (SD)	**Time (s) to ½ recovery (SD)**
FDP		
Control	32 (14.3)*	94.7 (63.2)
Intermediate	34.3 (9.5)*	46.7 (32.3)
Advanced	42.8 (9.3)*	12 (8.9)***,**
Elite	63.1 (7.6)	8.4 (3.4)***,**
FCR		
Control	22.7 (16.8)	30.4 (25.3)
Intermediate	14.6 (7.8)*	97.2 (65)
Advanced	28.9 (15)	15.5 (18.1)**
Elite	36.5 (0.4)	6.8 (4.9)**

% de-oxygenation Δ represents the difference between baseline O_2% and maximal de-oxygenation % achieved during the contraction.
*Shows the group is significantly different ($p < 0.05$) from the elite group
**Shows the group is significantly different ($p < 0.05$) from the intermediate group
***Shows the group is significantly different ($p < 0.05$) from the control group

DISCUSSION

Findings of the current study suggest that not only was maximal de-oxygenation significantly greater in elite rock climbers, but the time taken to reach half recovery was also significantly less. All elite climbers de-oxygenated the FDP and FCR to a similar extent, the small SD (Table 1) suggests they may have been close to the physiological limit of being able to perfuse O2 within the muscle. The significantly quicker time to half recovery in the FDP and FCR is suggestive of the elite and advanced climbers having potential differences in oxidative metabolism, more specifically, being able to re-synthesis PCr at a faster rate. What is not known is whether these are pre-requisites which govern performance, or muscle adaptations.

REFERENCES

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The effect of arm and grip position during finger flexor strength measurement in sport climbers

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INTRODUCTION

Finger flexor strength and endurance are considered to be two of the key aspects of climbing performance. Handgrip dynamometry remains the most prevalent test used in climbing studies, although Watts et al. [1] proposed that the test may lack specificity to climbing. However, various studies have assessed climber finger strength using specific devices with different arm positions and grip positions [2-5].

The aim of the study was to evaluate the validity and reliability of four different arm positions and four climbing grip positions for finger flexor strength measurement in sport climbers. To complete this research the study was completed in two phases to assess the reliability and validity of, firstly, the four different arm positions and secondly for the four different grip positions.

METHODS STUDY 1

Forty six climbers completed finger flexor strength measurement on a climbing specific device with four different arm positions: 1 - handgrip, shoulder flexed at 0°, elbow fully extended; 2 - shoulder flexed at 90° and externally rotated, elbow flexed at 90° (position 90/90); 3 - shoulder abducted at 130°, elbow flexed at 50° (position 130/50), 4 - shoulder flexed at 180°, elbow fully extended (position 180/0). Intra-session reliability from 3 trials was assessed by an intra-class correlation coefficient (ICC) and standard error of measurement (SEM). To assess the criterion related validity repeated analysis of covariance was used (4 x 2 x 2) with the arm position as a within subject factor, sex and climbing ability as between subject factors, and body mass as a covariate.

RESULTS STUDY 1

A high ICC was found for all arm positions ranging from 0.95 to 0.98 and SEM ranging from 22-26 N. The highest variability explained by climbing ability for finger strength was found in the 180/0 position ($\eta_p^2 = 0.25$) and 130/50 position ($\eta_p^2 = 0.25$). The handgrip test had the lowest validity as seen against reported climbing ability ($\eta_p^2 = 0.05$).

METHODS STUDY 2

Fifty-five climbers with climbing abilities RP (redpoint) between 4c and 9b+ on the French scale volunteered to the study. Open grip (OG), crimp grip (CG), index + middle finger (IM), middle + ring finger (MR) were tested on a 23 mm wide wood-edge. The climbers were asked to stand on the scale platform and to progressively lower their weight on the tested arm. Strength was calculated by subtracting the lowest value shown on a scale from the body mass. Intra-session reliability was calculated from three trials and inter-session reliability from the testing repeated after one week.

RESULTS STUDY 2

The ICC coefficients and SEM ranged for all grip positions between 0.88-0.97, 22-42 N and 0.88-0.94, 30-53 N for intra-session, respective inter-session reliability indicating a high level of consistency and stability for the test's scores. The criterion related validity for RP and OS was found to be highest in OG and CG. The coefficient of correlation was found to range between 0.788 - 0.811 from the RP or OS performance. Criterion related validity was slightly lower in MR, with the lowest validity stated in IM position (R = 0.677-0.753).

CONCLUSIONS

The positions 180/0 and 130/50 appear to be most suitable to assess finger flexor strength, with the 90/90 position providing substantially less validity. Handgrip dynamometry had the lowest criterion validity when compared with these proposed tests and, therefore, is not recommended to assess finger strength in climbers.

The use of a climbing fingers board and digital scales corresponds to a suitable arm position for finger flexor strength measurement and appears to represent a relatively inexpensive, straightforward, reliable and valid method to assess climbing-specific finger strength using different grip positions. Open grip and crimp grip were found most specific to self-reported climbing performance. In future research and testing, it would be worthwhile to assess the two-finger positions especially when wishing to identify the uniqueness of each finger position.

REFERENCES

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Internal responsiveness of two methods for assessing maximal strength and peak rate of force development in lead rock climbers

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[1]*Department of Neurological and Movement Science and CeRISM, University of Verona, Verona, Italy*

***Summary* – The aim of this study was to compare the internal responsiveness of the maximal voluntary contraction (MVC) and peak rate of force development (pRFD) measured with a specific climbing dynamometer (SCD) and handgrip (HG). Twenty-three amateur climbers were tested before and after a route (7b+). The pRFD showed higher responsiveness compared to MVC in SCD. The MVC in HG showed higher Signal to Noise ratio due to its reliability. The pRFD in SCD was considered appropriate to investigate muscle fatigue in sport climbing.**

INTRODUCTION

In order to examine the appropriateness of a tool to measure changes over time (as after a climbing route) an important measurement attribute is the internal responsiveness [1]. Maximal voluntary contraction (MVC) of the finger flexors has been suggested to be a determinant in sport climbing performance [2]. However, the peak of rate force development (pRFD) can be more appropriate than MVC for evaluating neuromuscular characteristics. The aim of this study was to compare the internal responsiveness of MVC and pRFD assessed using a specific climbing dynamometer (SCD) (SCD-MVC and SCD pRFD) and handgrip (HG) (HG-MVC and HG-pRFD) in sport climbers.

METHODS

Twenty-three amateur climbers (age 32 ± 9 years; height 177 ± 8 cm; weight 67 ± 8 kg) performed 6 x 4 s contractions (2 SCD-MVC, 2 SCD-pRFD, 1 HG-MVC and 1 HG-pRFD, randomized in the sequence) before (PRE) and after (POST) a route (grade 7b+). The SCD tests were performed with the hand in “open-crimp” position. Instructions were: to contract “as hard as possible” and “as hard as quick as possible” for MVC and pRFD, respectively. All data were normalized to body mass and analysed after Log-transformation. Internal responsiveness (±90%CL) was assessed using the best score in every session and calculated as Cohen’s effect size (ES), standardize response mean (SRM) and signal-to-noise ratio (S/N). Changes after the route (i.e. muscle fatigue) was examined as percentage and 90% CI.

RESULTS

The values measured in PRE, POST and the internal responsiveness are presented in Table1. Percentage changes and 90% CI are presented in Figure 1.

Table 1. Values of PRE, POST and internal responsiveness calculated for every measurement tool and typology of contraction.

Variable	SCD-MVC (N/kg)	SCD-pRFD (N/kg/s)	HG-MVC (N/kg)	HG-pRFD (N/kg/s)
PRE	6.84 ± 0.97	19.31 ± 3.48	7.19 ± 0.97	20.79 ± 3.50
POST	6.28 ± 1.18	14.85 ± 2.95	6.45 ± 1.05	17.68 ± 3.80
ES (±90%CL)	-0.66 (±0.34)	-1.48 (±0.37)	-0.91 (±0.32)	-0.98 (±0.32)
SRM (±90%CL)	-0.70 (±0.36)	-1.44 (±0.36)	-1.02 (±0.36)	-1.09 (±0.36)
S/N (±90%CL)	-0.01 (±0.01)	-0.02 (±0.005)	-0.03 (±0.01)	-0.02 (±0.01)

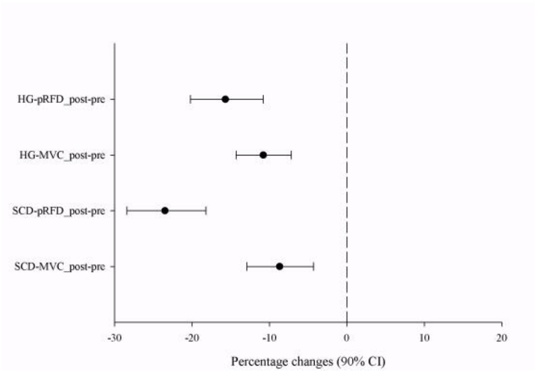

Figure 1 Percentage changes after climbing in MVC and pRFD measured with SCD and HG during.

DISCUSSION

The decline of all measurements confirmed the occurrence of muscle fatigue after climbing the lead route. The SCD-pRFD showed higher ES and SRM compared to SCD-MVC, HG-MVC and HG-pRFD. However, the S/N for HG-MVC was higher compared to HG-pRFD due to its higher reliability (typical error as CV was 4.9 and 9.1%, respectively) [4]. In conclusion, this study showed the pRFD to be more appropriate compared to MVC in the specific assessment for investigating fatigue in climbing activity. Since the SCD showed construct validity (i.e. performance as construct) [5] and face validity (as more closely mimic the climbing grip styles), the SCD-pRFD should be considered appropriate to investigate muscle fatigue in sport climbing.

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Numerical climbing fall simulator

M. Spörri

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***Summary* – This program is a simple tool to calculate a climber's fall. It numerically simulates all forces within the safety chain and the movement both of the climber and the belayer in two-dimensional space. Many effects are taken into account, such as real rope and belay device characteristics, knots, air drag, friction and deformation of the climber.**

INTRODUCTION

The use of a mathematical model to analyze a climber's fall can sometimes be the only way of getting information on loads at crucial locations within the safety chain. This specially applies to situations, where real full scale tests are not only complex and expensive to conduct, but also can be very dangerous, as both the climber and the belayer would be exposed to unknown risk and danger. This new program analyses the complete situation of a climber's fall using the method of numerically integrating the differential equation of motion. By implementing a 3-parameter viscoelastic rope model, the different behavior for dynamic and static loading are correctly simulated. The programming is done in Microsoft Excel using Visual Basic for Applications (VBA). Previous models [1] simulated the fall in one dimension using a two parameter rope model.

METHODS

The complete simulation model is depicted in figure 1, showing all parameters influencing the calculation [2].

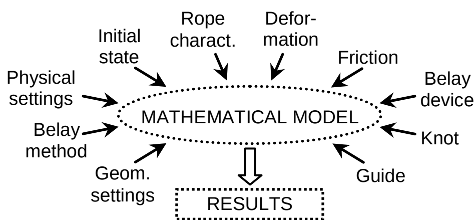

Figure 1 Complete simulation model

Geometrical settings: Fix positions of the anchor and the 1st protection.
Belay method: mobile (moved by the rope force) or fixed belayer.
Physical settings: mass of the climber and the belayer, air velocity, gravity.
Initial state: positions of climber and belayer, initial velocity of the climber.
Rope characteristics: physical properties of the rope (rope parameters).
Deformation: parameters to simulate the body-deformation of the climber.
Friction: coefficient of friction of the rope running around the 1st protection.
Belay device: static (no rope slip) or dynamic belaying (force limitation).
Knot: parameters to simulate the knot that attaches the rope to the climber.
Guide: guide to simulate laboratory falls with a rigid mass.

The numerical integration of the differential equation of motion is done with Euler's method. The rope parameters are calibrated using a special program mode where the simulated rope values are compared with the actual rope values that are commonly available from product data sheets of rope manufacturers. An energy analysis shows in detail how the fall energy is absorbed.

Figure 2 shows the geometrical situation. All motion takes place in two-dimensional space. The belayer is self-belayed with a sling to the anchor, so she/he can only move within the boundaries of the circle (mobile belayer).

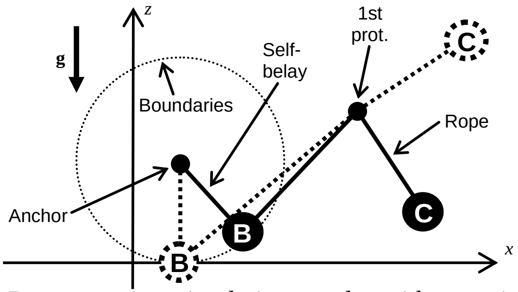

Figure 2 General fall situation: The rope passes from the belayer (B) through the 1st protection to the climber (C). The dotted lines and circles represent the situation before the fall

By comparing simulation results with experimental fall studies and known end values (e.g. weight force, position) the simulation program is validated.

RESULTS

Figure 3 shows the results of the simulated standard fall as defined in EN 892:2004. This test is used to determine the impact force and the maximum dynamic elongation of the rope.

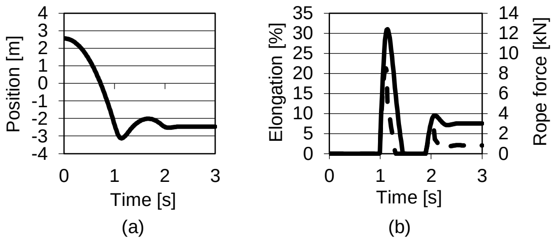

Figure 3 Simulation results for standard fall with the Mammut rope Revelation: (a) position of the falling mass, (b) dynamic elongation and rope force (dashed line)

DISCUSSION

This theoretical simulation of climbing falls allows predictions of e.g. maximum forces, rope stretch and movements. It can be used to efficiently compare the influence of different parameters on certain values without having unpredictable effects of operators affecting the results.

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Geometric Entropy During Rock Climbing – Lead vs Top-Rope Ascents

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***Summary* – Digital video images of rock climber ascents were analyzed to determine geometric entrophy under lead and two top-rope conditions. Statistical analysis revealed no significant differences in geometric entropy between any condition. Individual responses varied by climber and suggest further study with larger samples.**

INTRODUCTION

A primary objective during rock climbing is to ascend specific route terrain with an economy of motion. The complexity of movement of a climber's center of mass has been described as geometric entropy [1]. It has been proposed that lower geometric entropy could represent more economical movement [2]. Recently, Watts, et al. found changes in energy expenditure to be related to changes in GE during climbing [3]. Of recent interest are possible physiological differences between two ascent styles; top-rope and lead [4]. In top-rope, an anchored safety rope is always above the climber to protect against long fall distances. In a lead ascent, the climber must connect the rope to a series of installed anchors while moving over the route. With lead ascents, longer falls are possible and different body positions may be necessary to enable secure connections of the rope to the anchors. Whether geometric entropy varies for lead vs top-rope climbing styles is not known. The purpose of this study was to compare the measured line of motion and degree of entropy for climbers during ascents under top-rope and lead conditions.

METHODS

Six experienced rock climbers, four male and two female, mean (±SD) age = 34.5±15.8, volunteered and signed informed consent to participate in the study. Lead ability ranged 5.8-5.11 YDS/5a-6c French/15-22 Ewbank. The study design and methods were approved by the University Institutional Review Board prior to commencement of the study.

Data were collected at an established outdoor sport climbing area with sandstone rock type. Each participant ascended a route under three conditions. The first ascent was performed as Top-Rope (TR1) where the rope was anchored above the climber. The second and third ascents were performed as Lead (LD) and Top-Rope (TR2) in random order. Each ascent was recorded via high-definition digital video at 30 Hz. A single marker point at the back center of each participant's waist harness was manually digitized by two independent investigators using MaxTRAQ 2D software (ver 2.2) at 6 Hz and interpreted as an estimate of the participant's center of mass (CM_E). The displacement of CM_E was expressed as the length of the line of motion (LM). Geometric Entropy (GE) was calculated according to the method described by Sibella et al [2]:

$$GE = \ln*((2*LM)/CH))$$

where CH is the value of the convex hull about the LM. A Pearson Correlation Coefficient (Microsoft Excel, Windows 8, 2013) was calculated between digitizers for each ascent condition. Reliability = k*r / (1+(k-1)*r) was calculated between coders/digitizers such that k = number of digitizers and r= correlation coefficient. A within subjects, repeated measures ANOVA with Bonferroni post hoc testing was utilized (IBM SPSS Statistics 21; 2012) to test for differences among ascent conditions with significance set at $P < 0.05$.

RESULTS

There were no significant differences in LM or GE between digitizers for any ascent condition, thus data for the two digitizers were averaged for subsequent analysis. Mean (±s.d) values for LM and GE were 81.5±4.6 vs 79.7±3.8 vs 77.6±3.0 and 1.02±0.06 vs 0.96±0.04 vs 0.92±0.03 for LD, TR1 and TR2 respectively. There were no significant differences for LM and GE across all ascent conditions.

DISCUSSION

Watts, et al. [3] have found GE to decrease with repeated TR ascents of a specific route, however differences between LD and TR ascent styles have not been previously reported. The present study indicates no difference in GE between LD and TR ascents for the routes studied. The small sample of subjects studied could be a factor. Three participants had higher GE during LD than either TR condition, however two particpants had lower GE during LD than either TR condition. It is possible that individual preference relative to ascent style exerts an effect. Also, the specific routes selected were one full rating grade (Yosemite Decimal System) below each subject's best outdoor ascent without falls. Further research with larger samples is necessary to determine if route difficulty relative to climber ability is a factor.

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Body position and technique effects on displacement in the dyno maneuver in rock climbing

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Summary **- This study compared vertical displacement of the hand when performing a rock climbing dyno maneuver with squat jump versus counter-movement techniques. These techniques were tested at three different starting positions with variable distance between hand and foot holds. Thirteen recreational rock climbers performed two squat jump and two counter-movement dynos at each starting position. We showed that there were no significant differences in vertical displacement of the hand between jump techniques. However, a significant improvement in vertical displacement of the hand occurred as the participants moved from the low to middle and middle to high starting positions.**

INTRODUCTION

While observations and suggestions for body position [1,2,3] and jump technique [1,2,3,4] when performing the dyno maneuver in rock climbing have been made, these variables have yet to be examined scientifically. Therefore, the current study investigated vertical displacement of the hand (VDH) during a squat jump (SJ) vs counter-movement (CM) jump technique at three different starting distances between hand and foot holds.

METHODS

Thirteen recreational rock climbers: Mean ± SD =22 ± 5.2 y; 65.5 ± 8.2 kg; 172.5 ± 5.2 cm participated in the study. Participants reported a mean climbing ability of 5.11 YDS/VII+ UIAA/6c French/22 Ewbank based on their hardest red point grade completed. Testing was performed on a 90º bouldering wall. A block of wood protruding 3.8 cm from the wall was used as the starting foothold for each starting position. A large feature was used as the starting hand hold. The distance between the hand and foot holds measured 104.14 cm, 86.36 cm and 60.96 cm for the high, middle, and low starting positions respectively. Video analysis was used to determine VDH. A marker was used on the back of the participant's hand and digitized using digitizing software (MaxTRAQ 2D, Innovision Systems Inc, Columbiaville, MI, USA).

Participants performed six trials, consisting of four dynos at each starting position, two per technique, in a randomized order. The SJ dyno consisted of assuming a squat position with the arms fully extended, for a minimum of three seconds, then performing the dyno. The CM dyno consisted of standing up on the foot hold so the arms became at least parallel with the floor, followed by a quick counter movement of the legs and execution of the dyno. The highest

VDH in each trial was used for statistical analysis. Descriptive data were determined using statistical software (SPSS Inc., version 21, Chicago, IL). A 2X3 Repeated Measures ANOVA (jump technique X starting position) was used to analyze the data. Statistical significance was set at $P < 0.05$.

RESULTS

Results for the VDH are displayed in Table 1. No significant differences ($p > 0.05$) were found between jump techniques. Significant improvements in VDH occurred from the low to middle and middle to high starting position ($p < 0.05$). There was no significant interaction ($p > 0.05$).

Table 1 Mean ± SD maximum VDH (cm) at each starting position for SJ and CM techniques.

	Low[a]	**Middle[b]**	**High**
SJ	245.8 ± 12.8	250.9 ± 13.7	256.2 ±15.2
CM	246.2 ± 15.2	250.2 ± 14.3	253.6 ± 14.6

[a] Significantly different from Middle and High conditions
[b] Significantly different from Low and High conditions

DISCUSSION

The purpose of the current study was to examine VDH when using a CM and SJ technique at three different starting positions. Popular performance observations and suggestions seem to describe an optimal starting position of close hands and feet [1,2]. However, the current researchers showed, as the hands and feet became closer, VDH significantly decreased. This is likely due to the subsequent decreases in available range of motion.

Additionally, using a CM jump technique has been suggested [1,2,3,4]. The current authors showed no significant difference in VDH between CM and SJ techniques. A CM technique increases the biomechanical complexity of the task, which theoretically allows it to be executed in a variety of ways [5]. Although muscular strength and power are factors in determining the maximal jump height that can be reached, actual performance involves the reliance on optimal control and recruitment of motor units [6]. Thus, elite rock climbers may be better able to utilize the benefits of a CM technique while performing the dyno maneuver due to skill acquisition factors.

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Relationship between climbing specific grip techniques, hold depth and maximal finger force capacity of rock climbers

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***Summary* – The effect of climbing grip techniques and hold depths on maximal finger force capacities (MFFC) was studied with ten advanced climbers. Participants performed maximal finger contractions on four different size of hand holds (1 to 4 cm). Three grip techniques (slope, half crimp, full crimp) were examined. A specially designed apparatus instrumented with a force sensor was used to record the finger forces. The results showed that MFFC in both vertical and anterior-posterior direction differed significantly according to the hold depth and grip techniques.**

INTRODUCTION

Grip strength is crucial for rock climbing and is generally one of the main reasons of failure on a route [1]. Although there are many different grip possibilities, slope and crimp grip techniques are the most commonly used ones in rock climbing. These grip techniques were studied by many researchers [2, 3, 4] but few study investigated the effect of the hold size on these grip types and on the finger force capacity [1, 5]. The aim of this study was to understand the effect of climbing grip techniques and hold depths on MFFC in both vertical and anterior-posterior direction.

METHODS

Four different size wooden handholds with flat grip surfaces were produced and fixed on a specially designed wall mounted apparatus instrumented with a force/torque sensor (ATI Industrial Automation, Apex, NC). Force data was amplified and recorded at 1000 Hz with Labview (NI, Austin, TX). Hand and forearm positions were tracked using a camcorder (Basler A602fc, 100 Hz) in the sagittal plane and analysed with SIMI Motion analysis software. Ten male climbers (average of French 7c redpoint grade level) participated in the study. Participants were positioned in the upright posture facing the wall and parallel to the hold plane. The height of the hand hold was adjusted and participants were instructed to pull the hold maximally in the vertical direction. When MFFC was achieved, they were informed to progressively increase the forearm angle and transform the force direction from vertical to anterior-posterior by maximizing the anterior-posterior force. Each participant performed two trials per condition (4 depths x 3 grips) separated by a 3 min rest periods. Repeated measure ANOVA and Tukey's post-hoc tests were used to analyze the data.

RESULTS

MFFC in the vertical direction ranged from 350.8 ± 56.0 N to 575.7 ± 54.4 N and differed significantly according to the hold depth and grip technique. In the anterior-posterior direction, MFFC varied from 69.8 ± 20.0 N to 138.0 ± 43.1 N and differed significantly according to the hold depth (Figure 1). At the point of MFFC, wrist angle varied between 51.6° ± 7.8° and 19.1° ± 14.6° extension. Statistical analysis revealed that wrist angle differed significantly according to the grip type and hold depth.

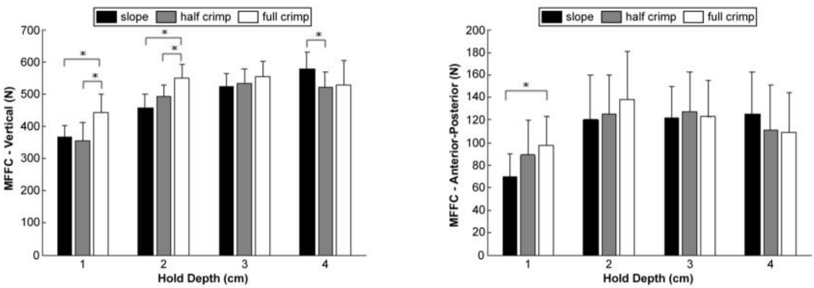

Figure 1 MFFC (N) in vertical and anterior-posterior direction with standard deviations. Significant differences between grip techniques were shown (* P<0.05) for each hold depths.

DISCUSSION

The main results of the study showed that for all grip techniques MFFC increased with increasing hold depth till a plateau point. The plateau points differed by the grip techniques and seemed to be associated with finger-hold interaction. Moreover, it was observed that climbers have different hand-forearm posture strategies with slope and crimp grip techniques when applying maximal anterior-posterior forces. These findings help to understand the possible parameters of choosing a grip technique such as hold shape and required grip force characteristics for the targeted movement.

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A Preliminary Analysis of Motivation and Goal Orientation in Rock Climbers

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Summary –The purpose of this study was to examine goal orientation and motivation in rock climbers. The sample included 92 volunteers who currently participate in the sport. Each subject completed the Sport Motivation Scale II, Task and Ego Orientation in Sport Questionnaire and demographic questions related to current rock climbing participation. Overall, climbers scored highest on intrinsic motivation and task orientation. Analysis of variance showed significant differences in the motivation subscale scores of identified regulation with age, introjected regulation with years experience, and integrated regulation with skill level. No differences in goal orientation were found with respect to climber characteristics.

INTRODUCTION

Motivation and goal orientation are both key elements in an athletes' long-term commitment and interest in their sport. Understanding motivation and goal orientation can aid in the creation of training programs to ultimately improve adherence and performance. Rock climbing has recently experienced significant growth, although little research has been conducted to examine these constructs within this population. The purpose of this study was to examine goal orientation and motivation in rock climbers and determine if differences in scores are related to the variables of age, gender, self-reported skill level, years climbing, and current involvement in the sport.

METHODS

The study included 92 volunteers ages 18 and over, who self-identified as rock climbers who actively participate in the sport. Subjects were recruited from a small region in the Southeastern United States at two indoor climbing venues as well as through posts on climbing-related social media sites. Subjects were limited to those who participate in traditional, sport, and top-rope climbing, as well as bouldering. The study did not include mountaineering or ice climbing. Each subject completed an anonymous questionnaire consisting of the the Sport Motivation Scale II (SMSII) [1], the Task and Ego Orientation in Sport Questionnaire (TEOSQ) [2], and additional demographic and climbing specific interest items created by the research team. The SMSII is an 18-item likert scale that measures six regulation subscales: intrinsic, integrated, identified, introjected, external and non-regulation. The TEOSQ is a 13-item likert scale that measures how a person defines sport success in relation to being either ego or task oriented. Demographic and climbing specific questions included age, gender, self-reported skill level, and current and past climbing participation.

Analysis of Variance was used to determine if differences existed in subscale scores for motivation and goal orientation based on age, gender, years climbing, type of climbing, indoor or outdoor climbing preference, self-reported participation, and self-reported skill level.

RESULTS

A total of 92 rock climbers ages 18-61 (*M* age=31.7 yr., *SD*= 9.62) volunteered to participate in the study. Subjects included 43 females and 49 males. Subjects reported spending the majority of their time participating in indoor climbing (55.4%) and sport climbing (66.3%). Self-reported skill levels ranged from 5.6-5.13d YDS and bouldering skill levels ranged from V1-V9. A wide range of climbing experience was reported with total time involved in the sport ranging from 1 month to 42 years with an average of 6.5 years.

The SMS II subscale mean scores ranged between 4.04 for non-regulation (*SD*= 1.7) to 16.3 for intrinsic regulation (*SD* = 3.9). A one-way ANOVA showed significant differences in the subscales scores of identified regulation and age $F(2, 89) = 3.57$, $p=.034$, introjected regulation and years climbing $F(2, 89) = 6.72$ ($p=.002$), and integrated regulation and self-reported skill level $F(3, 88) = 3.07$ ($p=.032$).

Descriptive analysis indicated the TEOSQ subscale mean score for task orientation was 4.0 (*SD* = .91) and ego orientation was 2.12 (*SD* = .91). A one-way ANOVA showed no significant differences in task and ego orientation with age, gender, years climbing, type of climbing, indoor or outdoor climbing preference, self-reported participation, or self-reported ability ($p>.05$).

CONCLUSIONS

Overall, climbers had high internal regulation and low non-regulation. With respect to goal orientation, overall climbers scored higher on task orientation which has been associated with intrinsic motivation. Analysis of variance showed the effect of age was significant in identified regulation, years climbing was significant in introjected regulation, and self-reported skill level was significant in integrated regulation. This suggests that age and other climbing-related factors may play a role in how individuals are motivated to engage in the sport.

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Anthropometry, physical fitness and psychological profile of adolescent rock climbers from South of Spain: predictors of performance

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INTRODUCTION

Climbing research on anthropometrical, psychological and physiological characteristics and adaptations has been mainly focused on adults [1-4], with a few high quality studies conducted in children or adolescents [5-7]. For a better understanding of this emerging sport, it is needed more information about physical fitness and anthropometric characteristics of young climbers, and which of these characteristics predict sport performance in climbing.

OBJECTIVES

(i) To describe the physical fitness and anthropometric characteristics as well as psychological predictors of performance of young Spanish elite climbers. And to compare them with reference data from large national or European surveys. (ii) To identify which of those factors determine climbing performance in youth.

METHOD

A set of anthropometric, physical fitness and psychological parameters were assessed in 19 young elite climbers aged 11 to 18 years. Anthropometric and fitness data were compared with Spanish and European sex- and age-specific reference data. Climbing performance was evaluated based on their maximum onsight climbing rates.

RESULTS

Overall, climbers had significantly lower levels of adiposity and higher levels of fitness than reference data. Somatotype mean was 2.5±1.1, 1.2±1.6 and 3.9±1.2 for Endomorphy, Mesomorphy and Ectomorphy, respectively. Years climbing and training level (days/week) were predictors of climbing performance (r=0.73, p=0.001 and r=0.63, p=0.009, respectively). Moreover, results also showed that climbing performance in youth were predicted by high mesomorphy (r=0.60, p=0.015), low body surface (r=-0.52, p=0.037), and daily motivation (r=0.71, p=0.002).

CONCLUSIONS

Adolescent climbers have lower levels of adiposity and better fitness than sex- and age-matched reference values. Our findings suggest that, mesomorphic somatotype, low height and ectomorphy, low body surface and high levels of daily motivation might be predictors of climbing performance according to our stadistic models.

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Human factors in avalanche decision making among mountaineers in Scotland.

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Summary **- Heuristics are mental shortcuts used to formulate decisions. Previous research has shown that using certain heuristics in avalanche prone terrain increases the risk of accidents, namely Familiarity, Social Proof, Scarity, The Expert Halo, Acceptance and Consistency. Three hundred and forty interviews were carried out in the Scottish Cairngorms to investigate heuristic traps in winter mountaineers' decision making. All six heuristic traps were identified in the mountaineers' decision making, with the Social Proof heuristic found to be most prevalalent. Secondary factors significantly influenced the risk of using heuristics to make decisions. The results have major practical implications for future avalanche training courses.**

INTRODUCTION

Heuristics are described as "mental shortcuts used to help us make rapid decisions without formal analysis" [1]. In avalanche terrain, heuristics run the risk of causing mountaineers to ignore danger signs; this is known as a heuristic trap [2]. Previous studies have highlighted certain personal and demographic factors that can increase the risk of involvement in an avalanche incident. These include; Gender, Age, Country of residence, Activity of choice, Number in group and Level of avalanche training [2][3][5]. Human factors research has mainly focused on investigations of previous avalanche accidents rather than the prevalence of current heuristic trap behaviour in the mountaineering population. The effectiveness of avalanche training in preventing heuristic traps has yet to be fully investigated.

The current study had two aims:

1) To evaluate the type and prevalence of heuristic traps influencing decision making among winter mountaineers in Scotland.

2) To assess whether certain demographic and personal factors influence the prevalence of these heuristic traps among winter mountaineers in Scotland.

METHODS

A qualitative structured interview was implemented, based around McCammon's categorisation of heuristics [2][5]. Data collection took place for 7 weeks in the winter of 2014. The sample group was made up of climbers and walkers. A total sample of 340 participants was collected.

Thematic analysis of participants' answers created categories for quantitative analysis and gave an insight into the varying justifications behind different avalanche safety decisions. Pearson's Chi Test was used to investigate whether any personal or demographic factor influenced the prevalence of use of each heuristic trap.

RESULTS

All 6 heuristic traps were shown to influence the mountaineers' decision making. These were Familiarity, Social Proof, Scarcity, Acceptance, the Expert Halo and Consistency heuristics. The Social Proof heuristic was found to be the most prevalent, affecting 45.7% of the population. Thematic analysis of participants' answers showed that the justification behind why decisions were made varied greatly including different levels of perceived susceptibility by participants to heuristic trap thinking. Five out of the 6 heuristics were influenced by secondary factors with Activity of choice; Age of participant; Country of residence; Frequency of activity; Gender; Number of years' experience; and Level of avalanche, all shown to influence the prevalence of use of each heuristic trap.

DISCUSSION

Our study results support the conclusions of previous work by highlighting that heuristics are present in mountaineers' decision making and their presence is influenced by secondary factors [2][3][4][5].

Our results can help promote participation in avalanche courses by showing the benefits of avalanche training in avoiding heuristic traps. A greater understanding of groups most at risk of heuristic traps can help to modify future avalanche training programmes; focus can be put on teaching the dangers of certain heuristics to high risk groups.

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Talus fractures in climbers

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***Summary* – Talus fractures are quite rare in climbers, but sometimes having invalidating consequences. So I have gathered data on 25 talus fractures to identify causes, consequences, best type of treatment and prognosis. It emerged that the type of climbing determines the energy level of the trauma and so the seriusness of the fracture. The outcome depends on the type of talus fractures and the entity of the fracture. Considering the heterogeniety of the types of talus fractures and the reduced size of the group, it was impossible to identify the best treatment for every type of talus fractures.**

INTRODUCTION

Talus fracture (TF) is quite frequent in high energy traumas [1], even if quite rare in climbers [2]. The talus has a reduced blood supply, when it becomes compromised by trauma to the bone it does not form a good bone callus and there is a risk of aseptic necrosis [3]. Furthermore the pain that derives from the fracture can cause algodystrophy, with an increase in the pain and consequential diminishment of weight bearing, which results in decalcification and an ulterior increase in pain [1]. Because of these complications often TF leads to problems in climbing and in every day life [4]. For this reasons I have a undertaken a statistical analysis of TF in climbers to establish their causes, their consequences, the best type of treatment for them and their prognosis.

METHODS

I asked my patients and other climber volunteers on the web to fill out a questionnaire. I gathered data from 24 patients, who were climbers and had 25 TF (one was bilateral).

RESULTS

Regarding the type of activity in which the trauma occurred: 37,5% multipitch, 37,5% crag, 4% indoor bouldering, 21% other. The diagnosis were the following: infraction (Hawkins I) [5] 17%, mild scomposition (Hawkins II) 25%, severe scomposition (Hawkins III) 45%, associated luxation (Hawkins IV) 16%, exposition 12%. Treatment: plaster cast 62%, Kirshner wire 12%, percutaneus screw 37,5%, open reduction and screw 37,5%. After the trauma 67% had a decrease of range of motion and 70% had pain in the following cases: always 4%, walking 20%, running 50%, climbing 8%.

DISCUSSION

The data reported in this study demonstrate that: the consequences of TF are very often invalidating and an high percentage needed surgical intervention. TF are not all the same, they have different degree [5]. In this study nearly all the TF had an high degree, but these patients contacted me in quality of expert in climbing pathology, because they had problems going back to climbing, this is what happens with the high degree TF. On average the ability of the climber after TF was reduced by one grade, but the climbers that had low degree TF stepped up their grade as time passed altering the statistics. It resulted from the data that all the boulderers hurted themselves falling onto the mattresses. In our opinion this data should not be interpreted as if this is the only way, it can also happen if they fall outside the crash-pad, but as there were only a few boulderers in the study non were found. The high percentage of TF (37%) that happened during multipitch might surprise some as in a year there are usually a reduced number of hour passed in the multipitch and falls are usually less frequent than in crag or bouldering. But the falls were longer (15 meters!), the energy was higher and therefore fractures were more frequent.

CONCLUSION

The cause of TF in nearly always a fall from a height whit an impact of the foot against the ground, the wall or the mattresses. The TF are varied with different causes and seriousness. Because they are caused by falls with different characteristics, so they need of different treatments and very often leave problems that go from the decrease of range of motion to chronic pain. In the worst cases the climbing activity can be impaired.

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Epiphyseal stress fractures of adolescent climbing athletes – a 3.0T MRI evaluation

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Summary **- This study investigated 3T MRI for baseline assessment of epiphyseal finger phalanx stress fractures and for follow up evaluation of fracture healing.**

INTRODUCTION

Epiphyseal stress fractures of finger phalanges are frequently encountered injuries in adolescent competitive climbers. The objective of this study was to investigate the value of 3.0 Tesla magnetic resonance imaging (MRI) for baseline and follow up assessment of epiphyseal finger phalanx stress fractures in a collective of 7 consecutive adolescent climbing athletes.

METHODS

Baseline MRI was performed in 8 fingers of 7 adolescent athletes (mean age 13.8 years, female : male = 2 : 5) with clinically suspected stress fracture of the fingers acquired during climbing sport. In all patients conventional radiograph imaging was available before MRI, the conventional radiographs showed no pathology in 7 out of 8 fingers. Follow up MRI was performed after functional therapy with training interruption for 6 weeks (n = 6) and 12 weeks (n = 1). Images were analysed retrospectively and independently by two readers using an MRI grading score from 0 (no pathology) to 4 (bone marrow oedema and clear depiction of a sharp fracture line with surrounding inflammatory soft tissue reaction).

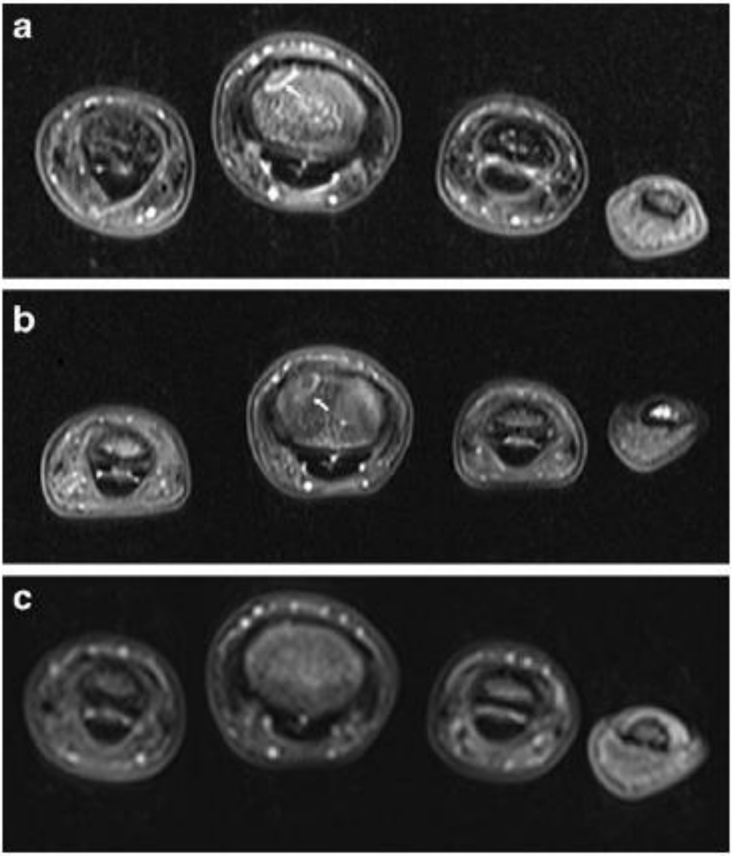
RESULTS

A total of 8 baseline and 7 follow up MRI scans were analysed. In 7 out of 8 fingers a stress fracture line Salter-Harris III and in all fingers a bone marrow oedema was diagnosed in the epiphyseal base of the middle phalanx. The average grading score was 3.25 in the initial MRI and 1.43 in the follow up MRI indicating fracture healing in all fingers. Kappa value for interobserver variability was 0.86 representing almost perfect interobserver agreement.

DISCUSSION

3T MRI is a suitablee diagnostic tool for baseline assessment of epiphyseal finger phalanx stress fractures and for follow up evaluation of fracture healing, even in cases where conventional radiographs show normal results.

FIGURES



Fat saturated proton density weighted sequences in the axial direction of a 15 year old male with epiphyseal stress fracture. The initial MRI show a bone marrow oedema and a sharp fracture line through the middle phalanx base (a). A follow up MRI after functional therapy and sustained training interruption reveal reduction of bone marrow oedema but a persistent fracture after 6 weeks (b). A second follow up MRI shows fracture healing with remaining bone marrow oedema after prolongation of therapy and refraining from training for another 6 weeks (c).

Static stretching does not impair sport specific measures of upper-limb force and power in rock climbing

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INTRODUCTION

Recent research has shown that static stretching (SS), as a warm-up prior to an athletic event, may impair muscular performance via reductions in maximal voluntary contraction, isometric force, isokinetic torque, one-repetition maximum lifts, vertical jump height, sprint speed, running economy and balance [1,2]. Researchers have also found decrements in strength and power of up to 30% following an acute bout of SS [2] with impairment lasting up to two hours [3]. Since upper-body power and strength are important factors in rock climbing [4], the question remains whether or not SS should be incorporated into a warm-up for climbing.

Therefore, the aim of this investigation was to determine the effect SS had on climbing-specific measures of upper-limb force and power; including maximal finger flexion force (MFF), rate of force production (RFP), and arm jump power (AJP) during an arm jump (AJ).

METHODS

Nineteen recreational rock climbers volunteered to participate in this study. Climbers were randomized into a SS or non-stretching (NS) control group. MFF for the dominant and non-dominant hands were measured with a piezoelectric force sensor (PCB Piezotronics 208A13 Depew, NY, USA) fitted with a plate to accept the first digits of the four fingers. Participants were instructed to hold a maximal flexion of the fingers for 300 ms. Participants completed 2 trials with each hand. The trial with the highest force for each hand was used. The RFP was measured as the rate of change in the force for the first 50 ms of the trail. An AJ was used to measure upper body-power. An AJ is defined as an explosive pull-up motion, in which the climber released the dominant hand at the peak of the jump to a high reach [5]. All participants completed two AJs. The average values over both trials were used. AJP was calculated using the Lewis Formula [5]. Power=√4.9*BM*√JH [6]. Where BM is body mass in kg and JH is jump height in cm. The participants then completed three stretches to target the forearm flexor muscles based on the stretching regimen of Evetovich et al. [7]. Participants in the NS group sat at rest for eleven minutes, the duration of the stretching protocol. All participants were then reevaluated on the climbing-specific measures.

RESULTS

There were no significant differences in any of the measures recorded in this study. See Table 1 for results.

Table 1 Mean ± standard deviation for dominant hand maximal finger flexion force (DMFF), dominant hand rate of force production (DRFP), and AJP.

	SS		NS		
	Pre	Post	Pre	Post	Sig.
DMFF	19.26 ± 5.06	18.12 ± 5.46	20.2 ± 4.09	20.29 ± 3.98	0.39
DRFP (kg/s)	27.95 ± 9.73	25.05 ± 7.32	30.18 ± 7.32	28.18 ± 6.61	0.178
AJP (w)	1036.43 ± 267.93	1018.92 ± 281.61	1127.87 ± 308.64	1110.05 ± 312.95	0.124

DISCUSSION

There were no significant decrements in any of the variables examined in this study. The main contributing factor of SS induced impairment is change in the compliance of the musculotendinous unit (MTU) of the stretched limb. A high stiffness of the MTU ensures a fast transmission of the muscular force to the bones, creating the explosive force needed for powerful movements [8]. Because the arm jump occurs slowly relative to a standard leg jump, it is possible the decreased stiffness of the MTU following SS does not slow the transmission of muscular force to the bones and would not affect power output. Studies conducted using longer duration contractions or slow SSCs tend to show no effect or an increase in performance following stretching [1].

Ultimately SS has been shown to increase range of motion of the affected limb, and consequently may increase rock climbing performance. Because a high range of motion may be needed in many climbing specific movements and SS does not seem to impair upper-limb force and power performance, this suggests that SS could be a beneficial component of a warm-up for rock climbing.

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Computer Connected Force Platform Performance Assessment and Training Tool for Rock Climbing

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***Summary* – Use of a force platform software during a hangboard finger training as a performance assessment and training tool for rock climbing.**

INTRODUCTION

Traditional training on hanging board is widely used for rock climbing. However, it does not allow precise measurement of training intensity variation. Pressure sensor allows this level of precision and variability [1,2] but are not widely available. Therefore, we developed a software intended to use a widely available force platform (FP) as specific performance assessment and training tool (PATT) for rock climbing.

METHOD

General principle: Effort calculation is based on the partial weight measured on the FP subtracted to the measured total body weight (BW). (1)

$$\text{BW} - \text{Measured Weight} = \text{Suspended Weight} \quad (1)$$

Protocol:
- The user stands on the FP (Wii balance board ©) and get his weight measured.
- A hangboard disposed directly over the FP is used for suspension exercises.
- The foot of the user remains on the FP throughout the suspension exercises.
- Percentage of BW and absolute weight lifted are calculated by the PATT.
- Direct visual feedback is provided to the user on the computer interface.
- The FP error is about one kilogram [3].

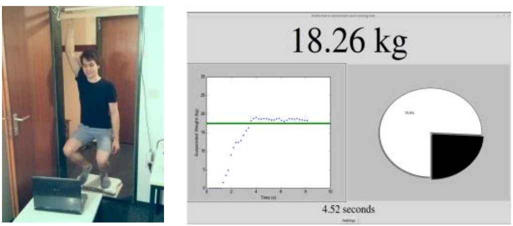

Figure 1 [Left] Climber suspended on the hangboard over the Wii FP placed on the ground.
[Right]The interface of the software allows the user immediate visual feedback of his absolute (left) and relative (right) effort.

RESULTS

Established bluetooth connection with the FP receives the reaction with the floor data. The *Nintendo Wii Balance Board ©*, the *Snake Byte Bitness Board ©* and the *Big Ben Balance Board ©* are all compatible with the PATT software. Figure 2 shows raw data from a 45 minutes endurance training. It consisted in two repetitions of 15 minutes exercise separated by a 10 minutes break. The exercise was one handed hold pull at 50% of maximal strength, alternating left and right hand each 10 seconds. Maximal strength was calculated as maximal BW lifted in a trial of one handed pull-up.

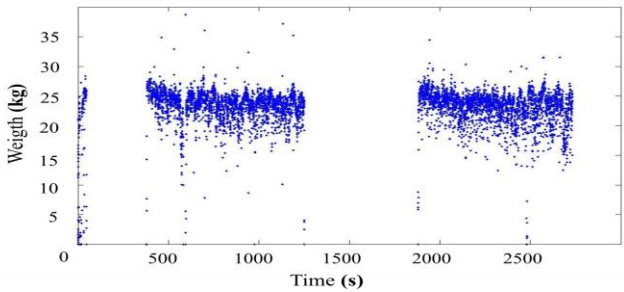

Figure 2 Suspended weigth over time during a 45 minutes aerobic finger endurance training

DISCUSSION

Training with the feet on the balance using the PATT improves the control and precision of training intensity. This provides a safe and stimulating environnement for performance enhancement specific to rock climbing.

A drawback of this system is that the forces in the plane of the balance are not measured by the PATT. However this bias is systematic toward underestimation of measured effort. The difference between real effort and calculated effort is most likely minimal with the disposition of the FP under the hangboard.

This PATT has the advantage of being widely available. This tool allows personalized rock climbing training for users of all level. It further offers endless possibilities of connectivity with smartphones and computers. In the future, users may share their training data with researchers, coaches or friends.

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Postural adaptations in female elite rock climbers: The «Climber‘s Back»

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INTRODUCTION

Male rock climbers develop postural adaptations called «climber’s back», characterized by an increase of the thoracic kyphosis and the lumbar lordosis [1]. These postural adaptations are proportional to individuals’ climbing performance. The goal of this study is to establish whether elite female rock climbers develop the same spinal postural adaptations as their male counterparts.

METHODS

36 women (19 elite climbers and 17 non-climbers) have been included in this cross-sectional study. Static and dynamic measurements of the thoracic and lumbar spine have been conducted with the « MediMouse®», a noninvasive computer-assisted device used to measure spinal shape and mobility. Muscle length measurements of Pectoralis Major, Ilio-psoas and Hamstrings were performed according to the Jenda protocol [2]. Statistics were performed with Excel® spreadsheets and analyzed with R 3.1.0. The Student’s t-test was used to identify statistical differences between static and dynamic measurements of the two groups and “Cochran Armitage test” was used to analyze the muscular length data.

RESULTS

The elite female climbers did not show an increased thoracic kyphosis or lumbar lordosis compared to the non-elite climbers. Instead, they showed a reduced thoracic kyphosis when measured in static upright position, particularly at Th1-Th3 level (Th1/2 $p<0.001$ and Th2/3 $p<0.05$) (Figure 1). They also presented a cranial displacement of the lumbar-thoracic curves inflection point (at level Th11-Th12) in comparison to the classical thoraco-lumbar joint (Th12-L1 level). In addition, climber’s thoracic mobility during flexion-extension in the sagittal plane was significantly more limited ($p<0.05$) than the mobility of non-climbers whereas climber’s lumbar range was increased ($p<0.05$) (Figure 2). In addition, left Ilio-psoas and left hamstrings ($p<0.05$) of climbers were more shortened than the one of non-climbers.

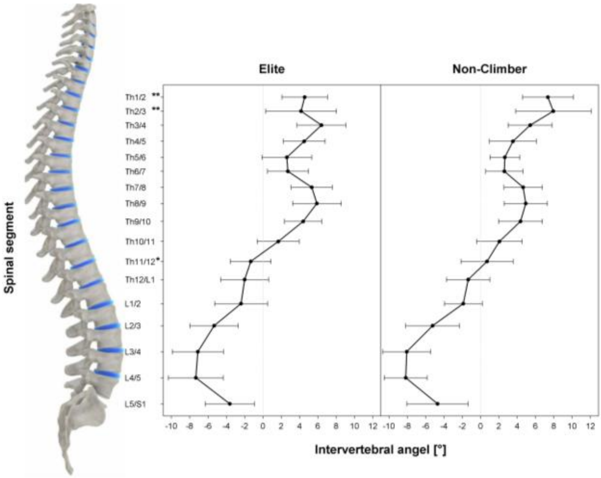

Figure 1 Individual inervertebral angles in neutral upright position. Significant differences between groups marked with an asterisk (*p<0,05, **p<0,01).

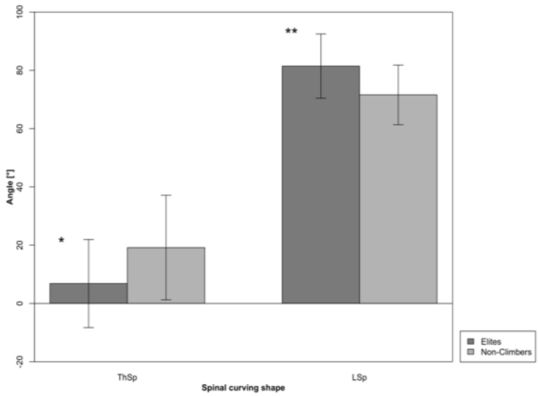

Figure 2 Global thoracic and lombar mobility during flexion-extention movement. Significant differences between groups marked with an asterisk (*p<0,05, **p<0,01).

DISCUSSION

Results show that static and dynamic spinal adaptations of high-level female rock climbers are different from their male counterparts. This can be explained by a difference in climbing technique or by differences in muscles morphology. Further studies are needed to confirm these results, to better understand the mechanisms involved, and to evaluate the pathological consequences in order to provide evidence based prevention recommendations to the climbers.

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Pulley Ruptures in Rock Climbers: Outcome of Conservative Treatment with Pulley Protection Splint – First Results

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***Summary* – 47 pulley ruptures were treated conservatively using a novel pulley protection splint (PPS). Thereby, flexor tendon bowstringing was reduced significantly. Most climbers regained their former climbing difficulty level and excellent functional results were obtained. We therefore recommend the PPS for conservative pulley rupture treatment.**

INTRODUCTION

Pulley ruptures are the most frequent injuries in sport climbing [1] and lead to an increased tendon phalanx distance (TP distance) also referred to as bowstringing [2,3,4,5].

With conservative treatment good results are obtained [2,5] and it has become standard in uncomplicated pulley ruptures [1]. However, TP distance has been reported to remain increased after conservative treatment [1,3].

A novel in-house developed pulley protection splint (PPS, Fig. 1a) seems to be an answer to this problem. The splint's shape allows a particularly firm fixation on the finger without blood vessel or nerve compression (Fig. 1b), which enables the pulley to heal in an almost physiological length.

This study aims to evaluate the effectiveness of conservative pulley rupture treatment with the PPS regarding TP distance reduction, functional and sport specific outcome.

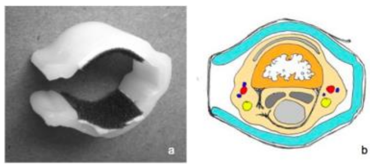

Figure 1 a) Pulley protection splint, b) the splint's shape prevents compression of blood vessels and nerves

METHODS

28 A2 pulley ruptures and 19 A4 pulley ruptures were included in this study. 2 of the A2 pulley ruptures were combined with an A3 pulley rupture. The subjects were instructed to wear their custom-made PPS permanently until the first follow-up. TP distance was measured with ultrasonography (US).

39 subjects could be followed up with US a mean of 66.9 days after the first consultation. 44 subjects completed a questionnaire a mean of 2.8 years after pulley rupture. Besides subjective evaluation of therapy outcome, it included instructions for self motion and strength measurement.

RESULTS

Therapy significantly reduced TP distance both after A2 ($p<0.001$) and A4 ($p<0.001$) pulley ruptures (Table 1). TP distance was reduced in all subjects.

Table 1 Therapy effect

Pulley	TP distance ± SD		Reduction ± SD
	Diagnosis	**Follow-up**	
A2	4.4 mm ± 1.0	2.3 mm ± 0.6	46.8% ± 13.4
A4	2.9 mm ± 0.7	2.1 mm ± 0.5	27.3% ± 12.8

72.1% have regained their initial climbing difficulty level. Of the 27.9% who did not, 58.3% climb less than before their injury (all for reasons not related to the pulley injury, such as lack of time, shift in interests), 33.3% climb as much as before and 8.3% climb more frequently than before.

93.0% can expose their formerly injured finger to maximal loads, 7.0% are restricted little while climbing. 72.1% report no, 23.3% hardly any, and 4.7% occasional pain while or after climbing.

84.9% estimate the finger's pattern of motion as inconspicuous, 15.1% as slightly disturbed. 81.4% negate a loss of strength, 18.6% report minor strength loss. The motion and strength measurements strongly confirm these statements.

97.7% have no constraints in every day life, 2.3% report of reduced finger dexterity. 90.7% assess the results of their treatment as very good, 9.3% as good. 100.0% would undergo the same treatment again.

DISCUSSION

In contrast to previous opinions, TP distance can be reduced with conservative treatment of pulley ruptures using the PPS. Such a nearly physiological end state seems to be beneficial to the patient, as the excellent functional and sport specific outcome suggests. Ac cordingly, satisfaction among the patients is very high. We therefore recommend the PPS as means of conservative treatment after pulley ruptures.

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