Competitive Performance Predictors in Speed Climbing, Bouldering, and Lead Climbing

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The study modeled the influence of anthropometric components, climbing-specific power, strength and endurance parameters, flexibility, coordination, and motor planning skills on competitive climbing performance in speed, bouldering, and lead climbing. Sixty-one competitive climbers (26 women [18.1 ± 1.9y], 35 men [21.4 ± 6.1y]) participated. PCA and MRA were used for statistical analyses. Significant predictors for speed climbing performance (R^2 = 44% and 35%) were lower (ß = .43 and .47) and upper body power and strength (ß = .40 and .37) for women and men, respectively. For women's bouldering performance (R^2 = 39%), they were hip flexibility (ß = .42) and upper body power and strength (ß = .37), for the men's (R^2 = 53%) lower (ß = .41) and upper body power (ß = .41) and body fat (ß = .37). For women's lead climbing (R^2 = 58%) upper body power and strength (ß = .59) and finger endurance (ß = .48) predict performance, for the men's (R^2 = 58%) lower (ß = .36) and upper body power (ß = .28), body fat (ß = .27) and motor planning skills (ß = .27). The multivariate models provide a framework for scientifically grounded climbing training by emphasizing the role of specific performance components.

Keywords: performance analysis, elite climbing, bouldering, lead climbing, speed climbing

Word count: 4364

Introduction

Scientific analyses of competition performance's main prerequisites and components are required to further develop peak performance in competitions. At present, multivariate analyses in sport climbing are rare. Mermier (2000) aimed to identify the anthropometric and physiological determinants of lead climbing performance based on a large number of variables categorized into "training," "flexibility," and "anthropometric" components, with a descending proportion of variance clarification. Baláš et al. (2012) explained lead climbing performance based on hand and arm strength and endurance and the exogenous variables body of fat percentage, climbing volume, and climbing experience. Magiera et al. (2013) assessed the variables that predict self-reported lead climbing performance and extracted three sets of variables corresponding to physical, technical, and mental characteristics. Laffaye et al. (2016) likewise performed a multivariate analysis on lead climbing ability and extracted three components: training, muscle, and anthropometry. Lastly, MacKenzie et al. (2020) analyzed the role of physical and physiological characteristics in lead climbing ability and identified shoulder power and endurance as crucial components. Secondary determinants were finger, hand, and arm strength, core-body endurance, aerobic endurance, flexibility, and balance.

These examples show that previous studies included different variables and therefore identified a varying number of different components. The existing multivariate analyses are limited to lead climbing only, with bouldering and speed climbing remaining unaddressed.

Apart from the multivariate studies presented above, the present research focuses on single characteristics and their contribution to climbing performance (for a review, see Saul et al. (2019)).

The increased professionalization and popularity of the sport, including its election as an Olympic discipline, are conducive to a high interest in studies providing valid measurements of competitive climbing performance. Yet in almost all studies, climbing performance is quantified by self-reported ability assessment, which provides a valid and accurate reflection of lead climbing ability (Draper, Dickson, Blackwell, Fryer, et al., 2011) but does not necessarily reflect competitive climbing performance. Therefore, for studies about competitive climbing, it is of uttermost importance to use valid measurements for competitive climbing performance: either the ranking or the scores the ranking is based on.

The only previous study dealing with competitive climbing performance is from Mladenov et al. (2009). They determined the correlation between anthropometric and strength characteristics and achieved ranking at a bouldering World Cup in 2007 and found significant correlations between ranking and age, experience, and height, but not for any of the other anthropometric or strength characteristics. Bouldering performance depends on a great variety of skills whose relative importance is primarily influenced by the characteristics of the set boulder problems (Augste et al., 2021), which could explain the small predictive values of anthropometric and strength characteristics.

To conclude the above findings, we can observe that there is currently a research gap regarding multivariate models to predict competitive climbing performance.

Another essential aspect to be addressed is the severe underrepresentation of climbing-related studies on women in the current literature. Women, when included, have been the minority, and studies with only female participants are rare. Exceptions are the studies from Giles, Barnes, et al. (2021), Grant et al. (2001), and Wall et al. (2004). Furthermore, few sex-specific analyses have been performed (Baláš et al., 2012; MacKenzie et al., 2020).

To address both aspects (the above-mentioned research deficit on multivariate models to predict competitive climbing performance and the lack of sex-specific analyses), the present study aims to perform sex-specific multivariate analyses of competitive climbing performance in the present-day disciplines of speed, bouldering, and lead.[1]

METHODS

Procedure

For the multivariate analyses, hypothetically relevant variables for climbing performance in the respective disciplines were tested with specific performance tests in a study of competition climbers. These variables were either identified through a systematic literature review or derived from interviews with expert coaches (Augste & Künzell, 2017). The 14 tests included in the test battery were evaluated in preliminary studies and showed sufficient reliability (all $ICC > .86$) and validity (all $R > .52$) (Augste et al., 2020a). The participants performed all tests within a single test session such that 1) recovery time between single tests targeting the same muscle groups was maximized, and 2) maximum strength tests were performed before strength endurance tests. For each test, athletes received instruction regarding the procedure and completed a familiarization trial consisting of one attempt for the power, maximum strength, flexibility, and coordination tests, and a few repetitions for the endurance tests. The

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[1] Hatch and Leonardon (2021). Olympic Combined is not considered since no competitions in the format used for the 2024 Olympic Games had taken place so far and therefore no rankings are available.

familiarization trial was done for each test separately and immediately before the actual test. A few minutes of rest were given to minimize the influence of fatigue on the test results. Test familiarization and testing were performed within the same session to reduce the impact on the participants' training schedules and therefore enhance study compliance.

Although the test protocol called for only one attempt, athletes were encouraged to make another if they felt they had not achieved maximum performance. The best result was included in the final data analysis.

Variables

Independent Variables

The following tests were performed; for further details, see Augste et al. (2020b).

- Anthropometry

  Anthropometric measurements included height, arm span, body weight, and fat percentage. In addition, the arm span to height index was calculated. Measurements were taken with a tape measure or digital scale with 1 centimeter or kilogram accuracy. Body fat percentage was determined through bioimpedance (BC-545N, Tanita Europe BV, Netherlands).
- Upper limb power and maximum strength

  Maximum finger strength was measured in half crimp and open hand finger position on two different hold sizes (8 mm Beastmaker micro and 23 mm custom-built rung with 12 mm radius) to specifically target both the m. flexor digitorum profundus and m. flexor digitorum superficialis (Schweizer & Hudek, 2011). Athletes stood on a force plate (Kistler Instrumente GmbH, Germany) in an upright body position with straight arms as recommended by Michailov et al.

(2018) and maximally loaded the rung for at least 3 seconds by bending the knees. If necessary, additional weight was attached to the athlete's harness. The maximum average value of the loaded weight for a 3-second period was calculated and divided by the athlete's body weight.

The maximum strength of the arm flexors was measured using the same method as used for finger strength, except a bar was used, and the athletes loaded their arms at a 90-degree elbow angle.

Upper body power was tested using the power slap test described by Draper, Dickson, Blackwell, Priestley, et al. (2011). Hanging from the rung on the power slap board, athletes performed an explosive initiation of a pull-up followed by the release of one hand hitting the board at the highest possible point. The vertical distance between the rung's upper edge and the highest point of the visible imprint was measured. Absolute distance and distance relative to arm span were considered.

- Lower limb power

Athletes performed unilateral and bilateral countermovement (CMJ) and bilateral squat jumps (SJ). A newly developed test similar to the box jump step-up was also applied. The box height was adjusted to standardize the knee angle of the take-off leg to 90 degrees. Athletes jumped up explosively while keeping their hands on their hips and their lower leg straight without performing a countermovement. The vertical jump performance for all jump tests was calculated via flight time.

- Strength endurance of the upper limbs

To mimic the load structure in lead competitions (Winkler et al., 2022), an intermittent finger endurance test consisting of a loading phase of 7 s hanging with straight arms on a crimp followed by 2 s of rest was performed. Completed repetitions were counted until contact with the hold was lost before the end of the load phase. Furthermore, a 30-second continuous finger endurance test on a 23 mm-rung, as described by Michailov et al. (2018) was performed to measure the average force normalized to body weight.

- Maximum core strength and endurance

One core maximum strength test and one core strength endurance test were performed, as suggested by Winkler (2018). For the maximum strength test, athletes held a bar and placed their feet on two footsteps attached to a board (inclination: -60 degrees). The distance between the bar and the footsteps was equal to the vertical height of the tuberculum majus. Athletes were instructed to release both feet simultaneously and to minimize backswing. The maximum backswing angle was assessed using a smartphone attached between the athlete's shoulder blades and running an app for digital angle measurement with a recording function. For the strength endurance test, the distance between the bar and footsteps was reduced and set to equal the difference between the athlete's height and the vertical height of the lateral joint line of the knee. Athletes alternately stepped on the footsteps in a diagonal manner from the hanging position without swinging. Repetitions were counted until the athletes failed to step on the footsteps on three consecutive attempts.

- Flexibility

For hip flexibility assessment, two different tests were used. The starting positions for both tests were the same. Athletes stood on two footsteps set shoulder-width apart on a vertical wall and held onto a rung adjusted to a height that required them to stand upright with their arms fully extended. For the lateral-frontal leg lifting test, athletes lifted one leg as high as possible while straightening the leg. For the frontal knee raising test, the aim was to lift the knee as high as possible while maintaining a frontal position controlled by wall contact of the contralateral hip and the knee and heel of the lifted leg. The vertical distance between the footsteps and the highest part of the foot or knee, which could be maintained for two seconds, was measured.

- Coordination

  To assess the simultaneous coordination level of limbs, athletes had to jump sideways to four climbing holds mounted on a vertical wall. The time delay between the contact of the first and the last limb with the respective climbing hold was measured.

- Motor planning

  Athletes had to visualize four competition-style boulder problems of submaximal difficulties and record the planned order of movements on a chart before attempting the boulders. The ratio of matches between the visualized and realized moves was determined.

Dependent Variables

Climbing performance as the criterion variable was operationalized as follows: For speed, personal best times on the 15 m standard route were obtained from publicly available competition results or personal training best times measured by an approved automatic timing system. For lead and bouldering, a ranking list of athletes in the respective disciplines was created based on placements in all official climbing competitions in 2018 and 2019. An athlete was ranked above another if they performed better more frequently than the other.

Participants

Sixty-one German competitive climbers (26 female, 35 male) participated in the study, from regional squad athletes to national team athletes. Participants were included in the study if a) they were allowed to compete in the adult category and b) they participated in at least one official competition, irrespective of the climbing discipline, in 2018 or 2019. Participants' assignment to the climbing disciplines was based on competition results; if they had a valid result in bouldering, lead or speed their data were used for separate discipline-specific analyses.

Subject characteristics were assessed according to the recommendations by Draper et al. (2015). Participants received online questionnaires after test completion and were requested to complete within the following week. Subject characteristics are presented in table 1.

*** Insert Table 1 here ***

The local university ethics committee approved the study (Augsburg University, approval number: 18/05), and all athletes gave written consent to participate.

Statistical Analyses

First, variables that showed neither a significant correlation nor mean differences between performance groups concerning climbing performance were excluded. Next, the remaining variables were grouped using factor analyses. The selection regarding the number of factors and the rotation method was based on the interpretability criterion, resulting in a simple structure. Multiple imputations, that estimated missing data of the independent variables with 20 iterations (Corbeil, 2016), were averaged to create the final data set used for factor analysis (Sauer, 2010). Multiple regression analysis was applied using the factor scores as independent variables to determine the influence of the identified components on climbing performance. IBM® SPSS® Statistics (Version 26) was used for all statistical analyses.

Results

Descriptive results of all tests are presented in table 2.

*** Insert Table 2 here ***

The multivariate models for each discipline and sex are shown in Figures 1-6. The extracted components are presented in the middle column with their respective variables and factor loadings on the left. The influence of the respective components on competition performance is quantified via the standardized beta coefficient obtained from multiple regression analysis. All components that enhanced the overall model fit are shown.

*** Insert Figures 1 - 6 about here ***

The proportion of variance explained varied. For women, climbing performance was best explained in lead ($R^2 = .577$), followed by speed ($R^2 = .437$) and bouldering ($R^2 = .386$), whereas for men, it was highest in bouldering ($R^2 = .534$) followed by lead ($R^2 = .518$) and speed ($R^2 = .348$). Consequently, the variance explained was higher for women than for men in speed and lead but not in bouldering.

For women, arm strength and power were among the highest predictors across all disciplines. Exceptions were lower body power in speed climbing and flexibility in bouldering, which were the only components with a higher predictive value than arm strength and power.

Finger strength and endurance are two more extracted components. Finger strength but not endurance predicts speed climbing times; both predict bouldering performance. In lead climbing, finger endurance was significant but finger strength was not. Of the other assessed variables (coordination, anthropometrics, and motor planning), coordination enhanced the model fit in speed climbing but not in bouldering and lead, while anthropometrics and motor planning did not show predictive value in any of the disciplines.

For men, the highest predictor across all disciplines was lower body power, followed by upper body power for bouldering and lead, and power and maximum strength for speed. Strength and strength endurance further enhanced the overall model fit in all disciplines, but for lead climbing this was the case only for maximum strength and not for strength endurance. The only predictive anthropometric variable was body fat percentage, which significantly predicted bouldering performance and showed a trend towards being significant in lead, but didn't play any role in speed climbing. Similar results were found for coordination, which enhanced the overall model fit in bouldering and lead but not in speed climbing. Motor planning and core endurance contributed to variance explanation only in lead climbing.

Discussion

This study is the only multivariate analysis that models the influence of different performance components on competitive climbing performance. Given the multifactorial nature of performance, each athlete uses a specific set of skills to master the climbs with varying requirements across different disciplines and route-setting styles. Furthermore, the performance components are partly complementary (Magiera et al., 2013). Multivariate models do not provide a complete understanding of climbing performance, but since studies on competition climbing are scarce in general, they do provide a framework for scientifically grounded climbing training by emphasizing the role of specific performance components (Baláš et al., 2012). Targeted training of components that predict climbing performance has been shown to improve climbing performance (MacKenzie et al., 2020).

The results and training implications for each discipline are discussed separately below.

Speed

Given the nature of the sport, speed climbing performance depends mainly on speed, power, and maximum strength of the lower and upper limbs.

Accordingly, for women, lower limb power was the best predictor of speed climbing time, followed by the arm strength factor. For men similarly, lower limb power was the highest predictor, followed by the factor representing arm power and maximum strength of the finger flexors.

These findings align with existing studies, which indicate that jumping performance parameters predict speed climbing time (Krawczyk et al., 2020). Additional variables that could enhance the explained variance might be reaction times to the starting signal, technical components such as optimizing the trajectory path of the center of mass (Legreneur et al., 2019), and anthropometric components (Krawczyk et al., 2018). The latter may not come into play in our study due to the relatively low level of the participants compared to the world's best speed climbers.

Bouldering

For competitive bouldering, multivariate analyses revealed different predictors for women and men, which implies that they should set different training priorities.

For women, hip flexibility measured by the lateral-frontal leg raising test best predicted competition performance. The remarkable importance of hip flexibility seems to be a unique feature of competitive bouldering, given that in previous studies, flexibility showed no relation to bouldering performance (Giles, Barnes, et al., 2021; Wall et al., 2004). This might be because foot placements in competitive climbing on artificial climbing walls are highly limited compared to outdoor bouldering. High levels of flexibility enable athletes to reach stretched-out body positions and improve the direction of force applied to holds by increasing the range of center of gravity displacements and limb positioning. Ultimately, flexibility may lead to an expansion of an athlete's movement repertoire, which has the potential to increase performance by allowing new solutions for bouldering problems (Künzell et al., 2021). Based on the high importance of flexibility for competitive performance and the above-discussed advantages of high levels of flexibility, effective training programs to improve climbing-specific hip flexibility should be implemented.

The high predictive value of flexibility in the women's but not in the men's category could be due to differences in route setting styles between sexes.

Additionally, we found high importance for upper limb power, maximum strength, and strength endurance, which is in line with other studies on bouldering performance (Wall et al., 2004) and self-reported bouldering abilities (Augustsson et al., 2018; Giles, Barnes, et al., 2021; Giles, Hartley, et al., 2021; Torr et al., 2020).

For men, lower limb power is the highest predictor of bouldering performance. This factor may also be of particular relevance to competitive bouldering due to the discipline's specific requirements. More than 50% of the bouldering sequences in World Cups are dynos, and the top 20 athletes score significantly better in this category than lower-ranked athletes (Augste et al., 2021). Route setters aim to set visually attractive boulder problems, which, in contrast to outdoor bouldering, contain many dynamic elements. Given the differences between competitive and outdoor bouldering, it is unsurprising that in the study by Gąsior (2020), the dynamic and kinematic parameters of the lower limbs didn't influence self-reported ability levels. For competitive bouldering, however, adding often-neglected strength and conditioning programs for the lower limbs more frequently, especially for lower body power, may be beneficial for the athlete's performance.

Of almost similar predictive value is upper limb power. Other studies confirm its outstanding role in bouldering performance, both as a primary discriminant between boulder and lead climbers (Fanchini et al., 2013) and between boulderers of different levels (Gąsior, 2020). Therefore, power should be trained and assessed in addition to maximum strength. Power training recommendations highlight the use of movement patterns, loads, and velocities that are specific to the sport's demands and emphasize that traditional strength training exercises are recommended for less-trained athletes when it comes to movement patterns. In contrast, ballistic and plyometric exercises are mandatory for highly trained athletes, such as competitive boulderers (Cormie et al., 2011).

The only anthropometric variable that predicted bouldering performance is body fat percentage. This contrasts with Mladenov et al. (2009), who found a significant correlation between ranking and height (apart from age and experience). The more heterogeneous sample in our study might explain the study's differences.

The maximum strength of finger flexors and upper limbs also enhanced the overall model fit, but wasn't a significant predictor for competitive performance. Given that male boulderers are characterized as having higher levels of finger and arm strength and similar levels of finger endurance compared to lead climbers (Fanchini et al., 2013; Stien et al., 2019), it is not surprising that these variables predict bouldering performance, which is in consensus with several other studies (Augustsson et al., 2018; Fanchini et al., 2013; Gąsior, 2020; Giles, Hartley, et al., 2021; Macdonald & Callender, 2011; Stien et al., 2019). In the only other study of competitive bouldering (Mladenov et al., 2009), no significant correlations were found between handgrip or finger strength and competition ranking. Considering our findings, this strengthens the hypothesis that for competitive bouldering, upper limb power is more important than maximal finger flexor strength, and thus should be prioritized in training.

Lead

For competitive lead climbing, performance was explained by only two factors in the women's category, whereas many more factors enhanced the overall model fit for men. The dissimilar results found for women and men could either be an actual difference due to non-identical competition requirements or be biased by differences in sample sizes and the climbing levels of participants.

For women, two extracted factors, arm strength and finger endurance, explained 57.7% of competition performance. Their relevance is supported by MacKenzie et al. (2020), in which shoulder power and endurance factors, which consist of measures similar to the arm strength factor in our study, explained 62% of self-reported lead climbing abilities. The high amount of variance explained by arm strength and finger endurance only, underlies their high relevance for competitive performance and these qualities are thus recommended as a primary training priority.

For men, in contrast, the numerous factors contributing to climbing success (presented in descending order) are lower limb power, upper limb power, constitution (body fat percentage), motor planning abilities, core endurance, coordination, and maximum strength of the upper limbs.

A notable finding is that lower body power is the highest predictor of climbing performance. To our knowledge, no studies exist that have analyzed the relationship between lower body power and lead climbing performance, and this factor has not been assessed in existing multivariate analyses (Baláš et al., 2012; Laffaye et al., 2016; MacKenzie et al., 2020; Magiera et al., 2013; Mermier, 2000). The fact that lower body power is important for climbing is also shown by Li et al. (2018), who showed that climbing enhanced vertical jump performance among college students, and in the study by Ryepko (2013), in which lead climbers had higher levels of jumping power than mountaineers. As for bouldering, we can conclude that strength and conditioning programs for the lower limbs should be performed regularly.

In contrast, upper limb power is a well-studied performance indicator (Draper, Dickson, Blackwell, Priestley, et al., 2011; Laffaye et al., 2014). Whereas in previous multivariate studies maximum upper limb strength was extracted as one of the main determinants, in our research, power had a higher predictive value than maximum strength, which enhanced the overall model fit but wasn't a significant predictor of climbing performance. Therefore, as for bouldering, power should be trained and assessed in addition to maximum strength.

The only predictive anthropometric parameter was body fat percentage. However, the role of body fat percentage is inconsistent between studies. Though elite climbers have the lowest values (Saul et al., 2019), it has little predictive power. The highest value among the multivariate analyses was found by Baláš et al. (2012), who reported body fat percentage as the only anthropometric variable directly related to climbing performance, with an explained variance of 22% for women and 11% for men. In contrast, Laffaye et al. (2016) found only 4% and Mermier (2000) 0.3% of explained variance by various anthropometric parameters, while Magiera et al. (2013) as well as MacKenzie et al. (2020) found no significant relation.

Motor planning, assessed in our study via the agreement between visualized and realized moves, refers to the so-called route reading skill: the ability to decode and recall movement sequences. Sanchez et al. (2012) showed that route previewing positively influenced climbing efficiency but not success in routes that were easier than the participant´s level. However, the influence of route previewing might be different in real competitions, given the high complexity of competition-style routes and, in contrast to Sanchez et al. (2012), a route difficulty at or above the competitors' level.

Core endurance is another performance factor that has received little attention in climbing-specific scientific literature. In our study, it wasn't a significant performance contributing factor but it did enhance the overall model fit. Similarly, in the study by MacKenzie et al. (2020), it correlated positively with climbing performance but wasn't included in the final model.

Finally, high levels of coordination seem beneficial. In a systematic review, Orth et al. (2016) pointed out that advanced climbing performance is characterized by smoothness and fluency, which is achieved by optimizing perceptual and movement-related behavior, limb activity, and postural adjustments. In our case, coordination, specifically the simultaneous coordination of limbs when making dynamic moves, improved the model fit and underlined that good coordination addresses today's requirements of competitive lead climbing. Therefore, since modern lead routes are designed by stringing together several boulder problems, it is recommended that dynamic-coordination moves be included in technique training for lead climbing as well.

Limitations

The current study provides valuable insight into the main determinants of competitive climbing. However, since there is no uniform ranking list based on multiple competitions attended by many competitors, the described procedure to create ranking lists in Germany necessitated a wider time span between performance assessment and competitions. Furthermore, although sport climbing has been included in the canon of Olympic sports, competition climbing is still a niche sport. Therefore, even though we tried to recruit as many competition climbers as possible, and most of the national squad athletes participated in our study, the sample size must still be considered very small from a statistical point of view regarding the calculation of factor analysis. One limitation is that physical performance indicators were mainly measured, with mental, skill, and tactical factors being underrepresented. This is because no validated test protocols exist for these factors, and further research is needed. The integration of these parameters might enhance the model fit for multivariate analyses.

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Declaration of interest statement

The corresponding author declares no conflict of interest for himself and his co-authors.

Appendix

Table 1: Subject characteristics

	Women		Men	
	M	SD	M	SD
Age [years]	18.1	1.9	21.4	6.4
Lead: Self-reported ability[1][IRCRA scale]	19.7	2.1	22.4	2.6
Bouldering: Self-reported ability[1] [IRCRA scale]	21.1	2.1	24.6	2.6
Speed: Personal best 15 m standard route [s]	12.8	3.0	11.0	4.5
Weekly training session[2]	4.6	1.4	5.0	1.9
Training session duration[2] [min]	177.9	42.2	167.3	32.1
Percentage of lead training[2] [%]	38.8	26.1	34.2	18.1
Percentage of bouldering training[2] [%]	43.5	22.4	57.1	19.0
Percentage of speed training[2] [%]	9.1	7.5	5.0	8.4
Percentage of indoor climbing[2] [%]	82.1	20.1	86.9	9.0

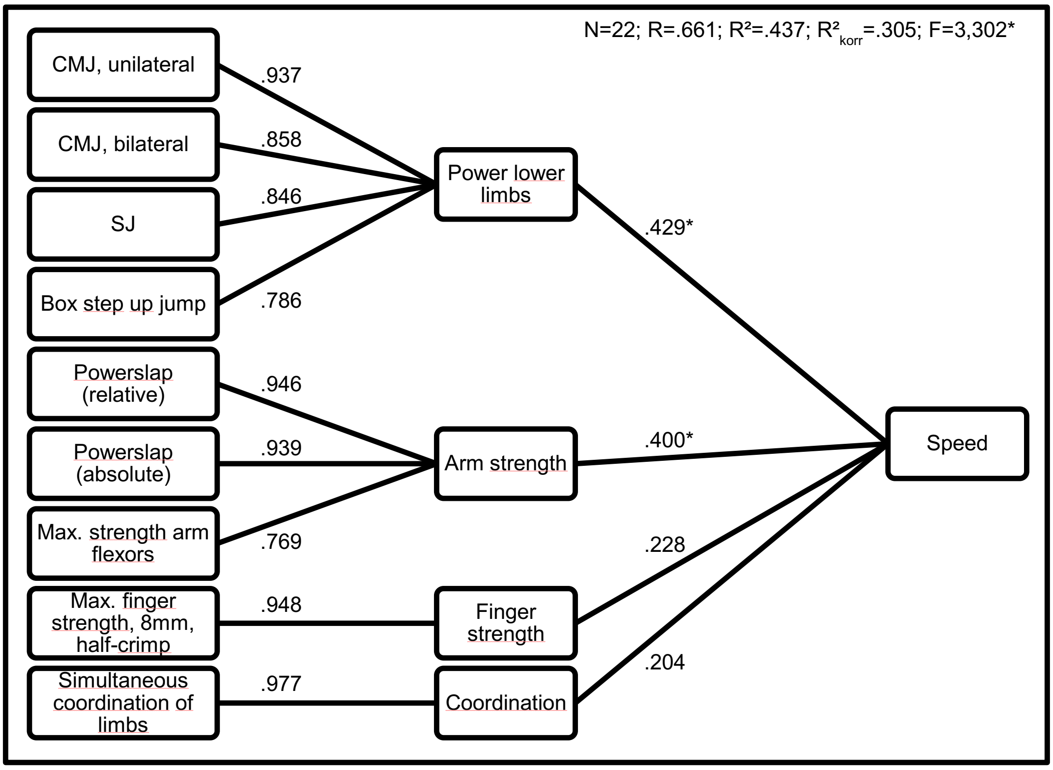
Legend: [1]3 hardest ascents in the past three months, [2] in the past 12 months, "Other training content "not displayed in the table.

Table 2: Descriptive test results

	Women		Men	
	M	SD	M	SD
Anthropometrics				
Body height [cm]	166.0	4.3	176.5	6.3
Body weight [kg]	58.5	4.9	66.3	7.3
Body fat [%]	18.0	3.8	8.2	2.9
Arm span [cm]	168.5	4.9	184.1	7.7
Arm span to height index	1.02	0.02	1.04	0.02
Power and maximum strength of the upper limbs				
Max. finger strength, 23 mm, open hand [%][1]	85.6	11.2	97.8	16.9
Max. finger strength, 23 mm half-crimp [%][1]	76.4	10.7	92.2	12.1
Max. finger strength, 8 mm, open hand [%][1]	44.3	6.5	50.9	10.7
Max. finger strength, 8 mm, half-crimp [%][1]	43.2	6.6	55.6	10.0
Powerslap [cm]	80.1	8.7	98.3	8.5
Powerslap [%][2]	47.7	5.2	52.9	3.9
Max. strength arm flexors [%][1]	85.1	12.0	106.5	12.7
Power of the lower limbs				
Box step-up jump [cm]	11.3	2.3	13.9	3.7
CMJ, bilateral [cm]	28.9	3.8	37.7	6.0
CMJ, unilateral [cm]	13.8	2.1	17.2	4.0
SJ, bilateral [cm]	26.9	3.5	35.4	5.6
Power endurance of the upper limbs				
Intermittent finger endurance [rep]	11.9	3.9	16.3	6.0
Continuous finger endurance [%][1]	55.1	8.2	71.5	9.8
Body tension				
Maximum strength [°]	-65.3	18.3	-66.3	14.9
Strength endurance [rep]	10.4	6.7	27.7	11.6
Flexibility				
Lateral-frontal leg lifting [cm]	146.9	26.1	129.9	16.6
Lateral-frontal leg lifting [%][3]	89.2	16.7	74.7	10.3
Frontal knee raising [cm]	93.6	6.0	98.3	5.1
Frontal knee raising [%][3]	56.8	3.5	55.4	1.9
Coordination				
Simultaneous coordination of limbs [s]	0.94	0.66	1.15	0.52
Motor planning				
Agreement between visualized & realized moves [%]	48.6	11.3	55.5	11.0

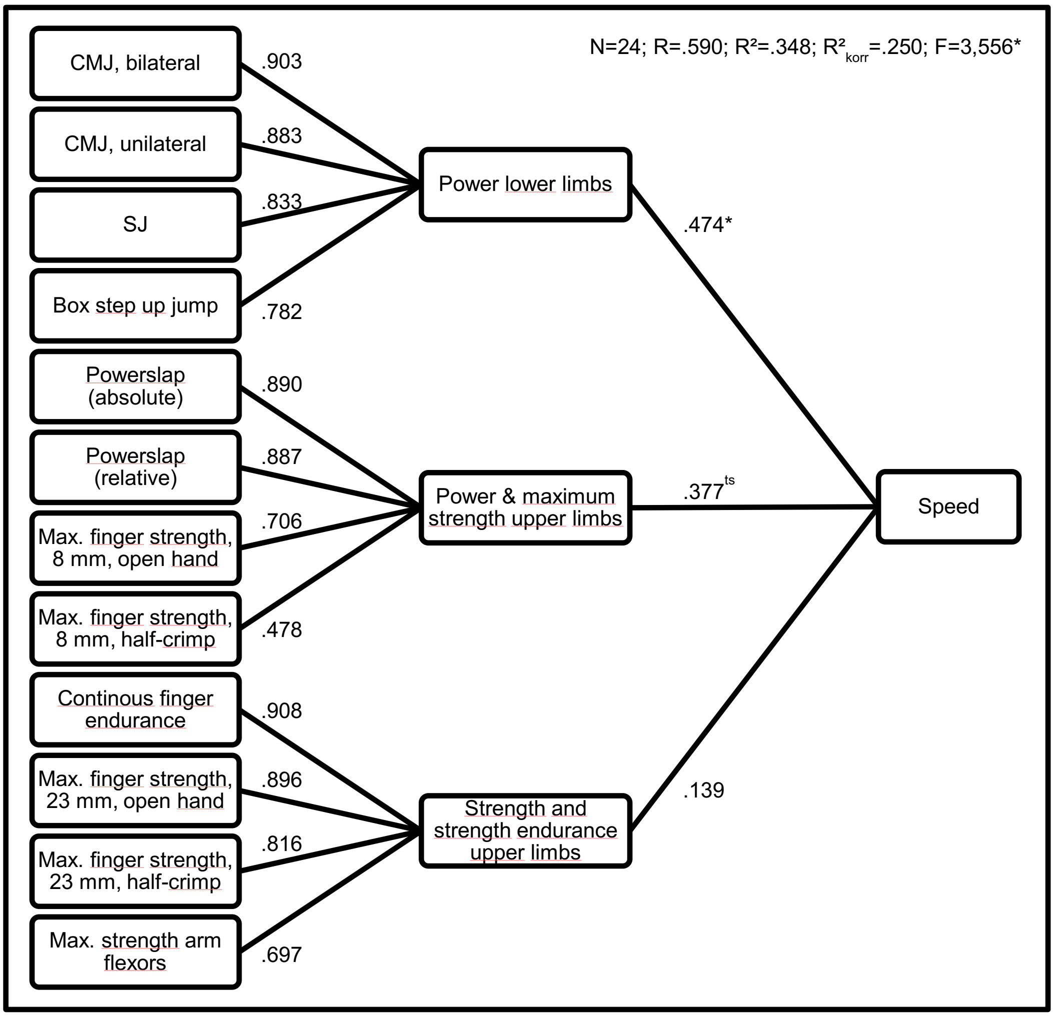
Legend: [1] in relation to body weight, [2] in relation to arm span, [3] in relation to body height

Figure 1: Multivariate model of speed climbing performance in the women's category



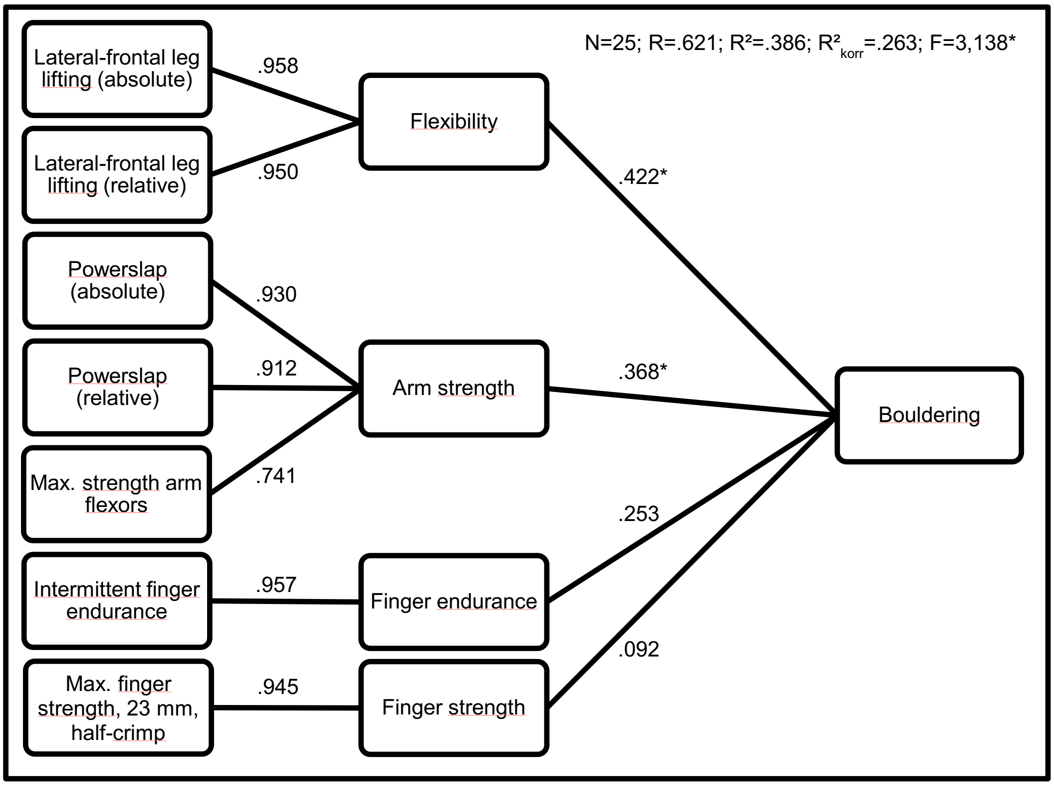
* $p < .05$

Figure 2: Multivariate models of speed climbing performance in the men's category



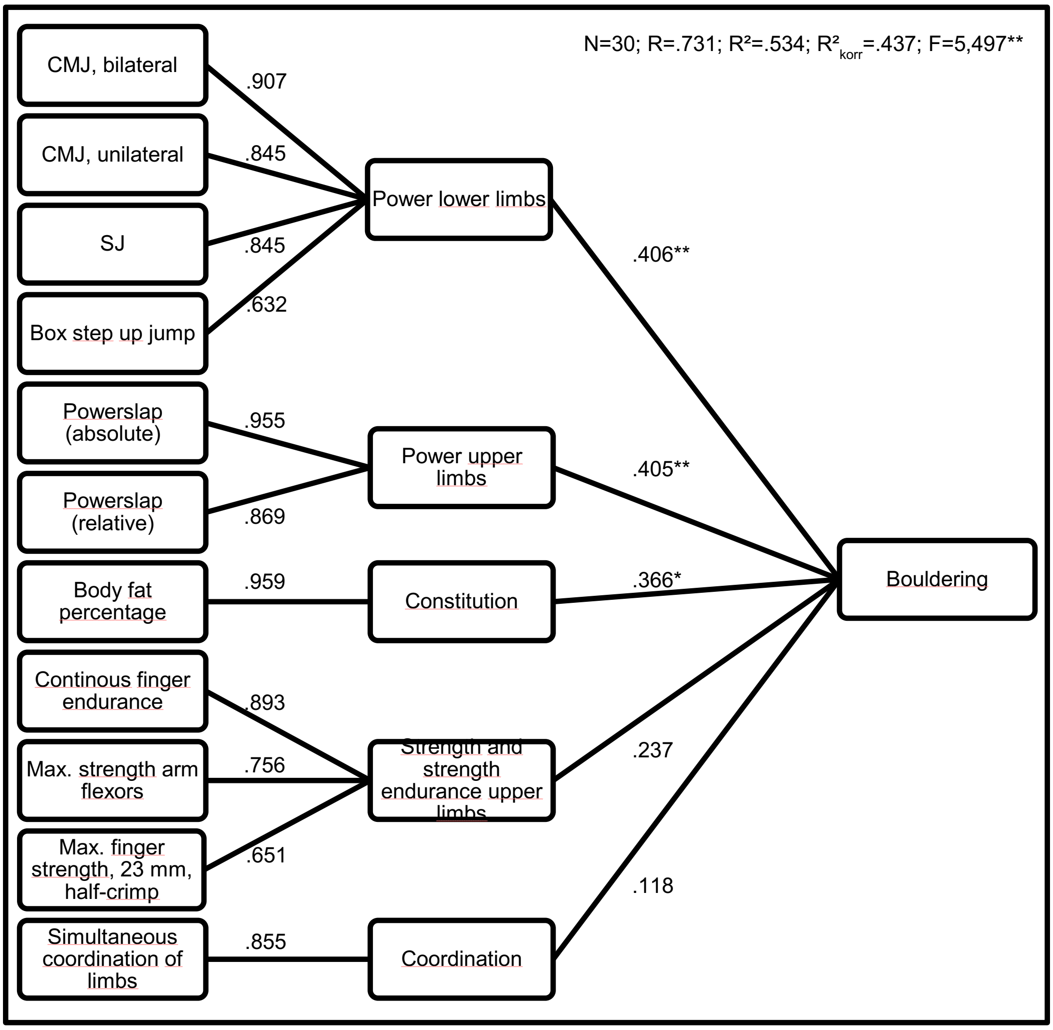
* $p < .05$, ts $p < .1$

Figure 3: Multivariate models of bouldering performance in the women's category



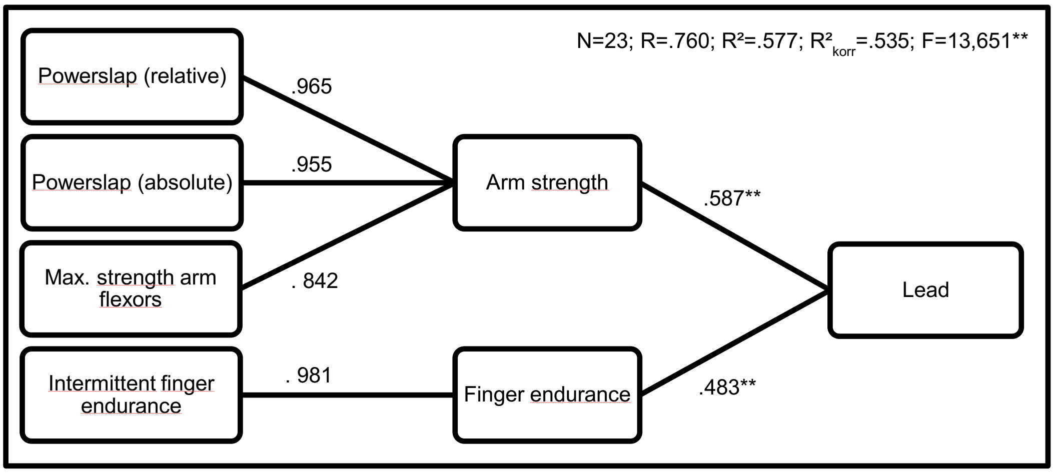
* p < .05, ts p < .1

Figure 4: Multivariate models of bouldering performance in the men's category



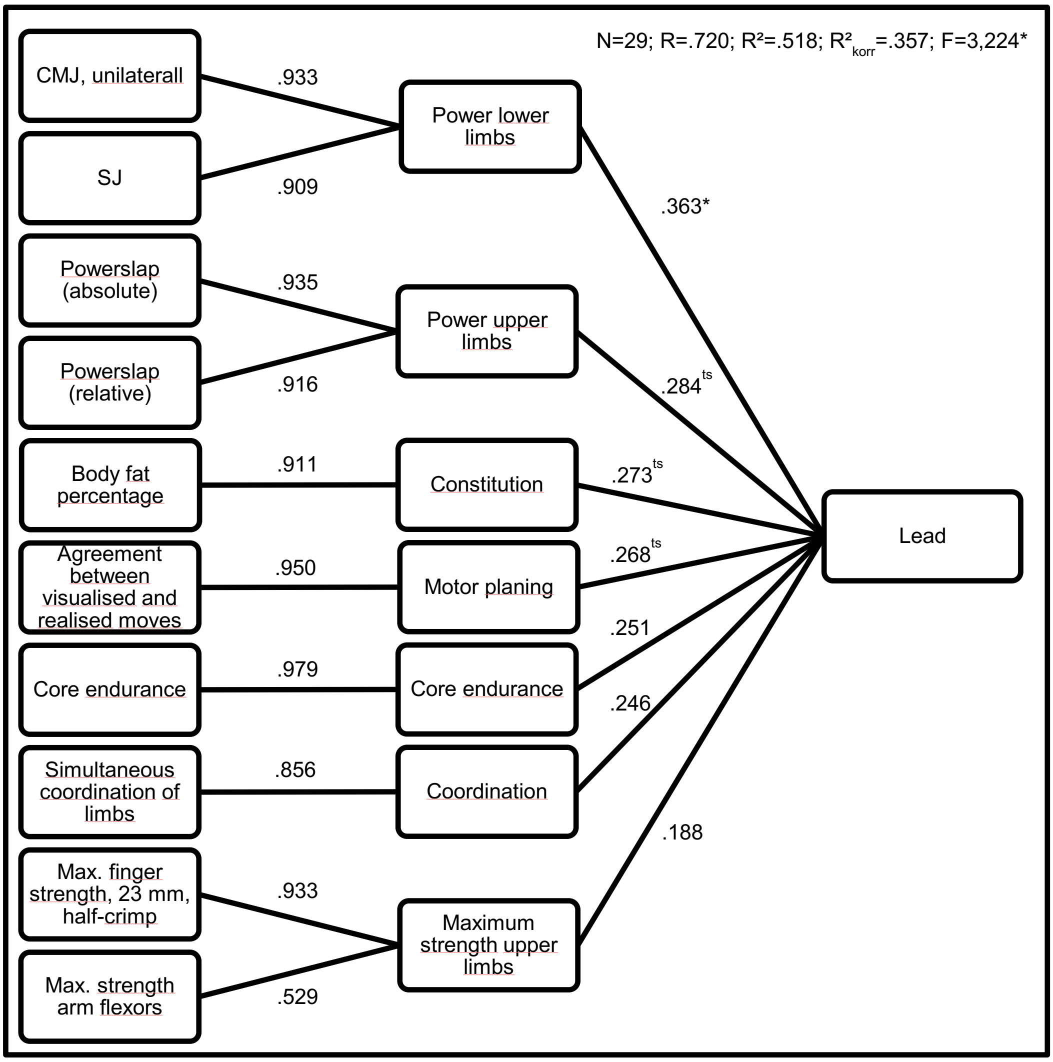
** $p < .01$ * $p < .05$

Figure 5: Multivariate model of lead climbing performance in the women's category



** p < .01

Figure 6: Multivariate model of lead climbing performance in the men's category



* p < .05, ts p < .1

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