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Finding new creative solutions is a key component in world-class competitive bouldering

Introduction

Bouldering is a complex sport that requires not only physical fitness, but also cognitive skills. It is not without reason that in bouldering we speak of “solving a boulder problem”. Nevertheless, the scientific analysis of the performance-determining factors in bouldering focuses mainly on the conditional abilities. For this purpose, the abilities of elite climbers were usually compared with those of advanced and beginners. The unanimous result of these investigations is that elite climbers have a better ratio of finger strength to body weight than advanced and beginners (Baláš, Pecha, Martin, & Cochrane, 2012; Laffaye, Levernier, & Collin, 2016; Macdonald, & Callender, 2011). Strength endurance also plays a decisive role (Fryer, Giles, Palomino, de la O Puerta, & España-Romero, 2018; Macdonald & Callender, 2011; Philippe, Wegst, Müller, Raschner, & Burtscher, 2012). However, e.g. finger strength may well discriminate beginners, near elite and elite climbers, but this does not allow the conclusion that it is causal for performance differences within the group of elite climbers. At least, elite coaches have their doubts. In a qualitative survey of head coaches from Austria, Germany and Switzerland all coaches agreed that finger strength is a decisive factor in bouldering, but they argued that at the highest level of competition all participants have sufficient strength. Without strength “you won’t get the ticket”, but then it does not matter for the competition performance “whether you can do 5 or 7 one-armed pull-ups”, said the German coach (Augste & Künzell, 2017, p. 52, own transla-

tion). Rather, coordinative and cognitive abilities are the decisive factors for top performance, according to the coaches. Therefore, in our study we evaluate competition performance of the world’s top level boulderers on behalf of one cognitive component, the ability to create different solutions for a boulder problem in order to solve it.

There are several formats for boulder competitions, which generally include an observation period and a climbing period. In the observation period, athletes may inspect the boulder and touch the starting holds, but are not allowed to climb. In the climbing period, they have an infinite number of attempts to climb the boulder within a certain time. In the world cup finals, observation period takes 2 min and climbing period 4 min. No athlete regularly flashes all boulder problems, i.e. solves the boulder problem in the first attempt. An unsuccessful first attempt is very likely and intended by the route setters. After an unsuccessful attempt the athletes are confronted with the question whether they should change their action plan and try a qualitatively different solution in the second attempt or whether they should stick to their plan and only change details like the force application or the grip technique. Of course, the answer to this question depends partly on the specific boulder problem. However, in our study we averaged over a large number of attempts and were able to determine an overall success rate for maintaining or changing the action plan. To determine the impact of the ability to create new solutions to a boulder problem we proceed in two steps. First, we analyse whether creating

a new action plan is more or less successful than sticking with the first developed plan. Second, we investigate whether the application of the more successful strategy is linked to the ranking in the world ranking list.

Methods

Data collection

To measure the number of changes in the action plan in solving boulder problems of top athletes, we analysed the freely accessible video recordings of the finals of the 2017 Bouldering World Cups in Meiringen (Switzerland), Chongqing (China), Nanjing (China), Tokyo (Japan), Mumbai (India) and Munich (Germany). The Chairperson of the local ethics committee and Data Protection Officer had no objections and issued a negative clearance. Six male and six female athletes, who performed best in the qualification and semifinals, participated in the respective finals. They each had to solve four boulder problems, each within a climbing time of four minutes and with an unlimited number of attempts within this time. In total the athletes completed 1007 attempts within 288 climbing periods (6 athletes × 6 World Cups × 4 boulder problems × 2 sexes). The average number of attempts was 3.5 per climbing period.

Participants

In total, 15 female and 15 male athletes qualified for at least one of the World Cup finals analysed. One female athlete qualified for six finals, one for five finals, three for four finals, one for three finals, one

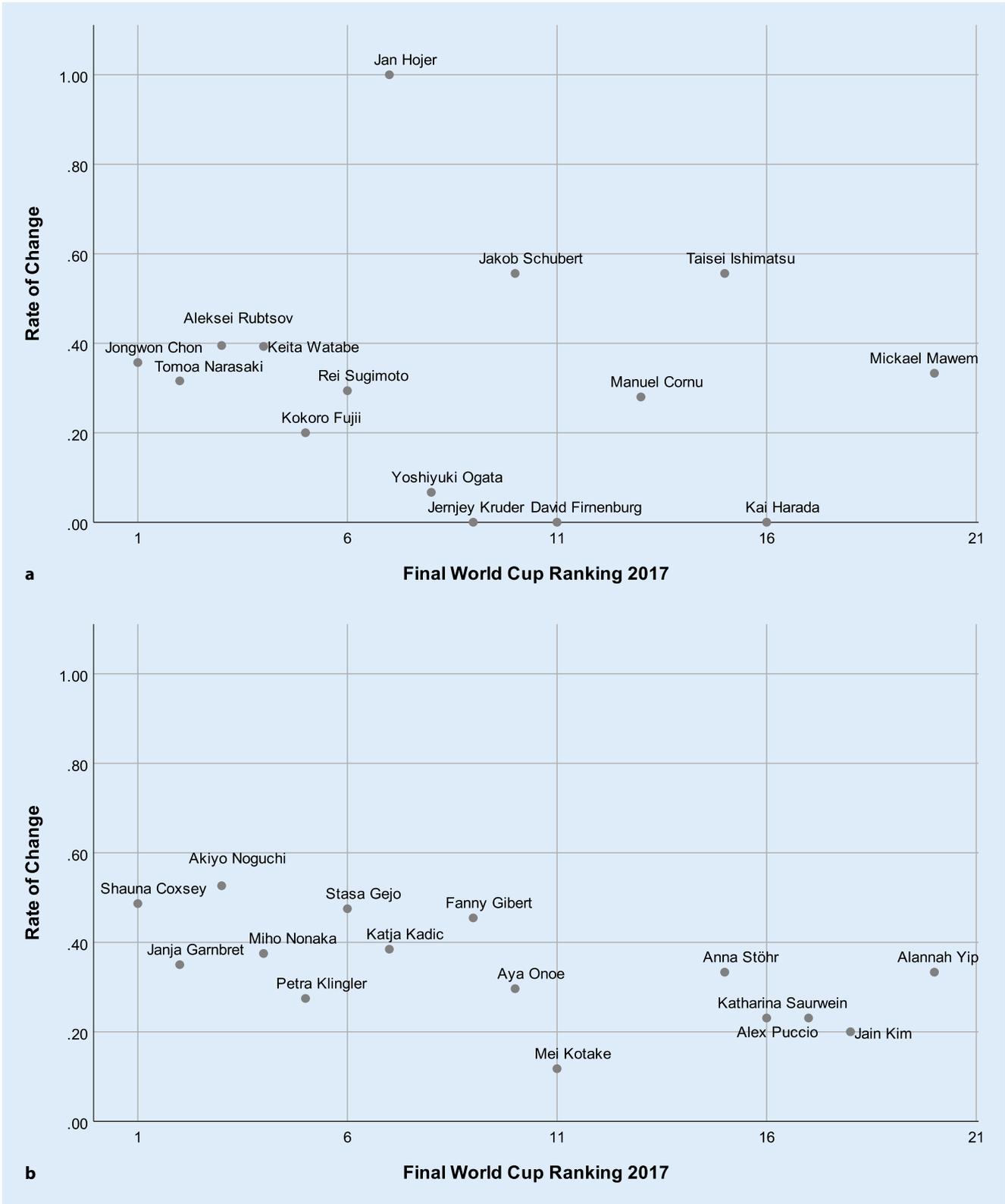


Fig. 1 ▲ Correlation of the final world ranking list 2017 and the rate of change for men (a) and women (b)

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Abstract

Bouldering is a sport climbing discipline in which short, extremely difficult climbing routes, so-called boulder problems, have to be mastered. Besides excellent physical condition, the ability to read a boulder and to generate motor solutions for the boulder problem is probably a performance-determining factor. In a full survey of all participants of the 2017 Bouldering World Cups we investigated how athletes deal with an unsuccessful first attempt. We distinguish between follow-up attempts in which athletes retry the same solution as before and follow-up attempts in which they find a new solution. We could show that the success rate of new solutions is substantially higher than the repetition of the old solution. Furthermore, there is a correlation with the frequency of finding new solutions and the position in the world ranking. We conclude that the ability to create several solutions for boulder problems is a very important component of performance in bouldering.

Keywords

Sport climbing · Problem-solving · Performance-determining factors · High-performance sport · Expert

for two finals and eight for only one final. None of the male athletes qualified for all six finals, one for five finals, three for four finals, two for three finals, four for two finals and five for only one final. All athletes signed a declaration of consent that pictures and videos of their performances at the Boulder World Cups will be recorded and may be published on the internet by the International Federation of Sport Climbing. Please note that our survey is a full survey of the population of all World Cup finalists and no random sample was taken. Therefore, we report the data only descriptively and do not use inferential statistical calculations.

Dependent variables

In the following we use the term climbing strategy for action planning in bouldering, as it is more common in climbing. A change in climbing strategy has been observed when the athlete has used a clearly visible different solution for the current attempt than for one of the two previous attempts. By definition, the first attempt was an attempt without change. An obviously visible different solution involves the use of holds in a different order, the use of different grip positions or the change from a dynamic to a static solution or vice versa. It excludes differences that are not visible to the naked eye, e.g. different force application, different body tensions, slight changes in joint angles and the like. Admittedly, this is a somewhat subjective measure. A student assistant—a licensed amateur climbing trainer—analysed each climbing attempt and rated the attempts with “change” or “no change” and compared them with the two previous attempts in the actual climbing period. In addition, the attempts of the World Cup finals in Chongqing and Munich were analysed independently by a second evaluator, an elite climber (French scale 8c+, 28 IR-CRA reporting scale, see Draper et al., 2015) and licensed route setter. Success and bonus holds¹ were taken from the official scores given by the judges.

¹ As of 2018, bonus holds will be referred to as zone holds under the ISCF competition rules. However, since our analysis uses data from 2017, we use the term “Bonus Holds”.

Results

Cohen’s κ was conducted to determine if there was a correspondence between the judgement of two evaluators as to whether the boulderers maintained or changed their solution based on the analysis of two competitions. The two evaluators agreed on no change in 196 attempts and on a change of solution in 56 attempts. However, scorer 1 scored 10 attempts as a change when scorer 2 scored them as no change and scorer 2 scored 16 attempts as a change when scorer 1 scored them as no change. There was a good agreement between the judgments of the two evaluators, $\kappa = 0.76$, $p < 0.001$ (Greve & Wentura, 1997).

In the analysed world cups the men made 489 attempts, 144 first attempts and 345 follow-up attempts where they had to make the strategic decision to change or not to change the approach to the boulder. The female athletes made 518 attempts, 144 first attempts and 374 follow-up attempts with the strategic decision.

The men changed their climbing strategy in the second or following attempt after failure in 105 attempts, of which 24 were successful and 81 were not successful, resulting in an average success rate of 22.9%. They stuck to their strategy in 240 attempts (excluding the first attempt), of which 11 were successful and 229 were unsuccessful, resulting in an average success rate of 4.6%. Accordingly, women changed in 141 attempts (31 successful, 110 unsuccessful, average success rate 22.0%) and did not change in 233 attempts (10 successful, 223 unsuccessful, average success rate 4.3%).

We determined the conditional success rate for each attempt, broken down by gender and change vs. no change. The conditional success rate for a strategy change is the percentage of successful attempts compared to all attempts with a strategy change (Table 1).

To determine the impact of the change in strategy on overall performance, we conducted a nonparametric correlation analysis between the overall change rate of each athlete and their final place at the 2017 Bouldering World Cup. For the male athletes the Spearman rho

(ρ) correlation coefficient was -0.231 (Fig. 1b), for the female climbers it was -0.69 (Fig. 1a). As this is a full survey, there is no probability of error, $p = 0$.

There are some outliers in the presented data that we have not eliminated. Rather, we have included them in the figures to show that caution is required in interpreting the results. For example, Jan Hojer achieved a rate of change of 100%, which is due to the fact that he only reached one final (in Munich), where he flashed boulders 2 and 3 and changed the strategy on trial 2 and 4 (of five trials) of boulder 1 and on trial 2 (of two trials) of boulder 4. On the other hand, Kai Harada (Chongqing) and David Firnenburg (Meiringen) did not change their

Table 1 Rate of success depending on the choice of strategy (change vs. no change). The values indicate the percentage of successful attempts among all attempts with (or without) strategy change

	Men		Women	
	Change (%)	No change (%)	Change (%)	No change (%)
Attempt 1	–	22.2	–	17.4
Attempt 2	40.0	6.9	24.3	4.9
Attempt 3	21.9	6.9	26.8	5.3
Attempt 4	12.0	0.0	15.6	7.3
Attempt 5 and following	17.4	1.9	19.4	0.0

strategy once, although we observed at least three or four different strategies of other athletes for all boulder problems in these World Cups.

Discussion

In our study we analysed the results of strategic motor planning processes in elite boulderers. We could show that these processes play an important role for the successful solution of boulder problems. We show that although the conditional success rate of strategy changes is much higher than the conditional success rate of attempts where athletes stick to the previous strategy, athletes more often stick to their strategy than change it. While men on average change strategy after failure in 30.4% of attempts, women change strategy after failure in 37.7% of attempts. Based on our research we could develop two pieces of advice for boulder coaches and athletes. First, athletes should learn to correctly assess the probability of success for a certain strategy once they have tried and failed. Second, athletes should always practice developing different climbing strategies for the same boulder problem. Both advices require the training of a predictive model that allows anticipating the effects of the movement (Wolpert, Ghahramani, & Flanagan, 2001; Wolpert & Kawato, 1998). We assume that these two components are what differentiates other elite athletes from the world's leading climbers. Above all, finding a single variable that correlates substantially with the performance differences of the world's top 20 athletes is a very rare finding in complex sports like bouldering.

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Compliance with ethical guidelines

Conflict of interest. S. Künzell, J. Thomiczek, M. Winkler and C. Augste declare that they have no competing interests.

All studies performed were in accordance with the ethical standards indicated in each case.

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