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Athletes' performance in different boulder types at international bouldering competitions

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ABSTRACT

The purpose of the study was to analyse the occurrence of different boulder types and the athletes' success rates in international competitions to contribute to the performance structure of competitive bouldering. Therefore, we classified 448 boulder sections of the final rounds of 14 Bouldering World Cups 2017 and 2018 using video analysis. We conducted analysis of frequencies, chi-square tests, binomial regressions and ANOVA for the respective analysis with regard to gender, competition round, wall section, and athlete level. In more than half of the boulder sections the crux was a dynamo. We found no differences between men and women in the occurrence of the different boulder types. Men solved significantly more boulder problems than women in the categories dynamo and mantle. Women were significantly more successful with slab problems. Lower ranked female athletes were significantly worse than the top 20 athletes in the dynamo, volume, and crimp categories, whereas men were worse in the categories dynamo, and slab. Our findings suggest that the training focus for athletes at international level should be on optimising dynamic moves. For female athletes, maximum strength of fingers and arms is more crucial for maximum achievement in competitive bouldering than for male athletes.

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climbing; bouldering; competitive climbing; finger strength; elite climbers

1. Introduction

The athlete's goal in competitive sports is to achieve maximum performance in the competition. In order to be able to specify training goals, it is of enormous importance to know the performance structure of a sport (Hohmann et al., 2020). The analysis of the competition requirements reveals how the structure of performance is composed in the respective sport. Once the relevant performance criteria have been determined, they can be specifically trained and optimised. However, there are hardly any published competition analyses for the sport of climbing.

For a long time, climbing has been exclusively a natural sport. Regular international climbing competitions in lead climbing only started to establish in the late 1980s. It was not until 1998 that bouldering was introduced as an official competition discipline (International Federation of Sport Climbing, 2019). Nowadays, international

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competitions such as continental championships, world cups and world championships are held regularly. Despite this widespread international popularity and the increasing professionalisation due to the inclusion of climbing as an Olympic sport, research is still quite limited in the field of competition analysis. Studies regarding bouldering competitions, for example, looked at knee injuries (Lutter et al., 2020), nutritional requirements (Smith et al., 2017), pre-performance psychological states (Sanchez et al., 2010) or strategic motor planning processes (Künzell et al., 2021). Other studies analysed physical parameters such as heart rate and blood lactate in bouldering competitions (Gáspari et al., 2015; La Torre et al., 2009). To date, only one study has been published that deals with a competition analysis in terms of the external competition load in bouldering. White and Olsen (2010) recorded the number of attempts per problem, the duration of the attempts, the time on holds, and the time to reach between holds and calculated exercise-to-recovery ratios. These last three studies already give some indications for relevant training contents. However, it is still rather unclear how crucial single aspects are for competitive performance. Michailov et al. (2009) found no correlations between the men's ranking in a bouldering world cup 2007 and various variables. They concluded that performance depended on a summary effect of different factors as the character of the boulder problems can have physical, technical and mental demands. This is mainly due to the competition mode, as described in the next paragraph.

In bouldering competitions, route setters set various problems in the artificial walls that the athletes have to climb in the various rounds of the competition. Thus, the route setters determine to a large extent the demands on the competition climbers. The boulders must not be too easy, so that not all athletes can complete them, but on the other hand they must not be too difficult, so that at least the best athletes achieve successful ascents. In addition, it is quite common that the boulders contain spectacular dynamic elements, so that the competitions are attractive for the spectators (Ashley, 2018, May 31). Thus, athletes face very different requirements within bouldering competitions.

For specific competition preparation, the question arises where the training focus should lie. Therefore, a task-specific analysis of international bouldering competitions is required. It is important to know to what extent which types of demands are imposed on the athletes in current competitions. This contributes to the knowledge of the performance structure of competitive bouldering. In order to derive the relevant training contents, it is important to know how often athletes currently succeed in solving the different types of boulder problems and how the top athletes differ from less successful athletes. The aim of the study was to determine the frequency of occurrence of different boulder types in international competitions. This included looking for noticeable abnormalities in different rounds of competitions as well as in different wall sections. In addition, it was aimed to find out whether the athletes completed the different boulder types with different degrees of success and how top athletes differed from less successful athletes.

2. Materials and method

For data acquisition, videos of boulder competitions were analysed. These videos were available on a freely accessible video platform on the internet (youtube.com). In addition, we accessed world rankings and results of competitions of the “International Federation of Sport Climbing” (IFSC), which were also freely available on an internet platform (digitalrock.de).

2.1. Sample

As a sample, we used all seven World Cups 2017 and all seven World Cups 2018. In every World Cup, both women and men participated. Within each of these competitions, we picked the semi-finals and finals. Normally, the best 20 women and the best 20 men from the qualification qualify for the semi-finals, and the best six women and the best six men from the semi-finals qualify for the final. In one World Cup, 21 men took part in a semi-final due to a tie after the qualification, in another World Cup, seven men took part in a final due to a tie after the semi-final. In the semi-final as well as in the final, women and men climbed four boulders each. The boulders are divided into two scoring sections, up to the zone hold and on to the top. Thus, we analysed 224 boulder sections for the women and 224 boulder sections for the men, i.e. a total of 448 rated boulder sections.

In order to assess the performance of the individual climbers, it was recorded for each climber who started in the semi-final and final whether he or she successfully completed the respective boulder section, i.e. reached the zone hold or the top hold. If this was the case, the number of attempts to reach the zone or top hold was also recorded. Thus, the number of analysed climbed boulder sections added up to 5,840.

2.2. Variables

Since the competitions are held for men and for women, this classification for the variable *gender* was also used in our study. The variable *round* was divided into final and semi-final. The ranking of the competitors is based on the number of successfully completed boulders and the number of reached zone holds, both in descending order, the number of attempts to complete the tops and the number of attempts to reach the zone hold, both in ascending order. Since the section up to the zone hold and up to the top are counted separately, we have also considered these two *sections* in a separate variable. One of the most important variables for addressing our research question is the *boulder type*. In order to determine the type of the boulder section, we identified the main challenge, the so-called crux of the respective section. Therefore, we observed each athlete in the section and took the point where most athletes fell off as the crux. From the multitude of possible boulder problems described by Köstermeyer (2018) we aggregated five different types: 1) Dynamo: dynamic moves to reach the holds. This category includes all moves that either involve jumping off, reaching with both hands or with a hand and a foot simultaneously, or several dynamic moves directly following each other. 2) Volume: strength requirements on voluminous holds. These include slopers and volumes as well as all other large holds that are grasped with the whole hand, with a pincer grip or meat-hook grip. In the meat-hook grip, the hand is wrapped over an edge with the palm on one side and the fingers on the other. 3) Crimp: strength requirements on crimps. In this category we classified boulder sections in which small holds are held with an open or crimped finger position. 4) Slab: balance requirements on slightly forward tilted walls with mostly small holds for hands and feet. 5) Mantle: strength requirements for mantling or stemming with the arms, for example, to overcome small terraces or, more common in competitive climbing, to overcome large volumes.

To test for performance differences between experienced elite climbers and climbers who do not qualify so often for the final rounds of the 20 best athletes at world cups, we recorded the variable *level*. For this purpose, we divided the sample into the top 20 athletes of the world ranking (69.9%) and lower or unranked athletes (30.1%). The ranking was determined at the respective time of the competition.

2.3. Reliablility

The variables gender and round could be clearly assigned. The sections up to the zone hold and up to the top are marked on the wall, so there was no problem with reliability here. Since the referee's decision in the competition was used to assess whether a section was successfully completed, this variable was also clearly recorded. The ranks in the world ranking list of the respective athletes are based on the official lists of the world federation IFSC, which means that there were no restrictions with regard to reliability. The only variable where different raters could come to different conclusions was boulder type. To test inter-rater reliability, two independent raters categorised 53 randomly selected boulder sections (12%). Although the raters were trained and both experienced climbers, a hundred percent agreement could not be assumed. Since different athletes sometimes had problems in different parts within a section, the determination of the crux was not always clear. Moreover, the transition between the categories is fluent. However, Kappa statistics showed a substantial agreement according to Landis and Koch (1977), *Cohen's kappa* = .679, df = 52, p < .001, 95% CI [0.51, 0.85].

2.4. Statistical analysis

All the analyses were performed using SPSS software (IBM SPSS, Version 26.0). To test for differences in frequencies between the boulder types and various variables such as gender, boulder section, and round we performed chi-square tests. For tests concerning the successful completion of boulder sections also chi-square tests were used, if there was only one independent variable. If the influence on completion of more variables had to be analysed we used binomial logistic regressions. One-way ANOVAs were carried out if the number of attempts was the depending variable. Scheffé's post-hoc tests were used in order to identify the groups which were different from each other. When only two groups had to be compared, which applies for the variable gender, we used t tests. The level of significance was set at $\alpha < .05$ for each procedure.

3. Results

3.1. Descriptive statistics

Table 1 shows the prevalence of the different boulder categories for women, men, and overall. In about half of the boulder sections the crux was a dynamic move. Strength issues on voluminous holds were found in about a quarter of the cases. In less than 10% of

Table 1. Prevalence of types of the boulders in different rounds, sections, and in total.

Type		Round		Section		
		Semi-final[a]	Final[a]	Zone[a]	Top[a]	Total[a]
		[%]	[%]	[%]	[%]	[%]
Dynamo	Women	43.8	55.4	44.6	54.5	49.6
	Men	50.9	58.9	49.1	60.7	54.9
	Total	47.3	57.1	46.9	57.6	52.2
Volume	Women	27.7	24.1	31.3	20.5	25.9
	Men	29.5	17.9	29.5	17.9	23.7
	Total	28.6	21.0	30.4	19.2	24.8
Crimp	Women	11.6	7.1	8.9	9.8	9.4
	Men	7.1	13.4	9.8	10.7	10.3
	Total	9.4	10.3	9.4	10.3	9.8
Slab	Women	10.7	8.0	13.4	5.4	9.4
	Men	6.3	3.6	5.4	4.5	4.9
	Total	8.5	5.8	9.4	4.9	7.1
Mantle	Women	6.3	5.4	1.8	9.8	5.8
	Men	6.3	6.3	6.3	6.3	6.3
	Total	6.3	5.8	4.0	8.0	6.0

[a]Percentages are relative to the category.

Table 2. Percentage of completed boulder sections and number of attempts needed.

Type		Completed [%][a]		Attempts[b] [N]	
		M	*SD*	*M*	*SD*
Dynamo	Women	57.8	49.4	2.38	2.00
	Men	65.3	47.6	2.08	1.68
	Total	61.8	48.6	2.21	1.83
Volume	Women	69.6	46.0	1.61	1.19
	Men	66.8	47.1	1.73	1.12
	Total	68.2	46.6	1.67	1.16
Crimp	Women	72.8	44.6	1.52	1.07
	Men	65.9	47.5	1.83	1.61
	Total	69.6	46.1	1.66	1.34
Slab	Women	71.2	45.4	2.11	1.62
	Men	53.4	50.0	2.16	1.46
	Total	64.5	47.9	2.12	1.57
Mantle	Women	65.9	47.6	1.34	,86
	Men	78.7	41.1	1.77	1.51
	Total	73.2	44.4	1.60	1.31
Total	Women	64.4	47.9	1.96	1.65
	Men	65.9	47.4	1.94	1.52
	Total	65.2	47.6	1.95	1.58

[a]Percentage refers only to attempted sections.
[b]Attempts were only counted for completed sections.

the boulder sections, respectively, the crux was categorised as either a strength problem on crimpy holds, a mantle or a slab.

The athletes completed about two thirds of the analysed boulder sections (s. Table 2). If a boulder problem was solved, in more than half of the cases (58.1%) the athletes needed one attempt, in 13.1% of the cases more than three attempts. In 75.9% (*SD* = 42.8%) of the boulders, the athletes reached the zone. After reaching the zone, in another 51.0% (*SD* = 50.0%) of the boulders the athletes succeeded in climbing to the top. Whereas the athletes on average needed 2.17 (*SD* = 1.78) attempts to reach the zone they needed 1.52 (*SD* = .96) attempts to the top. In the semi-finals, 63.5% (*SD* = 48.1%) of the sections were completed by the athletes in 1.98 (SD = 1.61) attempts. The top 6 athletes who reached the finals solved 70.6% of the boulder problems in the final in an average of 1.85 (SD = 1.51) attempts.

3.2. Inferential statistics

3.2.1. Prevalence of the different boulder types in relation to different factors

As expected, the categories we have defined did not occur with equal frequency in the Bouldering World Cups, $\chi^2(4) = 341.799$, $p < .001$. As described above, the share of dynamic requirements was by far the largest (s. Table 1).

Looking at the proportion of each boulder type in the sections up to the zone hold and up to the top, there were differences in the frequencies, $\chi^2(4) = 14.308$, $p = .006$, $\varphi = .179$. A tendency could be seen that slabs up to the zone were more frequent than in the section up to the top, $\chi^2(1) = 3.125$, $p = .077$. Mantle challenges, on the other hand, tended to be more frequent in the upper section, $\chi^2(1) = 3.000$, $p = .083$. Up to the zone, there were significantly more strength requirements on voluminous holds than in the upper section, $\chi^2(1) = 5.631$, $p = .018$. The number of dynamos and strength requirements on crimpy holds did not differ between the zone and the top. In 40.2% of the boulders the cruxes were the same up to the zone and up to the top, in 59.8% they were different.

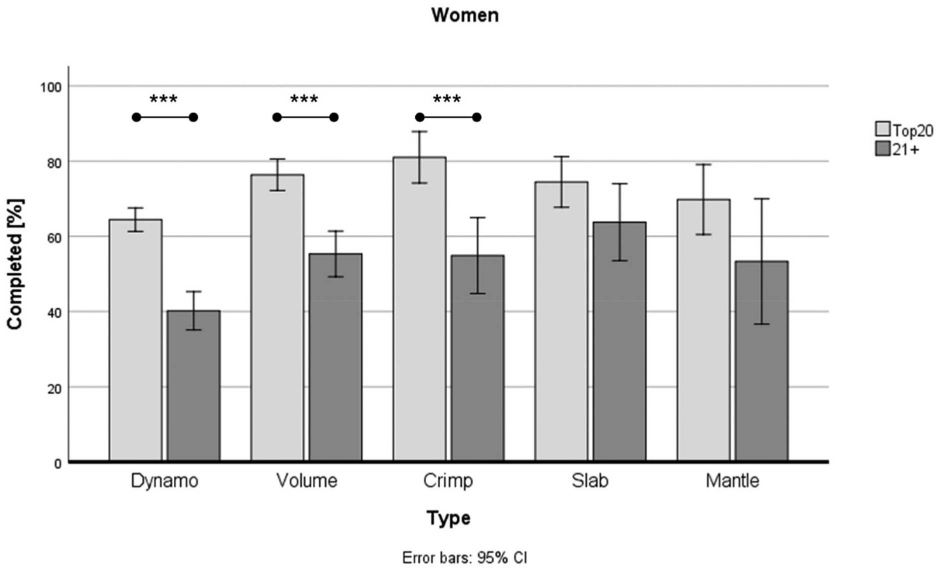
In none of the bouldering categories there was a different distribution between the semi-final round and the final round, $\chi^2(4) = 5.925$, $p = .205$, $\varphi = .115$ (s. Table 1). For men and women, essentially the same number of boulder problems were set in the respective categories. There was only a tendency that women had to master more slabs than men, $\chi^2(1) = 3.125$, $p = .077$.

3.2.2. Success in relation to different factors

Between the boulder types, the athletes' success rates were different, $\chi^2(4) = 31.222$, $p < .001$, $\varphi = .078$. Dynamos were completed significantly less often than sections with strength requirements on voluminous holds, $\chi^2(1) = 16.261$, $p < .001$, $\varphi = .064$, crimps, $\chi^2(1) = 10.779$, $p = .001$, $\varphi = .060$, and mantles, $\chi^2(1) = 14.850$, $p < .001$, $\varphi = .073$. Slab problems were harder to be completed than mantle problems, $\chi^2(1) = 6.132$, $p = .013$, $\varphi = .092$. Also, there was a significantly different number of attempts for the different boulder types, $F(4) = 25.390$, $p < .001$, $\eta 2 = .029$. Scheffé's post-hoc test showed that for dynamos and slabs significantly more attempts were needed than for crimp, mantle and volume problems (s. Table 2).

Looking at gender, men and women did not differ significantly in their success in climbing the boulder sections, $\chi^2(1) = 1.188$, $p = .276$, $\varphi = .015$. Furthermore, there was no significant difference between the genders in the number of attempts, $t(3,287) = .388$, $p = .698$, $d = .013$, 95% CI [−0.129, 0.086] (s. Table 2).

However, there was a significant interaction between boulder type and gender. First of all, this applies to the success rate, $\chi^2(5) = 32.922$, $p < .001$, Nagelkerkes $R^2 = .009$. Men solved significantly more boulder problems than women in the categories dynamo, $\chi^2(1) = 14.699$, $p < .001$, $\varphi = .077$, and mantle, $\chi^2(1) = 6.055$, $p = .014$, $\varphi = .143$. In contrast, women were significantly more successful with slab problems, $\chi^2(1) = 13.827$, $p < .001$, $\varphi = .180$ (s. Table 2). Furthermore, there is a significant interaction in the number of attempts in terms of gender and boulder type, $F(4, 1) = 5.554$, $p < .001$, $\eta^2 = .007$. Men



***p < .001

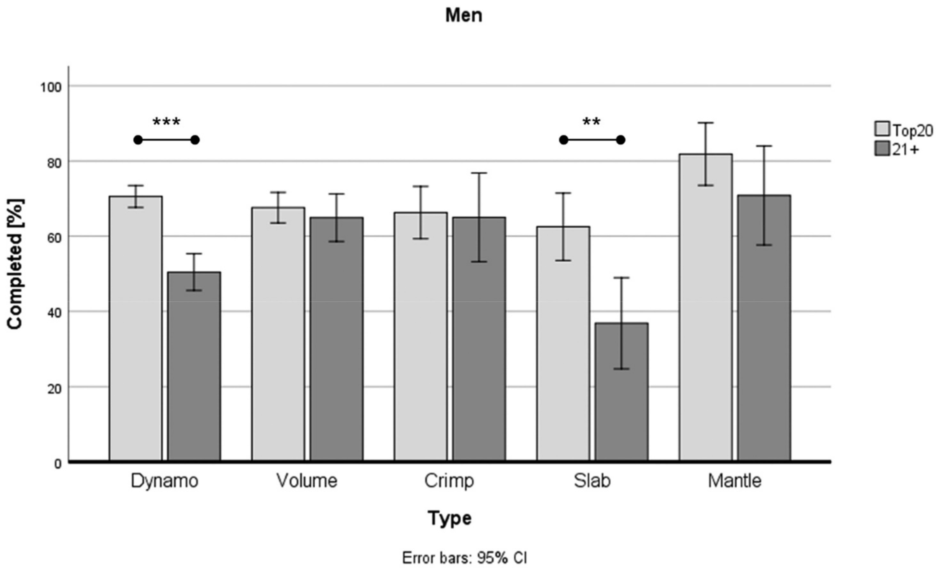
Figure 1. Percentage of succeeds in different boulder problems for female athletes in the top 20 of the world ranking and below.

needed fewer attempts for dynamos than women, $t(1{,}321) = 3.518$, $p < .001$, $d = .161$, 95% CI [−0.485, 0.110], but women needed fewer attempts for crimp problems, $t(253) = 2.076$, $p = .039$, $d = .230$, 95% CI [−0.016, 0.612], and for mantles, $t(213) = 2.665$, $p = .008$, $d = .350$, 95% CI [−0.112, 0.747] (s. Table 2).

The top 20 athletes in the world rankings were significantly more successful in solving the boulder problems in the final rounds of the world cups than athletes with a lower world ranking, $\chi^2(6) = 171.848$, $p < .001$, Nagelkerkes $R^2 = .045$. Furthermore, there was a significant interaction between world ranking and gender, $\chi^2(6) = 136.026$, $p < .001$, Nagelkerkes $R^2 = .036$. While both genders had a success rate of about 70% among the top-20 athletes (women: M = 70.6%, SD = 45.6%, men: M = 69.6%, SD = 46.0%), $\chi^2(1) = .407$, $p = .524$, $\varphi = .011$, women among the 21+ ranked athletes (M = 49.5%, SD = 50.0%) accomplished significantly fewer of the boulder sections than the men among the 21+ athletes (M = 56.1%, SD = 49.7%), $\chi^2(1) = 6.321$, $p = .012$, $\varphi = .066$.

Looking additionally at the type of the boulder section, we found some differences between the genders. The top 20 women outperformed the 21+ ranked athletes in all categories (s. Figure 1). For the categories dynamo, $\chi^2(1) = 56.211$, $p < .001$, $\varphi = .219$, volume, $\chi^2(1) = 32.137$, $p < .001$, $\varphi = .214$, and crimp, $\chi^2(1) = 19.386$, $p < .001$, $\varphi = .273$ the differences were significant, for the categories mantle, $\chi^2(1) = 2.754$, $p = .097$, $\varphi = .148$, and slab, $\chi^2(1) = 3.118$, $p = .077$, $\varphi = .109$, we found a tendency.

However, men showed a different pattern. In the categories dynamo, $\chi^2(1) = 45.923$, $p < .001$, $\varphi = .186$, and slab, $\chi^2(1) = 9.741$, $p = .002$, $\varphi = .246$, the top-20 athletes outperformed lower-ranked athletes. However, in the categories crimp, $\chi^2(1) = .032$, $p = .857$, $\varphi = .012$, volume, $\chi^2(1) = .478$, $p = .489$, $\varphi = .026$, and mantle, $\chi^2(1) = 2.474$,



***p < .001, **p < .01

Figure 2. Percentage of succeeds in different boulder problems for male athletes in the top 20 of the world ranking and below.

p = .116, φ = .121, the 21+ ranked athletes were not noticeably worse than the top-20 athletes (see Figure 2).

4. Discussion

The results of this study can be used to draw practical conclusions for training in competitive climbing.

The first indication lies in the finding that in about half of the boulder sections the crux was a dynamic move. Since we also found that athletes struggled with dynamos more often than with other problems and needed more attempts which has a high impact in the ranking as well, it seems to be very worthwhile to set a training focus on dynamic movements. Due to the nature of dynamos spatial and temporal precision are needed to hit the holds and stick to them. This supports the requirement for a lot of practice of a wide variety of dynamic movements, e.g. using different hand-hold configurations or sizes, to improve the accuracy (Orth et al., 2016).

One could have expected that the route setters would adjust to the higher level of the athletes in the final and set different and more difficult boulders than in the semi-final (Venho & Lankinen, 2018, June 12). However, we could not see any differences in the types of boulders. Moreover, the success rate of the athletes in the final was even higher than in the semi-final. In the semi-finals, 63.5% (SD = 48.1%) of the sections were completed by the athletes in 1.98 (SD = 1.61) attempts. The top 6 athletes who reached the finals solved 70.6% of the boulder sections in the final in an average of 1.85 (SD = 1.51) attempts. Due to many successful climbs, the competition remains attractive to the spectators as long as the routes still allow a differentiation between the top 6 athletes (Ashley, 2018, May 31; Venho & Lankinen, 2018, June 12).

The analysis of the distribution of the different types of boulders on the lower and upper sections revealed few peculiarities. Slabs occurred slightly more frequently in the lower section, mantles in the upper section. This has rather less to do with the route setters, but can be explained by the basic design of the climbing walls. They tend to be vertical in the lower section and to hang over in the upper section. There were more voluminous holds up to the zone hold than up to the top. However, no differences between the zone and the top were found for dynamos and for crimps. Here, the route setters seem to pay attention to a balanced ratio. In our opinion, the distribution of boulder types between the lower and upper sections has no implications for climbing training. However, it is interesting to note that in almost 60% of the boulders the demands up to the zone are different from those up to the top. In the immediate preparation for the next boulder in the isolation, the athlete should adjust the activation level to the demands of the boulder, e.g. be calmer if there is a slab problem and be more activated if there is a dynamo (Bali, 2015). Also during climbing, the change between different demands is not only physically but also mentally challenging. This adjustment to different demands in terms of activation levels should therefore also be considered in training.

When comparing the requirements that men and women face in competition, no major differences could be observed. The only thing was a tendency of more slab problems for women than for men, that women also solved more successfully. These slow controlled balance tasks do not occur very often overall, but they can certainly tip the scales in a competition. We found that, among men, the top 20 athletes are significantly superior to the 21+ ranked athletes especially in these tasks. Thus, intensive training of slab problems is derived as a training goal of male athletes who want to establish themselves among the world's best.

Men solved significantly more boulder problems with dynamos and they also needed fewer attempts. Consequently, the above recommendation for a training focus on dynamic moves applies even more to women than to men. More mantle problems were solved by men, but when women were successful in this category, they needed fewer attempts than men. Since mantle problems only have a share of 6% of all boulders in world cups, and since no relevant differences could be found for men and women of different levels, training mantles is not the primary goal, although it should not be neglected either.

The finding that the athletes needed only one attempt in more than half of the cases in which they solved a bouldering problem shows that they selected the accurate movements after previewing (Sanchez et al., 2019). The athletes still managed to complete sections successfully in more than ten percent of the cases even after four or more attempts. For reasons of competition tactics, multiple attempts should be made primarily in the dynamo and slab categories, which are not quite as exhausting as the requirements of the crimp, volume and mantle categories (Augste & Künzell, 2017). This is exactly what the athletes in our study did, so that no further advice is needed on this.

Overall, the athletes succeeded in reaching the zone hold in three quarters of the cases, while only in half of the cases they reached the top. The other way round is the number of attempts. If the athletes successfully completed the section, they needed more attempts to reach the zone hold than to reach the top. This can be explained by the fact that the athletes already have to put in a lot of effort to get to the zone. Thus, although they complete this section, they no longer have as much strength to reach the top. Another reason is that time is running out for climbing to the top if they have taken several attempts to reach the zone. Because the athletes can no longer make as many attempts as they want due to time constraints, the success rate is lower, and on the other hand, if they top, the number of attempts is also lower. It is difficult to derive training recommendations from this circumstance. The only consequences would lie in the competition tactics. However, it can already be observed that the athletes manage their attempts very well over time by estimating how much strength they have to invest in the respective section and what their chances of success are.

It is not surprising that the top 20 athletes in the world rankings were significantly more successful in solving the boulder problems in the final rounds of the world cups than athletes with a lower world ranking, because a good world ranking is, after all, the result of good competition results that follow from successfully solving the boulders. What is more interesting, however, is that in the area of the non-absolute world elite, the performance deficit among women compared to the top athletes is significantly greater than among men. Especially in the strength requirements, the 21+ ranked female athletes were particularly behind. With men, by contrast, it looks different. Although the male top-20 athletes outperformed lower-ranked athletes in the categories dynamo and slab, there were no significant differences in the categories volume and mantle. In crimp problems they were even almost equal. Thus, in men, the maximum strength does not seem to differentiate the absolute world elite in competitive bouldering from the somewhat less successful athletes. This is consistent with the findings of Cutis and Bollen (1993) who showed that there was no evidence that hand strength alone guaranteed success in competitive climbing. While this study dates back some time, Augste and Künzell (2017) also support this finding. They showed through guided interviews with national coaches that high maximum arm strength is more likely to be seen as a ticket to competitive climbing than a performance differentiating factor. This is also supported by the study of Michailov et al. (2009). They found that male bouldering world cup participants had greater hand strength than non-competitive elite sport climbers. However, the group of the competition boulderers was relatively homogeneous according to the specific strength. While in their study, as in ours, maximum strength was not decisive for success in the bouldering world cup, in our study accurate dynamic moves were crucial for the men. As a consequence, coordinative aspects and quick power development should be focused on in training as a basis for successful dynamos.

4.1. Conclusions

Literature on competition bouldering is hardly available so far. Among other factors, mainly maximum strength and strength endurance of the fingers and arms are referred to as performance factors (Medernach et al., 2015). Without a doubt, these are an important criterion in bouldering. Also our study showed that women in the non-top range have a strength deficit. A training focus should therefore be on the maximum strength of fingers and hands. However, our study also showed that a plateau has almost been reached among men in international competitive bouldering. The absolute top athletes no longer distinguish themselves from the other participants here. Overall, it can be stated that the training focus for competitive climbers in the international arena should be on dynamos. First of all, these are the most common crux. In addition, athletes in the non-top range have the greatest deficits in this type and could get closer to the absolute top of the world through targeted training of this aspect.

4.2. Limitations

A limitation of the present work is that we only considered the final rounds. Thus, no conclusions can be drawn about the prevalence of different boulder types in the qualification rounds, nor about the success rates of the additional 80 to 100 athletes per gender participating in the world cups. Another limitation is that we have always defined exactly one type for a boulder section, although there can be several cruxes in one section. So, one could divide a boulder into more sections. We have decided on one category per section, as also in the competition a score is only given per section. Furthermore, the boulder types could be further subdivided in order to be able to make even more differentiated conclusions. Nevertheless, our study represents a first approach to a task-specific analysis of international bouldering competitions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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