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Movement demands of elite female and male athletes in competitive bouldering.

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ABSTRACT

The aim of this study was to investigate the movement demands of elite female and male athletes in competitive bouldering (CB). Data collection included (a) the number of attempts per boulder (NAB), (b) the attempt duration per boulder (ADB), (c) the bouldering time to ascent a boulder (BTB), (d) the total bouldering time per boulder (TBB), (e) the rest time between attempts (RTA), and (f) the average gripping time (AGT) of the top 20 ranked female and male competitors during the qualification round of the bouldering world-cup in 2013 in Munich, Germany. The NAB and RTA were significantly higher in women (5.1 ± 1.9; 33.4 ± 15.5 s) compared with men (4.3 ± 2.2; 27.2 ± 13.7 s). In contrast, a significantly higher ADB, TBB, and AGT were found for men (23.8 ± 15.2 s; 79.6 s ± 15.7 s; 6.1 ± 2.3 s) compared with women (15.2 ± 8.8 s; 63.9 ± 19.9 s; 4.1 ± 2.7 s). These findings suggest that grip endurance can be considered a key factor in CB due to multiple attempts, relatively long bouldering times, and a short rest time between attempts. Moreover, the results emphasize the importance of a gender-specific training regimen in CB.

Key Words bouldering, sport climbing, grip strength, grip endurance, climbing time

INTRODUCTION

Competitive bouldering (CB) is a discipline of sport climbing completed on low height artificial walls with landing mats to ensure safety (Fanchini et al., 2013; La Torre et al., 2009; White and Olsen, 2010). On the international level, CB is organized by the International Federation of Sport Climbing (IFSC) and consists of (a) a qualification round with five boulders, (b) a semi-final round with four boulders, and (c) a final round with four boulders (Hatch, 2015). According to the IFSC-rules, the average number of handholds per boulder is four to eight and the maximum number of handholds is twelve (Hatch, 2015). Moreover, an attempt is considered successful when an athlete grabs the marked finishing hold with both hands or achieves a defined standing position on the top of the boulder (Hatch, 2015). With regard to the athlete´s scoring, competitors are ranked after each round according to the number of successfully completed boulders (top) and the total number of attempts to complete these boulders (Hatch, 2015). The rotation period system in the qualification and semi-final round requires that all boulders must be climbed in a prescribed order and with a fixed climbing time of five minutes for each boulder and a resting period between two boulders equal to the climbing time (Hatch, 2015).

With regard to the state of the art, scientific investigations remain sparse and numerous training methods published in coaching manuals and climbing magazines have not been investigated empirically (Fanchini et al., 2013; Macdonald & Callender, 2011; White & Olsen, 2010). Therefore, little is known on how to maximize individual performance in CB (La Torre et al., 2009; Macdonald and Callender, 2011). Macdonald and Callender (2011) investigated the athletic profile of highly accomplished bouldering athletes and found that their handgrip and climbing specific finger strength was superior to that of non-climbing controls and elite sport climbers. These results suggest that maximum grip strength can be considered a key factor in CB. Medernach et al. (2015a) investigated thirty-four male bouldering athletes´ use of fingerboards in the presence and absence of vibration stimulation to increase grip strength and found significant grip strength increases in both the vibration regimen ($+7.3\%$, $P < 0.001$) and the conventional fingerboard regimen

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(+5.0%, *P < 0.001*). In a different study, the authors investigated twenty-three highly advanced male boulderers for the effects of a four-week long fingerboard training on grip endurance and found significant (*P* = 0.004) grip endurance gains of 26 s (Medernach et al., 2015b).

With the purpose of testing objective data on how to establish strength and conditioning regimens, La Torre et al. (2009) and White and Olsen (2010) investigated the time-motion analysis of the movement demands of CB athletes. In the study of La Torre et al. (2009), the climbing times in eleven Italian elite climbers during two national bouldering competitions were investigated and the authors found a total bouldering time per problem of 65 ± 20 s and a total bouldering time for the entire competition round of 391 ± 85 s. However, it remains unclear as to what extent and how these findings can be applied in the implementation of training regimens in elite CB because the competition mode differed from the current IFSC-rules with a maximum bouldering and rest time for each problem of 6 min and a total number of six boulders. Moreover, the authors did not differentiate between female and male participants and the presence of a mixed sample could have, for instance, an influence on the total number of attempts or the overall bouldering time.

In a similar study, White and Olsen (2010) performed a time motion analysis of CB athletes and investigated six bouldering athletes during a national competition and found that athletes attempted a problem an average of 3.0 ± 0.5 times with attempts lasting 28.9 ± 10.8 s and rest periods of 114 ± 31 s between the attempts. However, data were collected on a small sample with six athletes, and the competition mode differed again from the current IFSC-rules with a total bouldering time of 6 min to complete a problem. In addition, the authors investigated only male athletes, and it remains unclear as to what extent the movement demands of female CB athletes differ from the authors´ findings.

In conclusion, the present study aimed to investigate the movement demands of female and male elite bouldering athletes with the goal of establishing evidence-based recommendations for strength and conditioning training regimens in elite CB. According to the findings from sport climbing, female athletes have reduced absolute grip strength and grip endurance compared to male athletes (Balás et al., 2012; Philippe et al., 2012), which could contribute to a more technical approach to solve a problem. In conclusion, we hypothesized that female participants would have on average a higher number of attempts (NAB) to find out a more strength-saving solution in an effort to climb a boulder. We expected that a higher NAB would lead to lower attempt duration per boulder (ADB) and a reduced total bouldering time per problem (TBB) as a consequence of the prescribed bouldering time of five minutes per boulder. In addition, we hypothesized that a higher NAB would

result in a lower bouldering time to successfully top a boulder (BTB) because, with an increasing NAB, athletes obtain more information on how to solve a problem. Finally, we expected that a greater NAB would result in a higher resting time between the attempts (RTA), and reduced absolute grip strength in women would also result in a lower gripping time (AGT).

METHODS

Subjects

To test our hypotheses, we investigated the movement demands of the top 20 ranked female and male competitors during three randomly selected bouldering problems of the qualification round during the bouldering world-cup in 2013 in Munich, Germany. All of the participants were elite-level competitors who regularly compete in international bouldering competitions. The bouldering world-cup in Munich from the 24th to 25th of August 2013 was the last round of the entire 2013 world-cup series and therefore enabled a representative top twenty ranking of international CB athletes. The right to video record included written consent of the athletes and was issued by the responsible person of the German Alpine Association. The study protocol received ethical approval from the University.

Experimental Design

Two Sony FDR-AX1EB 4K Ultra-HD-Camcorders (Sony Corporation, Minato, Tokyo, Japan) positioned 5 m from the bouldering wall were used to collect data, which included (a) the number of attempts per boulder (NAB), (b) the attempt duration per boulder (ADB), (c) the bouldering time to successfully top a boulder (BTB), (d) the total bouldering time per boulder (TBB), (e) the rest time between the attempts of a boulder (RTA), and (f) the average gripping time (AGT). These data were collected in six randomly selected bouldering problems of the qualification round. The investigated problems were boulder 3, boulder 4, and boulder 5 for men and boulder 2, boulder 3, and boulder 4 for women. The properties of the bouldering problems are displayed in Table 1. The start of an attempt was defined in accordance with the IFSC-rules as the point where the athlete leaves the ground with every part of the body and both hands are on the marked-handholds (Hatch, 2015). The successful completion of an attempt included the controlled position of the marked finishing hold (top) with both hands or an achieved standing position on the top of the boulder (Hatch, 2015). Movement analyses were performed using Adobe Premiere Pro CS6 software (Adobe Systems Corporation, San José, California, USA).

Table 1. Properties of the six randomly selected bouldering problems of the qualification round during the bouldering world-cup in 2013 in Munich, Germany.

Women	Boulder 2	Boulder 3	Boulder 4
Height (m)	4.0	4.0	4.0
Number of holds (n)	6	6	9
Description	Vertical (~0°)	Overhang (~20°)	Overhang (~20°)
Men	**Boulder 3**	**Boulder 4**	**Boulder 5**
Height (m)	4.0	4.0	4.0
Number of holds (n)	6	4	6
Description	Roof (90°)	Overhang (~30°)	Slab

Statistical Analyses

Statistical analyses were performed using the IBM SPSS Statistics 20 (IBM Corporation, Armonk, USA) and Microsoft Excel 2007 (Microsoft Corporation, Redmond, USA). All of the variables were assessed for normality of the distribution using a one-sample Kolmogorov-Smirnov test and a skewness and kurtosis z-value test. All of the study variables showed an approximately normal distribution. The data are reported as the means and standard deviations and an alpha level of $P < 0.05$ (2-tailed) was used to determine the statistical significance. All of the data were analysed twice by the same researcher. A multivariate analysis of the variance (MANOVA) was used to investigate the differences between women and men, with the Bonferroni post-hoc test used to investigate the differences between the different bouldering problems.

RESULTS

Descriptive data on NAB, ADB, BTB, TBB, RTA, and AGT are displayed in Table 2. The multivariate analysis of variance (MANOVA) showed a significantly higher NAB in female athletes (5.1 ± 1.9) compared with the male athletes (4.3 ± 2.2) with $F(1,112) = 4.2$; $P = 0.04$; $r = 0.2$ (Figure 1). In contrast, a significantly higher ADB was found in men (23.8 ± 15.2 s) compared with women (15.2 ± 8.8 s) with $F(1,112) = 13.6$; $P < 0.001$; $r = 0.4$ (Figure 2). For male athletes, 18% of all the attempts were longer than 30 s, 10% longer than 40 s, and 6% longer than 50 s, whereas for female athletes, only 7% of the attempts were longer than 30 s, 3.5% longer than 40 s, and only two attempts longer than 50 s. The highest ADB was 95 s in men and 67 s in women. A lower BTB was found in female participants (33.7 ± 13.9 s) compared to male participants (41.0 ± 14.5 s), although those differences were not significant ($P = 0.121$). TBB was significantly higher in men (79.6 ± 15.7 s) than in women (63.9 ± 19.9 s) with $F(1,112) = 7.9$; $P = 0.006$; $r = 0.3$. RTA was 33.4 ± 15.5 s in female athletes and 27.2 ± 13.7 s in male athletes with a significantly higher RTA in females, $F(1,192) =$

7.1; $P = 0.008$; $r = 0.2$. A significantly higher AGT was found in men (6.1 ± 2.3 s) compared to women (4.1 ± 2.7 s) with $F(1,624) = 58.3$; $P < 0.001$; $r = 0.3$.

Table 2. Results of the movement analysis during the qualification round of the bouldering world-cup in 2013 in Munich, Germany.

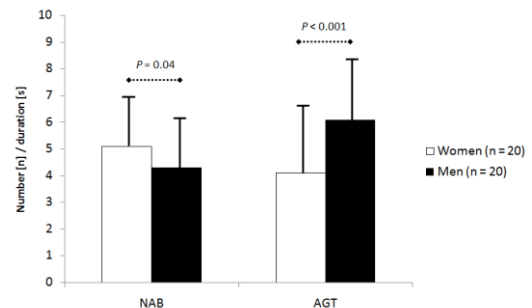|	Women	Men
Number of attempts (NAB)	5.1 ± 1.9	4.3 ± 2.2
Attempt duration per boulder (ADB)	15.2 ± 8.8 s	23.8 ± 15.2 s
Bouldering time for top (BTB)	33.7 ± 13.9 s	41.0 ± 14.5 s
Total bouldering time (TBB)	63.9 ± 19.9 s	79.6 ± 15.7 s
Rest time between attempts (RTA)	33.4 ± 15.5 s	27.2 ± 13.7 s
Gripping time (AGT)	4.1 ± 2.7 s	6.1 ± 2.3 s

Values are means ± s.

Figure 1. The number of attempts (NAB) and the average gripping time (AGT) with a significantly higher NAB and lower AGT in female athletes compared with the male athletes.
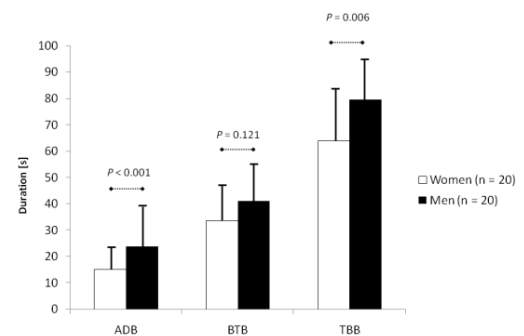

Figure 2. The attempt duration per boulder (ADB), the bouldering time to successfully top a boulder (BTB), and the total bouldering time (TBB) with a significantly higher ADB and TBB in male athletes compared with the female athletes.

In women, we observed significant TBB differences between the bouldering problems with $F(2,56) = 4.3$; $P = 0.019$; $r = 0.4$ and a significantly higher TBB in boulder 4 (72.3 ± 20.9 s) compared with boulder 2 (54.5 ± 16.4 s; $P = 0.016$). Non-significant differences were found in women for NAB with $F(2,54) = 0.17$; $P = 0.846$; $r = 0.08$, ADB with $F(2,56) = 1.9$; $P = 0.147$; $r = 0.3$, and BTB with $F(2,16) = 3.1$; $P = 0.076$; $r = 0.5$ (Table 3). Significant differences in NAB were found for men with $F(2,54) = 11.7$; $P < 0.001$; $r = .6$ and a significantly lower NAB for boulder 4 (2.6 ± 1.6 attempts) compared with boulder 3 (5.0 ± 2.1 attempts; $P < 0.001$) and boulder 5 (5.3 ± 1.8 attempts; $P < 0.001$). The ADB changed significantly between the male boulders with $F(2,56) = 14.1$; $P < 0.001$; $r = 0.6$ and a significant lower ADB in boulder 3 (12.6 ± 6.3 s) compared with boulder 4 (34.2 ± 17.9 s; $P < 0.001$) and boulder 5 (24.5 ± 10.6 s; $P = 0.014$). Significant BTB changes were found in men between the boulders with $F(2,22) = 5.7$; $P = 0.011$; $r = 0.6$ and a significant lower BTB in boulder 3 (28.6 ± 8.6 s) compared with boulder 4 (47.8 ± 13.1 s; $P = 0.009$). Significant differences in male TBB were found with $F(2,56) = 30.8$; $P < 0.001$; $r = 0.7$ and a significant higher TBB in boulder 5 (116.9 ± 34.8 s) compared with boulder 3 (51.6 ± 18.1 s; $P < 0.001$) and boulder 4 (71.1 ± 23.2 s; $P < 0.001$).

Table 3. The number of attempts (NAB), the attempt duration per boulder (ADB), the bouldering time for top (BTB), and the total bouldering time (TBB) for the different bouldering problems in women and men.

Women (n = 20)	Bl 1	Bl 2	Bl 3
Number of attempts (NAB)	4.9 ± 1.5	5.3 ± 2.3	5.1 ± 1.9
Attempt duration per boulder (ADB)	11.9 ± 4.2	16.5 ± 10.9	17.1 ± 9.3
Bouldering time for top (BTB)	23.1 ± 3.2	40.7 ± 15.7	33.1 ± 11.2
Total bouldering time (TBB)	54.5 ± 16	64.8 ± 19	72.3 ± 21
Men (n = 20)	**Bl 3**	**Bl 4**	**Bl 5**
Number of attempts (NAB)	5.0 ± 2.1	2.6 ± 1.6	5.3 ± 1.8
Attempt duration per boulder (ADB)	12.6 ± 6.3	34.2 ± 17.9	24.5 ± 10.6
Bouldering time for top (BTB)	28.6 ± 8.6	47.8 ± 13.1	40.1 ± 14.6
Total bouldering time (TBB)	51.6 ± 18	71.1 ± 23	116.9 ± 35

Values are means ± s.

DISCUSSION

The present study aimed to investigate the movement demands of elite female and male bouldering athletes during the qualification round of the bouldering world-cup in 2013 in Munich, Germany. To the best of our knowledge, this is the first study to compare the movement demands of female and male bouldering athletes in elite CB.

The major findings of the present study were that women attempt a boulder more often (NAB) and have a higher total resting time between attempts (RTA) compared with men. In contrast, men have higher attempt duration per boulder (ADB), a higher total bouldering time per boulder (TBB), and a longer gripping time (AGT) compared with women. In addition, the bouldering time to successfully ascent a boulder (BTB) was higher in men than in women, although this difference was not found to be significant. These results confirm our hypotheses that female athletes, in general, apply a more technical approach to solve bouldering problems, which may due to a lower absolute grip strength and endurance compared to male athletes. As a consequence, it is likely that women require on average a higher number of attempts (NAB) to find out the best solution to a given bouldering problem. As the total bouldering time per problem is limited to five minutes, it seems evident that a higher NAB and RTA leads to a lower attempt duration per boulder (ADB) and a reduced total boulder time per problem (TBB). In addition, a higher NAB results in a lower bouldering time to successfully top a boulder (BTB) because with each attempt, athletes get more details on how to solve the problem. Moreover, it is likely that athletes with a higher NAB need a longer rest time between attempts (RTA) and that reduced grip strength in women compared to men may explain the lower average gripping time (AGT). In summary, our findings suggest that the implementation of a gender-specific training regimen could be important for better CB performances.

However, our results also suggest that the external factors, including (a) the difficulty of a boulder, (b) the number of handholds of a boulder, (c) the style and complexity of a boulder, (d) the bouldering wall features on which the boulder was set, and (e) the prescribed order of the boulder have an impact on the movement characteristics in CB. Although the exact difficulty of each problem is not provided and depends on individual factors, it seems obvious that some problems are easier to ascent compared with others. In women, our results display a significantly higher TBB for boulder 4 compared with boulder 2, which may be explained by the higher number of handholds in boulder 4 (9 handholds) compared with boulder 2 (7 handholds). However, in men, ADB was significantly lower in boulder 3 compared to boulder 4 and boulder 5, although boulder 3 has an equal number of handholds compared to boulder 5 and more handholds than boulder 4. In addition, similar

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findings could be displayed for BTB with a significantly lower BTB for boulder 3 compared to boulder 4, although, boulder 3 has more handholds than boulder 4. Moreover, descriptive data showed on average a higher number of handholds for women (~7.3 handholds) compared with men (~5.3 handholds), although, ADB, BTB, and TBB are lower in women than in men. These findings suggest that various external factors may influence the movement characteristics to an unknown extent and that additional research is necessary to provide comparative data from additional CB. Moreover, the individual tactical approach also plays a decisive role in CB and may therefore have influenced the movement analysis reports. For instance, we suggest that the successful ascent of the first boulder may be preponderant for the self-confidence of some athletes in view of the following bouldering problems of a given competition round. In addition, it is likely that athletes generally try the last boulder of a corresponding round more often than the other problems because limited recovery (five minutes) between two boulders could lead to an early fatigue of the athlete and thus influence the athlete´s performance during the rest of a given round. As a consequence, additional studies will also be necessary to investigate these internal factors that may have an impact on the movement demands of elite bouldering athletes.

Descriptive data of the present study showed an average number of attempts (NAB) of four to five and a total bouldering time to successfully top a boulder (BTB) of ~30-40 s. In men, the average attempt duration per boulder (ADB) was approximately 24 s, which is in accordance with the findings of White and Olsen (2010), who observed that male bouldering athletes attempt a problem about three times with attempts lasting on average approximately 29 s. The total bouldering time (TBB) of ~64 s in women corresponds to the findings of La Torre et al. (2009) who observed a TBB of ~65 s in eleven Italian elite climbers during two national bouldering competitions, whereas the higher TBB results in men (~80 s) of the present study may be explained by the mixed sample of six male and five female athletes in the study of La Torre et al. (2009). The average resting time between the attempts (RTA) for both male and females was ~30 s with an exercise-to-recovery ratio of ~1:1, which is not in accordance with the findings of White and Olsen (2010), who observed a RTA of ~114 s with an exercise-to-recovery ratio of ~1:4. In contrast to White and Olsen (2010), we cannot confirm that athletes have sufficient time for recovery during the different problems, which corresponds to the findings of La Torre et al. (2009) who could observe mean peak blood lactate values after two bouldering competitions of 6.2 ± 0.9 mmol/L and 6.9 ± 1.2 mmol/L, respectively. The authors concluded that the anaerobic glycolytic metabolism is relevant in CB due to attempts lasting longer than 20 s. The different reports between the present study and the results of White and Olsen (2010) may be explained by the

investigated competition mode of White and Olsen (2010), which differed from the current IFSC rules.

In conclusion, multiple attempts to climb a problem (NAB) in combination with a relatively long bouldering time (ADB, BTB, TBB) and a relatively short rest time between the attempts (RTA) explain that competitors are given limited recovery time between the different attempts, and that a rapid recovery post attempt is highly important. As a consequence, despite the low height in CB, grip endurance can be considered a key factor, not only to allow for the successful attempt of a boulder, but also to facilitate a quick recovery between the attempts and to support the total volume of work throughout a competition round. In this context, it is interesting to compare our findings with those of Schädle-Schardt (1998) who investigated the movement demands in sport climbing and observed a total climbing time of 5-7 min, a total number of climbing moves of 50-60 and an average gripping time of 10 s. When compared to the results of the present study, we can assume a distinctly lower ADB, BTB, TBB, AGT, and a number of bouldering moves in CB compared to sport climbing competitions, which should be considered during the physical preparation for CB. With regard to practical advice, specific grip endurance exercises could contribute to better CB performances in elite athletes as athletes might profit from a reduced local forearm fatigue and persevere through longer bouldering sequences. According to our findings, we suggest high-intensity intermittent exercises of ~30-40 s in duration separated by short rest periods to increase grip endurance in CB.

A significantly higher average gripping time (AGT) of ~6 s in men compared to ~4 s in women may be explained by a higher absolute grip strength in male athletes. In the study by White and Olsen (2010), the authors display similar AGT reports for male athletes with an average time of gripping holds of ~8 s and ~0.5 s to reach the next handholds. These findings and an average of four to eight strenuous bouldering movements underline that grip strength is the primarily key factor in competitive bouldering (Fanchini et al., 2013; La Torre et al., 2009; Macdonald & Callender, 2011; White & Olsen, 2010). Fanchini et al. (2013) measured a significantly ($P = 0.005$) greater finger strength in highly advanced bouldering athletes in contrast to lead climbers of equal ability level. In an earlier study, Macdonald and Callender (2011) found finger strength in highly accomplished boulderers significantly greater ($P = 0.001$) compared to aerobically trained non-climbers and superior to that of elite lead climbers. In conclusion, sport-specific exercises to increase grip strength may be essential for maximizing individual performance and our findings suggest that grip strength training should involve an intermittent effort that reaches maximum intensity with four to eight repetitions separated by a short rest period of approximately 1 s.

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CONCLUSION

According to the main findings of the present study, elite female bouldering athletes (a) attempt a boulder more often, (b) have a lower attempt duration per boulder, (c) have a lower total bouldering time per boulder, (d) have a higher total resting time between the attempts, and (e) have a lower average gripping time compared with elite male bouldering athletes. These findings suggest that the implementation of a gender-specific training regimen could be important for better CB performances, although, external and internal factors have an impact on the movement characteristics in CB. Multiple attempts to climb a problem (~ 4-5) in combination with a relatively long bouldering time (~ 30-40 s) to top a problem and a relatively short rest time between the attempts (~ 30 s) suggest that grip endurance and a rapid recovery post attempt can be considered a key factor in addition to grip strength.

REFERENCES

1. Baláš, J, Pecha, O, Martin, AJ, and Cochrane, D. Hand-arm strength and endurance as predictors of climbing performance. _Eur J Sport Sci_ 12: 16-25, 2012.

2. Fanchini, M, Violette, F, Impellizzeri, FM, Maffiuletti, NA. Differences in climbing-specific strength between boulder and lead rock climbers. _J Strength Cond Res_ 27: 310–314, 2013.

3. Hatch, T. Rules 2015. International Climbing competitions. International Federation of Sport Climbing. Retrieved from http://www.ifsc-climbing.org/index.php/world-competition/event-regulation, 2015.

4. La Torre, A, Crespi, D, Serpiello, FR, and Merati, G. Heart rate and blood lactate evaluation in bouldering athletes. _J Sports Med Phys Fitness_ 49: 19-24, 2009.

5. Macdonald, JH and Callender, N. Athletic profile of highly accomplished boulderers. _Wilderness Environ Med_ 22: 140-143, 2011.

6. Medernach, J., Kleinöder, H., Lötzerich, H. Vibration training in indoor bouldering: Effects on strength and endurance. E-Poster at the 20th annual Congress of the European College of Sport Science, Malmö, Sweden, 2015a.

7. Medernach, J., Kleinöder, H., Lötzerich, H. Fingerboard in competitive bouldering: Training effects on grip strength and endurance. _J Strength Cond Res_ 29: 2286-2295, 2015b.

8. White, DJ, Olsen, PD. (2010). A time motion analysis of bouldering style competitive rock climbing. _J Strength Cond Res_ 24: 1356-1360, 2010.

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