Original Article

Pilot study: Performance-ranking relationship analysis in Czech crossfiters

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ABSTRACT

CrossFit is one of the fastest growing sports. Its growing popularity also applies to its competition form. This pilot study aims to analyse strength, endurance performance and their relationship to the resulting ranking in the CrossFit Open. Furthermore, the forms of training of elite Czech crossfitters are described in more detail. The research sample consisted of the 20 best Czechs (average height, age, and bodyweight of 180cm, 28.5 years and 90.7 kg respectively) according to the CrossFit Open ranking. The questionnaire was used to collect information regarding the training regime and their current performance parameters. Descriptive statistics include the correlation between individual performances and overall ranking. Crossfitters had very good strength parameters in exercises with external load and also with their bodyweight (average values: clean and jerk 141.5 kg, snatch 113.9 kg, back squat 184.1 kg, strict press 87.2 kg, deadlift 217.9 kg, strict handstand push-ups 21.5 reps., pull-ups 20.6 reps.). The Olympic weightlifting performance (snatch and clean and jerk) was the strongest predictor for placing (-.606 resp. -.625, α=.01). The weekly training time was 800-900 minutes and contained mostly combined training units with a total of 9.2. Given the interesting results achieved in this pilot study, more detailed and validated studies are needed. **Keywords:** Sports performance; Workout; Power; High intensity; Weightlifting.

INTRODUCTION

CrossFit is still one of the young sports disciplines and a sector that has seen a huge boom over the past 15 years. CrossFit is mainly operated by officially licensed gyms, which are found almost all over the world, and their number has exceeded 10,000 (Beers, 2014).

Over time, the competition form and the system by which competitions are organized has also been developed. In this respect, CrossFit is an original and similar concept in the sense of the world championship in other sports branches (Dawson, 2017). Since 2009, there have existed the so-called CrossFit Games. It is currently an "open world championship in CrossFit" that anyone can apply for. During the five weeks ('2019 Leaderboard', 2019), competitors have to pass 5 fitness tests (workouts) online, one each week (Kuhn, 2013), then proceed to the main competition.

This year more than 185,000 men and 140,000 women entered the CrossFit Open, joined by 327 men and 180 women from the Czech Republic[1]. The CrossFit Open is the only opportunity where most of the best crossfitters meet. It is, therefore, a relatively objective overview, which also serves as a feedback for coaches and competitors.

Serafini attempted to describe the performance of crossfitters entered for the CrossFit Open 2016 for the 1500 best-placed crossfitters in the world ranking (Serafini, Feito, & Mangine, 2018). The values were divided by level into five quantiles. One of the important findings was that with the increasing levels of crossfitters strength (snatch, clean and jerk, back squat) endurance performance (running 400m, 5000m) did not change significantly. A similar description is reported by Mangine (Mangine, Cebulla, & Feito, 2018), but they worked only with benchmark workouts and the research sample is a broad crossfitter base from the same competition. These performances show, among other things, a specific level of endurance ability where all modalities are mixed in different forms.

Dexheimer describes the determination of predictors for performance in CrossFit (Dexheimer et al., 2019), where the association of physiological variables (VO2max, Wingate test, 3 min running test), strength parameters in the form of "CrossFit Total" (include maximal lifted weight of back squat, deadlift and strict press) and their relationship to the selected benchmark workouts Fran, Grace, Nancy. VO2max was the strongest predictor, but only for the Nancy workout. Furthermore, a positive relationship between CrossFit Total and Wingate test was noted.

Butcher (Butcher, Neyedly, Horvey, & Benko, 2015) presents similar research, but he only used Cindy instead of Nancy's workout, but its composition is comparable. In this case, no statistical correlations were found between the physiological parameters and workout performance. Again, the research sample did not represent elite crossfiters, which can be judged by the reported average performance (Fran - 203s, Grace - 136s, back squat - 147 kg, strict press 69 kg).

The relationship of the physiological parameters (VO2max, Wingate test), experience with CrossFit and performance in original workouts were examined by Bellar (Bellar, Hatchett, Judge, Breaux, & Marcus, 2015). In one workout, a relationship with several factors (VO2max, age, experience) was found; respectively the time they spend training specifically for CrossFit.

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[1] *According to CrossFit Games Open Leaderboard 2019.*

In the study of Feito (Feito, Heinrich, Butcher, & Poston, 2018), the relationship of repeated intervals on Wattbike with the original 15 min workout was investigated. The competitive crossfiters participated in the research and it was stated that the ability to regenerate quickly between the intervals of maximum intensity was the most important for the chosen workout. Given the nature of the research, it can be hypothesized that a high level of aerobic and anaerobic endurance is essential to CrossFit performance.

CrossFit typically uses its own training methods but also applies the principles of competitive training (Wilson et al., 2012). In general, there is a lack of more accurate information on how to train individual crossfitters for the level of certain performance parameters (Goins, 2014). The analysis of strength and endurance performance is important to determine their position in overall CrossFit performance (success of an athlete) and subsequent transfer to practice (see Gerhart, Bayles, 2014 (Gerhart & Bayles, 2014)). The way of training, the number of training units and their content are essential for planning, tapering and increasing the overall performance of the athlete (Franchini & Takito, 2014).

The purpose of this research was to discover what strength and endurance performances elite Czech crossfitters achieve and to verify the importance of individual performances in the final ranking in the competition. In addition, the authors aimed to specify the training regime and concept of the content of training units. This is an original pilot study that analyses in detail a sample of athletes selected on the basis of the CrossFit Open results.

MATERIAL AND METHODS

Experimental approach to the problem
The questionnaire survey was used to collect information concerning anthropometry, selected performance parameters and training regime. It is an unconventional data collection in the context of strength and endurance performance, but Mangine (Mangine et al., 2018) and Serafini (Serafini et al., 2018) work with a similar research plan. The data were collected in April of 2019.

Participants
The research sample consisted of 20 men with the best results in the Czech CrossFit Open ranking. Participants were addressed using an online questionnaire consisting of open questions about their current performance. The respondents were told that the results would be anonymous, without assigning performance to a specific name, in order to limit overestimation of performance. All procedures were approved by the University of Hradec Králové ethics committee (decision no. 5/2019), and the athletes taking part in this study confirmed an informed consent form.

Table 1. Average values for the age, height and weight of the research sample.

	Total sample average	Average for the top 5 athletes
Age	28.5 years	25.2 years
Height	180.7 cm	181.4 cm
Weight	90.7 kg	92 kg

Table 1 shows summary statistics for the respondents, the top five competitors were analysed separately.

Measures
The questionnaire contained questions about the training regime – a number of training units, their length, content. Furthermore, the interviewees filled in their current performance. Their selection was guided by the

CrossFit's orientation and, at the same time, those that could have a meaningful value in relation to the overall performance were chosen. The basic exercises included Olympic weightlifting. Therefore, the maximum lift weights of these exercises were sought clean and jerk, snatch, back squat, front squat, deadlift, strict press. Another important part were the bodyweight elements, where the maximum number of strict handstand push-ups (with a wall support) and strict pull-ups on the horizontal bar were chosen. All exercises had a clear standard, which the competitors know and there is no risk of different technique (e.g. a range of movement). The last part was endurance performance: 5km on the rowing machine, 5km running, "Triangle" (40-minute interval training including assault air bike, rowing machine, concept SkiErg machine). Then the interviewees were given an open question where they could complete their endurance performance lasting at least for 5 minutes.

Ranking

The ranking of the competitors was based on the performance of the five CrossFit Open 2019 workouts. Athletes are scored by location and their results are added up.

Table 2. CrossFit Open 2019 workouts.

	19.1 (week 1)	**19.2 (week 2)**	**19.3 (week 3)**	**19.4 (week 4)**	**19.5 (week 5)**
Type	*15 min AMRAP*	*for repetitions and time*	*for time*	*for total time*	*for time*
Workout	19 wall ball shots 19 call row	Beginning on an 8-minute clock: 25 toes to bar 50 double unders 15 squat cleans, 135 lb. 25 toes to bar 50 double unders 13 squat cleans, 175 lb. If completed before 8 minutes, add 4 minutes to the clock and proceed to: 25 toes to bar 50 double unders 11 squat cleans, 225 lb. If completed before 12 minutes, add 4 minutes to the clock and proceed to: 25 toes to bar 50 double unders 9 squat cleans, 275 lb. If completed before 16 minutes, add 4 minutes to the clock and proceed to: 25 toes to bar 50 double unders 7 squat cleans, 315 lb.	200 ft dumbbell overhead lunge 50 dumbbell box step-ups 50 strict handstand push-ups 200 ft handstand walks	3 rounds of: 10 snatches 12 bar facing burpees Then rest 3 minutes before continuing with: 3 rounds of: 10 bar muscle-ups 12 bar facing burpees	33-27-21-15-9 reps of: thruster chest to bar pull-ups
Weights time cap	Throw 20 lb. ball to 10 ft. target	Time cap: 20 min	50 lb dumbbell, 24 in. Box time cap: 10 minutes	Snatch 95 lb.	Thruster 95 lb. Time cap: 20 minutes

Note: AMRAP – as many repetitions as possible.

Table 2 contains the list and description of all the 2019 CrossFit Open workouts.

Analysis

The data file was sorted out according to the order of individual competitors. Using the IBM SPSS software, version 20, the Spearman rank correlation coefficient was computed for all the obtained variables to verify not only the performance dependence of the selected exercises on the overall rank, but also the performance dependence of each exercise. The described software was also used for creating box graphs and descriptive statistics for the obtained data sample.

RESULTS

No endurance performance was included in the results section. This is because each response category had less than 50% filed items (unlike the rest of the responses that were complete) and therefore no valid statistical conclusions can be drawn. However, even this fact has a certain informative value, which is further discussed. In addition, average values from incomplete results for 5 km rowing (17:58) and 5 km run (21:50) are provided.
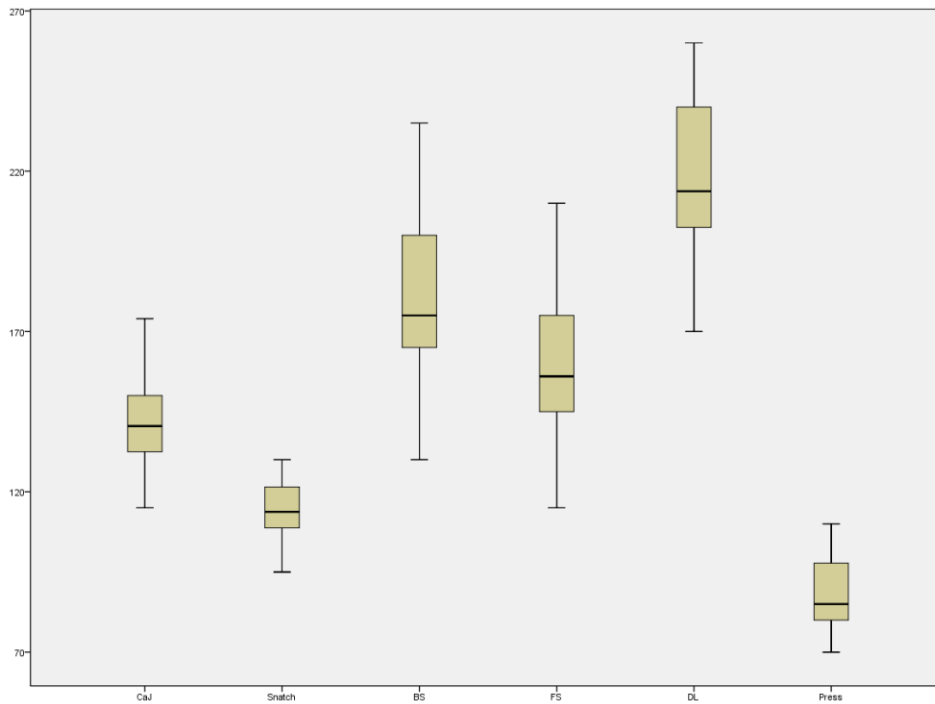
Table 3. Athlete performance summary: minimum, maximum, average and standard deviation of the tested exercises for the whole research subject sample.

	Minimum	Maximum	Average	Standard deviation
CaJ	115	174	141.5	14.41
Snatch	95	130	113.9	10.37
BS	130	235	184.1	26.93
FS	115	210	160.9	23.4
DL	170	260	217.9	24.32
Press	70	110	87.2	10.84
HSPU	12	32	21.5	6.32
Pull-up	10	31	20.6	4.76

CaJ – Clean and jerk, Snatch, BS – Back squat, FS – Front squat, DL – Deadlift, Press, HSPU – Handstand push-up, Pullup. Values with * represent amount of repetitions, other one repetition maximum weight in kilograms.

Table 3 shows the values in the measured tests. In weight tests with a barbell, the crossfiters showed highly varied performances; the differences were in the order of tens of kilograms. They differed most in the back squat, deadlift and front squat. On the contrary, we observe a consistent performance in gymnastic exercises. In the box graphs, the monitored parameters are further detailed.

Figure 1 contains box plot for barbell exercises representing one repetition maximums for the previously described athlete sample, while Figure 2 contain the amount of repetitions performed by the same athletes in the selected gymnastic exercises. In the top 5 athletes, we find higher values in all exercises, except for pull-ups, where comparable results were obtained (see Table 4). The greatest difference in terms of absolute values can be seen in the deadlift and both squat variants. In percentage recalculation, the differences between individual parameters are comparable, ranging between 5-9%.

Explanation: Axis Y – Lifted weight in kg, CaJ – Clean and jerk, Snatch, BS – Back squat, FS – Front squat, DL – Deadlift, Press.

Figure 1. Barbel exercises.
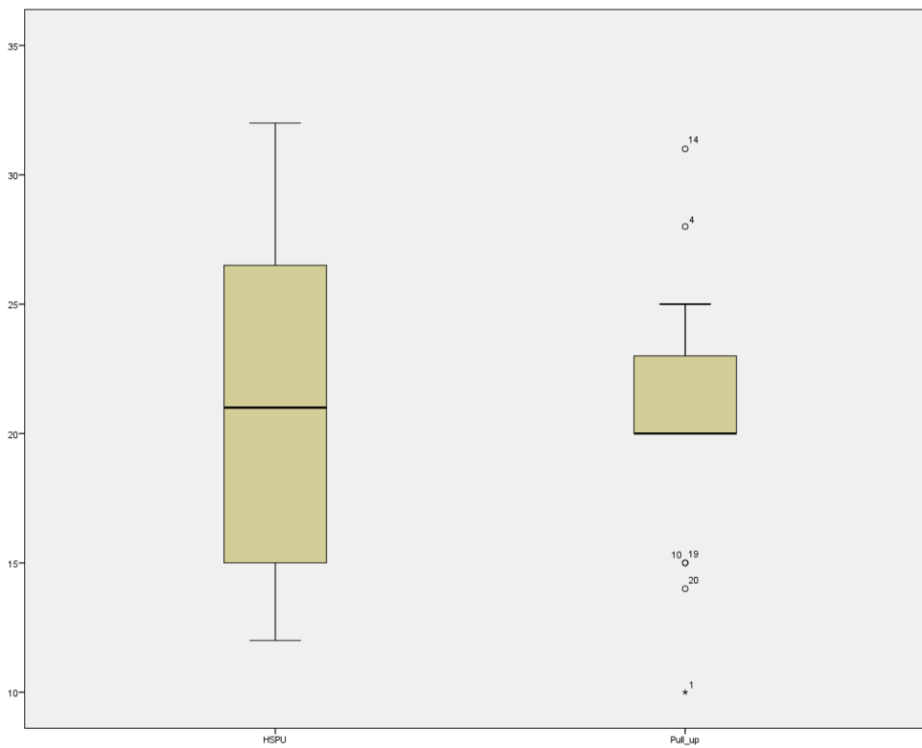
Explanation: Axis Y – A number of repetitions, HSPU – Handstand push-up with a wall support, Pull-up.

Figure 2. Gymnastic exercises.

Table 4. Top 5 athletes performance summary: minimum, maximum, average and standard deviation of the tested exercises.

	Minimum	Maximum	Average	Standard deviation
CaJ	125	174	151.3	18.53
Snatch	107.5	127	119.9	8.37
BS	164	235	198.8	34.05
FS	145	210	175	29.15
DL	205	260	233	24.39
Press	83	110	95.6	11.37
HSPU*	21	32	24.4	4.5
Pull up*	10	28	20.8	6.72

*CaJ – Clean and jerk, Snatch, BS – Back squat, FS – Front squat, DL – Deadlift, Press, HSPU – Handstand push-up, Pullup. Values with * represent amount of repetitions, other one repetition maximum weight in kilograms.*

Table 5. Spearman's correlation of the selected tests with the overall ranking.

	CaJ	Snatch	BS	FS	DL	Press	HSPU	Pull-up	Ranking
CaJ	1	.884**	.770**	.796**	.666**	.755**	.253	.121	-.606**
Snatch	.884**	1	.716**	.665**	.537*	.696**	.409	.222	-.625**
BS	.770**	.716**	1	.942**	.799**	.808**	.44	.301	-.366
FS	.796**	.665**	.942**	1	.853**	.861**	.438	.282	-.449*
DL	.666**	.537*	.799**	.853**	1	.754**	.407	.292	-.328
Press	.755**	.696**	.808**	.861**	.754**	1	.622**	.405	-.527*
HSPU	.253	.409	.44	.438	.407	.622**	1	.253	-.490*
Pull-up	.121	.222	.301	.282	.292	.405	.253	1	-.124
Rank	-.606**	-.625**	-.366	-.449*	-.328	-.527*	-.490*	-.124	1

**. significant at α = .01, *. significant at α=.05

Spearman's correlation showed the strongest relationship between the ranking and the performance in the snatch and clean and jerk (α = 0.01). Significant (α = 0.05) were also the results in the strict press, handstand push-ups and front squat. The relationship of the back squat and the deadlift was not significant. Interestingly, the strict press performance correlates positively (α = 0.01) with all exercises except with bodyweight movements. However, strong correlations were observed for most parameters and their complete list is in the Table 5.

Table 6. Description of the training units (TU).

	Total sample	Top 5
Experience	5.1 years	4.4 years
A number of TU per week	9.2	10.3
TU length	90 mins	80 mins
Mixed TU	4.8	5.4
Strength TU	2.7	2.8

Description of the training habits of the selected athlete sample is displayed in the Table 6. The number of training units per week was 9.2, which means that two-stage training is a common in the selected research sample. The time spent on training specifically for CrossFit was 5.1 years. It is a relatively short time, but it corresponds to the fact that it is a young sport discipline. In more than half of the cases, they use mixed training units that included strength, power and endurance parts or exercises. There are differences between

the top 5 and others in almost all monitored factors, the common feature being the number of pure strength training units. Although it varies in the number of units and their length, the result is comparable when converted to the total training time.

DISCUSSION

This is an original mapping of the performance and training approach of elite national CrossFit competitors. In contrast to these studies (Bellar et al., 2015; Butcher et al., 2015; Dexheimer et al., 2019; Meyer, Morrison, & Zuniga, 2017), this research takes into account the CrossFit Open performance, which consists of five workouts. These are not known in advance and there is limited time for their completion. All workouts together will test overall performance, not just certain selected modalities, and the end result has a good informative value.

The results section stated that many respondents did not know the answers to their current endurance performance unlike their strength performance, where they had a clear overview. The reason may be a lower accentuation of purely endurance performance (the so-called single modalities) in CrossFit competitions. Another cause may be the limited direct transmission of these parameters to the exercise itself - fitness tasks are usually composed of multiple modalities (Bellar et al., 2015). Also, it is not yet clear what influence, for example, the performance of 5km on the rower has on the multifactorial load typical of CrossFit. At the same time, there is too much variety in endurance testing - varying in length, resources and, moreover, in combination with personal preferences to track specific performance.

Due to the high importance of endurance abilities, which significantly contribute to the most CrossFit performances, it is necessary to capture this area during testing [8]. The essence of both anaerobic and aerobic fitness in the form of VO2 max was demonstrated by Dexheimer (Dexheimer et al., 2019) or Feito (Feito et al., 2018), although only for some workouts, the results were not related to the complex CrossFit performance.

Certainly, due to the complex nature of CrossFit, it is not possible to find one criterion to assess the potential of a crossfiter. At the same time, the tests should be specific as some devices are still under-used (i.e., assault air bike). A pure endurance activity lasting 5 to 20 minutes could have a certain informative value, where submaximal to maximal intensity is also achieved (see Feito (Feito, Giardina, Butcher, & Mangine, 2019)).

When compared to the Serafini study (Serafini et al., 2018), which included the 1,500 best men in the CrossFit Open 2016, the sample examined is on the border of the 1st best quantile. The top 5 would then rank in the 1st quantile, lagging only in the back squat, which had an average value of 201.6 kg. In terms of endurance ability, a partial comparison can be made for the 5 km run, where athletes from the 1st quantile reported an average of 21.3 min, which is a lower time compared to 21.8 min. However, it is important to mention the increasing level of performance parameters, which would probably be higher this year.

Strength performances in the back squat, deadlift and strict press are among the commonly used indicators in sports training (Ivey & Stoner, 2011). The bench-press is generally used instead of the strict-press (Simmons, 2007), but due to the nature of CrossFit, it is applied less frequently as in Olympic weightlifting. Basic barbell lifts expressed as bodyweight multiples are very often used as benchmarks of an athlete (Rippetoe & Kilgore, 2007), which is not yet widely used in CrossFit. In the case of this sample, obtained averages were the following: back squat 2x, deadlift 2.4x, strict press almost 1x.

An important factor also appears to be the vertical pressing strength, be it with a barbell or with your own body. Again, this shows the complex readiness of the athlete, who must have good strength parameters in many areas. Although the bar exercises are a standard part of the fitness "tasks", the upper body pulling strength was not significantly correlated with the overall ranking. However, it cannot be concluded that the recurrence parameter is not important. To interpret the correlation, we have to add that the results were very balanced. Therefore, the weak correlation of the monitored traits is described.

In the gymnastics exercises, the crossfitters performed very well. It turned out that even working with one´s own body must be on a very good level. It was not a maximum strength test like other parameters. Results in terms of a small difference between the top 5 and the others suggest that there could be a similar trend to that of Serafini (Serafini et al., 2018). As the level of the crossfiter rises, the power and weightlifting performances are increasing, while in others they show comparable results.

The correlation shows that the strongest predictors for the final ranking were snatch and the clean and jerk performance. A weaker correlation, although still statistically significant, is observed in the case of the strict-press, strict handstand push-ups, and front squat. Obviously, the Olympic weightlifting occupies an important position in relation to CrossFit performance. Working with a barbell is typical of CrossFit type of training, so it is also emphasized in the competitive concept (Mangine et al., 2018). For good placement within this set, it is necessary to reach approximately 113.8 kg in snatch and 141.5 kg in clean and jerk.

For CrossFit performance, it is important to combine power and endurance parameters. This is confirmed by Dexheimer (Dexheimer et al., 2019), Butcher (Butcher et al., 2015) or Bellar (Bellar et al., 2015). Research shows different correlations of individual performances and selected workouts, for which their nature is decisive.

The analysis of the data confirms the importance of back and front squat performance for the Olympic weightlifting and at the same time show a significant link to all strength elements except for gymnastic exercises. It is confirmed that both exercises are a good predictor of the strength performance not only of the lower half of the body (Schoenfeld, 2010). In addition to weightlifting, it is essential for good results in CrossFit also to have a good performance in the basic variants of squat with external load.

As in other sports disciplines, there is a big difference between the best and the rest of the group (Proietti et al., 2017). There are striking differences in weightlifting disciplines (about 10kg) as well as large dumbbell exercises, while in exercises with one´s own body the results are comparable. Lifting performance seems to have a much greater effect on competition placement.

The results show that for the CrossFit success, it is necessary to spend about 800-900 minutes of training per week, which requires two-phase training units. Because CrossFit is characterized by high intensity (Fernández, Solana, Moya, Marin, & Ramón, 2015), it is necessary to optimally set the content and time interval between units to avoid overload and maladaptation (Johnston et al., 2016). This time does not include, for example, regeneration techniques or massages, which are an important part of the training process.

The concept of the content of the training units seems to be a very individual matter. It is difficult to evaluate their exact content, yet it is clear that crossfiters devote a lot of time to mixed training of individual modalities. On the other hand, an analytical approach is applied in the independent development of individual motor skills, which is necessary for success in complex sports disciplines (Kniffin, Howley, & Bardreau, 2017).

For the sake of completeness, the main limitations of the research are presented. The data were collected in an unconventional way using a questionnaire survey. The authors did not have control over conducting the performances and had to rely on the credibility of the answers. However, the standard complex testing of the selected parameters for this sample seems very difficult to perform. It should also be taken into account that the research sample was selected based on the results of the CrossFit Open, which has its specificities and cannot be taken as an absolute measure of crossfitter performance.

Practical applications
 – Competitors should devote a lot of time to the Olympic weightlifting, respectively to the activities that will help them improve their performance.
 – For success, the strength performances not only with barbell but also with bodyweight are important.
 – Pay special attention to the level of aerobic and anaerobic endurance in testing.
 – In case of a high number of training units, optimally set their content and combination (with regards to overtraining and interference effect).
 – The exact number of training units and their duration is individual.

CONCLUSION

The performance and competition form of CrossFit is still relatively unmapped in terms of specific performance, training analysis and their relationship to overall success. The questionnaire survey showed that the crossfitters have very good weightlifting (snatch 113.9 kg, clean and jerk 141.5 kg) and strength performance (back squat 184.1 kg, deadlift 217.8 kg, strict press 87.2 kg). At the same time, it can be stated that they achieve relatively high repetition amount in gymnastic elements (21.5 hand-stand push-ups). The correlation showed a strongest relationship of $\alpha=.01$ between clean and jerk (-. 606) and snatch (-. 625) in terms of ranking in the top twenty at the CrossFit Open. The sample also confirmed the strict press as a general predictor of overall strength development. It also turned out that the top 5 crossfitters differ significantly from the rest of the sample, the difference in individual parameters is up to 9%. The weekly training time (800-900 minutes) is comparable to other (semi) professional sports. The content of the training units is mostly of a mixed character, but there is a lot of space devoted to the development of strength. The results are also valuable as information for trainers or competitors from the perspective of training organization, setting specific goals (e.g., strength/ technical development in a given exercise) and feedback compared to other crossfiters. Being the first research of this type, other similarly focused research is needed to verify these conclusions.

AUTHOR CONTRIBUTIONS

P.S. developed the theoretical formalism, collected data, L.R. performed statistical data processing, D.F. supervised the project.

SUPPORTING AGENCIES

DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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