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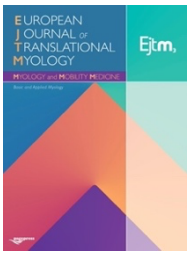

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Exploring the relationship between Total Athleticism score and CrossFit® Open Performance in amateur athletes: single measure involving body fat percentage, aerobic capacity, muscle power and local muscle endurance

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Abstract

There has been an increasing interest among CrossFit® coaches and practitioners in identifying indicators of sport performance. This study aimed to examine the correlation between anthropometric measures, cardiorespiratory capacity, power, local muscle endurance, and total athleticism score, with performance in the CrossFit® Open 2021. Fourteen male volunteers (aged 30.3 ± 5.8 years) participated in the study and underwent a series of tests on separate weeks. These tests included assessments of body fat percentage (subcutaneous adipose thickness measured at seven sites), maximal oxygen consumption (2 km test in rowing ergometer), muscle power (one repetition maximum in power clean), and muscle endurance (Tibana test, which included the conclusion of four distinct rounds of work). These results were used to calculate the total score of athleticism, which was then compared to the participants performance during the CrossFit® Open 2021. The athletes presented an average of body fat (8.6 ± 2.0%), maximal oxygen consumption (53.3 ± 2.4 mL. $(kg.min)^{-1}$), 2km row time (07:00 ± 00:21 mm:ss), 1-Repetition maximum in power clean (125.2 ± 21.2 kg) and Tibana test performance (281.0 ± 35.9 repetitions). Interestingly, the top five athletes with the highest scores also achieved the highest z-scores in the CrossFit® Open 2021.

Conversely, the four athletes with the lowest TSA score had the lowest z-scores in the CrossFit® Open. Moreover, almost perfect correlation ($r = 0.91$; $p<0.01$) was found between the total athleticism score and z-scores in the CrossFit® Open 2021. The total score may be a single measure and holistic indication of athleticism level in CrossFit®. Furthermore, coaches can potentially apply this useful tool for monitoring athletic performance and designing training sessions that address specific areas of CrossFit® performance.

Key words: high-intensity functional training; performance prediction; athleticism.

Functional fitness training characterizes one of the main trends in exercise science and practice in the last years, a type of training that incorporates aerobic capacity, strength, bodyweight endurance, bodyweight skills, and power.[1, 2] Functional fitness training continues to rank in the top 20 fitness trends of 2023 around the world.[3] CrossFit® (CrossFit, Inc., Washington, DC, USA) is a type of functional fitness training.[1] The growth of this fitness trend is exponential and can be explained due to psychological aspects,[4, 5] including people who are interested in health and physical fitness but also performance, through competitions.

The competitions of CrossFit® are based on a first stage – called The CrossFit® Open. This is an online competition considered one of the largest sports events in the world.[6] People at least 14 years old and with different levels of physical fitness could participate worldwide. There has been an increase in participation in the CrossFit® Open in the last five years: there were 239,106 participants in 2020, 263,529 in 2021, 294,980 in 2022, 302,240 in 2023[7] and 343,528 athletes in 2024. In 2021, only the top 10% of athletes advanced for the next stage of the competition (quarterfinals), and then number of athletes who advanced to the semifinals and finally the CrossFit® Games are dependent of the region. Despite the rising popularity of CrossFit® and some recent studies have endeavored to assess performance predictors and characteristics in both the open and CrossFit benchmark workouts,[8-10] there is a lack of literature regarding the

useful and measures that evaluated global athletic performance in functional fitness training modality.

In contrast to many conventional sports, classifying and determining the factors associated with success in CrossFit® open can be challenging due to its wide-ranging demands. CrossFit® open workouts exhibit a significant characteristic: they can vary greatly in terms of intensity, duration, skills required, and physiological demands.[11] Some authors have found a relationship between markers of muscle strength,[6, 11, 12] maximal aerobic capacity,[13] body composition,[11] and local muscle endurance[6] with performance in the CrossFit® Open. However, the degree of correlation appears to vary depending on the specific type of workout being analyzed. Consequently, certain workouts seem to exhibit a correlation with metrics related to aerobic fitness, while others demonstrate a stronger association with measures of power and muscle strength.

In accordance with Turner *et al.*,[14] the Total Athleticism Score (TSA) is a comprehensive assessment that comprises various physical performance feats considered crucial for success in a specific sport. It employs standardized scores, such as z-scores and t-scores, derived from a series of testing batteries. This approach enables practitioners to gain insights into individual athletes' performance within the context of their partners,[15] besides to establishing a ranking for the team. Consequently, a benefit arises when the coach furnishes a consolidated score for the athlete's physical fitness instead of dissecting each test result separately. This method can facilitate an efficient communication between coaches and athletes, optimizing the monitoring of athletic performance declines or evolutions.[16] This assessment serves as a valuable tool to better understand and enhance athletes' capabilities in their respective sports[15] and different activities have their own specific criteria for assessing athleticism[15] However, in CrossFit® there is no numerical score for athleticism; instead, coaches evaluate athletes based on a combination of skills, including local muscle endurance, speed, strength, power, and endurance.

The unknown demands of the workouts, the varying nature of the past competitions, and the restricted opportunity for athletes to gain specific competition experiences.[6] In contrast to other individual or team sports, scores that determined athleticism in CrossFit® are not yet known. To the best of our knowledge, no prior study investigated the TSA with CrossFit® performance in the context of actual competitions, rather than the standardized Workouts Of the Day (WODs) that athletes have been

previously exposed. Therefore, the investigation represents a pioneering effort to examine the correlation between anthropometric measures, cardiorespiratory capacity, power, local muscle endurance, and total athleticism score, with performance in the CrossFit® Open 2021. We hypothesize that athletes with the highest TSA score achieved the highest z-scores in the CrossFit®, indicating that this single assessment can be helpful for screening the athletic performance.

Materials and Methods

Participants

In total, 14 male volunteers with an average age of 30.3 ± 5.8 years were recruited. Participants recruited for the study had been actively participating in CrossFit® training sessions more than four times per week, and they were recruited through personal contact. All subjects were free of injury or known illnesses, were not using performance enhancing drugs, had at least 2 years of experience practicing with CrossFit®, and were familiar with the tests analyzed. Participants were advised to sleep six to eight hours the night before the tests, maintain regular nutritional and hydration habits, avoid intense exercise 48 h prior to the sessions, and avoid smoking, alcohol, and caffeine consumption 24 h before. All subjects provided informed consent and the study was approved by the University Research Ethics Committee for Human Use (2.698.225/Universidade Estácio de Sá/UNESA/RJ and ethics ID Pro00110581) and conformed to the principles of the Helsinki Declaration on the use of human participants for research.

Experimental design

The present study followed a cross-sectional design. All participants performed the baseline assessments two weeks prior to the CrossFit® Open 2021 (five workouts for 5 weeks) (February–March 2021). Figure 1 shows schematic illustration of the methodological steps in the present study.

Anthropometric and body fat measurements

Anthropometric measurements were conducted in the morning, with the subjects wearing light clothing and no shoes. The participants' weight was recorded using a Filizola® digital scale (Curitiba, PR, Brazil), with a capacity of 180 kg and precision to the nearest 0.1 kg. Standard methods recommended by the International Society for the Advancement of Kinanthropometry [17] were employed for each subject's measurements.

Body composition was assessed via skinfold technique (Lange® caliper, Cambridge Scientific Industries, Inc, Cambridge, MD). Subcutaneous adipose thickness was measured at seven sites (subscapular, chest, axilla, triceps, suprailiac, abdominal, and thigh) on the right side of the body. Once the fat thicknesses were recorded for each of the seven sites, body density was estimated using the Jackson-Pollock[18] generalized skinfold equation and percent body fat was estimated using the Siri equation.[19]

Maximal oxygen consumption

Indirect maximal aerobic capacity (VO_2 max) was assessed via a maximal 2-km rowing test.[20] For all exercise tests, a consistent rowing ergometer (model E; Concept 2, Morrisville, VT, USA) was utilized. Each subject individually adjusted their preferred stroke rate and drag factor during both the tests and the warm-up protocol. The standardized warm-up for the 2 km time trial consisted of the following: i) 4 minutes of easy rowing; ii) 4 sets of 1-minute rowing intervals with increasing intensity, including 10 hard strokes, 15 hard strokes, 20 hard strokes, and 10 hard strokes for each respective minute; iii) 2 minutes of easy rowing for recovery.

After a short rest the 2 km all-out time trial was performed. During this trial, participants exerted maximal effort to complete the 2 km distance.

Local muscle endurance

The Tibana test was applied to assess local muscle endurance. The section is characterized by metabolic conditioning demand and involves habitual functional fitness training exercises. The athletes were instructed to complete the maximum number of repetitions possible for each round.[21] Specifically, this test consisted of four distinct rounds of work, each separated by 2 minutes of rest.[6] The rounds were structured as follows: Round 1: Participants performed 4 minutes of As Many Rounds

As Possible (AMRAP) of five thrusters (60 kg for men and 43 kg for women) and 10 box jumps; Round 2: Participants performed 4 minutes of AMRAP of 10 power cleans (60 kg for men and 43 kg for women) and 20 pull-ups; Round 3: Participants performed 4 minutes of AMRAP of 15 shoulder to overhead lifts (60 kg for men and 43 kg for women) and 30 toes to bar; Round 4: Participants performed 4 minutes of AMRAP of 20 calories of rowing and 40 wall balls (9 kg for men and 6 kg for women).

CrossFit® Open 2021

The specific details of the five workouts used in this study, known as 21.1, 21.2, 21.3, and 21.4, are briefly explained below: i) 21.1: Participants had 15 min to complete 1 wall walk, 10 double-unders, 3 wall walks, 30 double-unders, 6 wall walks, 60 double-unders, 9 wall walks, 90 double-unders, 15 wall walks, 150 double-unders, 21 wall walks, and 210 double-unders; ii) 21.2: Participants had 15 min to complete 10 dumbbell snatches (22.5 kg), 15 burpee box jump-overs (60 cm), 20 dumbbell snatches, 15 burpee box jump-overs, 30 dumbbell snatches, 15 burpee box jump-overs, 40 dumbbell snatches, 15 burpee box jump-overs, 50 dumbbell snatches, and 15 burpee box jump-overs; iii) 21.3: Participants had 15 min to complete 15 front squats (45 kg), 30 toes-to-bars, 15 thrusters. Then, rest 1 minute before continuing with: 15 front squats, 30 chest-to-bar pull-ups, 15 thrusters. Then, rest 1 minute before continuing with: 15 front squats, 30 bar muscle-ups, and 15 thrusters; iv) 21.4: Participants had 7 min to complete the following complex for maximal load: 1 deadlift, 1 clean, 1 hang clean, and 1 jerk.

Total score of athleticism and z-score during the CrossFit® Open 2021

The total score of athleticism is derived by averaging a set of standardized scores (z-scores) from a series of tests undertaken by an athlete.[14, 22] A standardized score (of a single test or measure), and therefore the TSA (of a series of tests), allows coaches to examine contextualized data of individual athletes relative to their teammates and thus set benchmarks and training goals that are realistic to the demands placed on players by the club.[14]

In this study, the TSA was derived by averaging the z-scores of four tests or measures: percentage of body fat, time of 2 km row, power clean weight and Tibana test. To calculate the z-score for each test, the squad's average test score (n = 14) is subtracted from the athlete's test score, then this value is divided by the squad's standard deviation (SD). Thus, the equation reads as follows: z-score = (athlete score – team mean)/team SD. The score of 2 km row test and body fat were multiplied by -1 to ensure positive z-scores for the best results. Finally, the TSA was calculated by averaging all z-scores (body fat z-score, 2 km row z-score, power clean z-score and Tibana test z-score). A z-score of the CrossFit® Open 2021 was also calculated using the same methodology as the TSA to rank the results of the athletes. Z-score of the CrossFit Open 2021 was calculate by averaging the z-cores of the 2021.1, 2021.2, 2021.3 and 2021.4 benchmarks.

Statistical analysis

The data are expressed as mean value ± standard deviation (SD). Shapiro–Wilk test was used to check for parametric distribution of study variables. Simple Pearson's r correlations were used to determine the associations between the results of CrossFit® Open 2021 and the athletic performance measures. The magnitude of the correlations was classified as: $r \leq 0.1$ trivial; $0.1 < r \leq 0.3$ small; $0.3 < r \leq 0.5$ moderate; $0.5 < r \leq 0.7$ large; $0.7 < r \leq 0.9$ very large; $r > 0.9$ almost perfect.[23] The power (1-ß) of the Pearson r coefficient of correlation was calculated afterward (post hoc) using the sample size of this research (n = 14), an alpha equal to 0.05 and the r coefficient effect size for each correlation. Calculation of values was performed using G*Power Software (version 3.0.10, Germany) and we detected values above 80% for most correlations (exact values for each correlation presented in the results section). The level of significance was $p \leq 0.05$ and SPSS version 20.0 (Somers, NY, USA) software was used.

Results

Anthropometric and performance data presentation

The anthropometric profile, cardiorespiratory, and muscle strength values are reported in Table 1. As expected, the athletes have a low body fat percentage (8.6 ±

2.0%) and proper performance metrics (aerobic capacity, muscle power and endurance). Table 2 reports the repetition values obtained in Open 2021.1, as well as the time performed in Open 2021.2 and Open 2021.3. Finally, the load (kg) performed Open 2021.4 is reported.

Athlete values of the total score of athleticism

Figure 2 displays the radar chart plot with a series of values over multiple quantitative variables on axes starting from the same point. It is equivalent to a parallel coordinates plot, with the axes arranged radially, indicating t-scores of athlete as part of squad fitness testing. Dark colors represent higher values (green), while light colors represent lower values (red). Figure 3 shows each athlete's TSA score (expressing as a z-score; Figure 1A) and the z-score achieved during the four workouts of the CrossFit® Open 2021. The five athletes with the highest TSA score were the five athletes with the highest z-score of the CrossFit® Open 2021(Figure 3A). On the other hand, the four athletes with the lowest TSA score were the four athletes with the lowest z-score of the CrossFit® Open (Figure 3B).

Relationship between total athleticism score and CrossFit® Open performance

There was no statistically significant correlation between body fat percentage, CrossFit® Open performance and z-score ($p>0.05$). However, 2 km row test, VO_2 max, Power Clean, Tibana test and TSA had relationship with z-score in the CrossFit® Open 2021 ($p<0.01$). The specific r and p-values are shown in Table 3.

Discussion

The aim of this study was to examine the correlation between anthropometric measures, cardiorespiratory capacity, power, local muscle endurance, and total athleticism score, with performance in the CrossFit® Open 2021. First, we observed that muscle strength and endurance had a strong relationship with CrossFit® Open 2021 performance. Confirming our initial hypothesis, the findings indicated that the top five athletes with the highest TSA score also achieved the highest z-scores in the CrossFit®

Open 2021, and the four athletes with the lowest TSA score had the lowest z-scores in the CrossFit Open. Moreover, almost perfect correlation (r = 0.91) was found between TSA score and z-scores in the CrossFit® Open 2021, suggesting that the change in value of one variable is exactly proportional to the change in value of the other. Thus, the total athleticism score may be a single measure and holistic indication of athleticism level in CrossFit®. The Figure 4 clarifies of the concept, main outcomes, and practical applications of TSA score in CrossFit® context.

It has been reported that that when CrossFit® Open workouts consist of multiple rounds, competitors should employ a fast and sustainable pace to improve performance.[24] Furthermore, previous investigations found an association between muscle strength,[6, 11, 12] aerobic capacity,[13, 25] body composition,[11] and local muscle endurance[6] with performance in specific competitions. Nevertheless, the relationship between fitness measures and performance differs dramatically according to exercises that predominate in WOD, suggesting that isolated tests may not reflect the athletic profile. Considering that real-world sporting practice contemplates the different physical demands, athletic endeavors, and fitness components, a practical method that provides a single score of holistic fitness is required. Thus, TSA approach can help with planning and ranking, especially when there is team competition.

It is significant to highlight that z-score fluctuations are influenced by team mean or individual changes. Therefore, the values may not be directly transferable to all athlete levels. Furthermore, is recommended that coaches rationalize the fitness tests utilized in TSA, since the strengths and performance weaknesses of each athlete can be different. Future studies that instigate different test battery, competitions, and athlete levels are required, to elucidate the TSA validity involved in the distinct contexts.

Sports performance requires effective communication and interdivisional planning for the athlete. According to Turner *et al*.,[14] the TSA scores is an easy way to compile a clean number to label athletes against one another.[15] The histograms layouts may provide a logical and easy method to understand the ranking data, but not an end-all-be-all report. Adding other metric combinations that help explain multiple abilities in CrossFit®, the TSA report will become more robust in enhancing decision- making.

Concerning practical applications, coaches can utilize the TSA rather than separately each individual test performance, since the scores allow for the examination

of individual contextualized data relative to other athletes. As a result, there is an advantage when the coach provides a unified score for the athlete's physical fitness rather than analyzing each test result independently. This approach can enhance communication efficiency between coaches and athletes, optimizing the tracking of changes or advancements in athletic performance. Hence, the TSA can be valuable for monitoring athlete development over time and longitudinally.

Additionally, TSA can be useful in identifying possible deficient athletic performance, as well as designing realistic strategies in a particular competition. For example, the four athletes with the lowest TSA score in current study could have benefited from targeted multicomponent training, with a particular focus on restoring a several skills (muscle strength, cardiovascular, and local muscle endurance). Therefore, the TSA screening might offer well-organized information for a guide training program, besides establishing the distribution of the training session based on the demands that athletes will be exposed to different WODs.

Despite the transformation into a worldwide public sporting event, few studies were carried out on the appropriate predictor parameters that have a significant impact on CrossFit® performance. In the CrossFit® Games, the WODs are declared shortly before or even during the competition.[26] Consequently, the athletes are unable to prepare precisely for a particular performance. In this way, athletes should achieve full fitness to optimally cope with any conceivable challenge, including unknown physical demands. Hence, the continuous variation of the training program can be important, which reinforces the real importance of employment of the TSA score.

It is important to acknowledge certain limitations in our investigation. First, the regional athletes, amateur level and relatively small sample size may limit the generalizability of our findings. Second, the specific competition analyzed does not contain all powerlifting, weightlifting, and gymnastics exercises, which may not be directly transferable to other competitions with different WODs. Lastly, the cross-sectional design avoids the ability to detect causal relationship between variables.

Conclusions

In summary, athletes with the highest TSA score achieved the highest z-scores in the CrossFit® Open 2021. Furthermore, a strong correlation was found between TSA score and z-scores in the CrossFit® Open 2021, suggesting that this assessment can be helpful in screening the performance predictors in a particular competition. The findings of this investigation may be of interest to coaches working with CrossFit® athletes who aim to maximize their success by evaluating their physical fitness and designing training sessions that address their specific areas of improvement performance.

List of abbreviations:

AMRAP: as many rounds as possible

Kg: Kilogram

mL: Milliliter

SD: Standard Deviation

TSA: Total Athleticism Score

$VO_{2\ max}$: Maximal oxygen consumption

WODs: Workouts of the Day

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Contributions: all authors equally participated in developing this study and in writing the typescript. All authors read and approved the final edited typescript.

Conflict of interest: the authors declare they have no financial, personal, or other conflicts of interest.

Ethics approval: the Ethics Committee of Institution approved this study (2.698.225/Universidade Estácio de Sá/UNESA/RJ and ethics ID Pro00110581). The study is conformed with the Helsinki Declaration of 1964, as revised in 2013, concerning human and animal rights.

Informed consent: all patients participating in this study signed a written informed consent form for participating in this study.

Patient consent for publication: written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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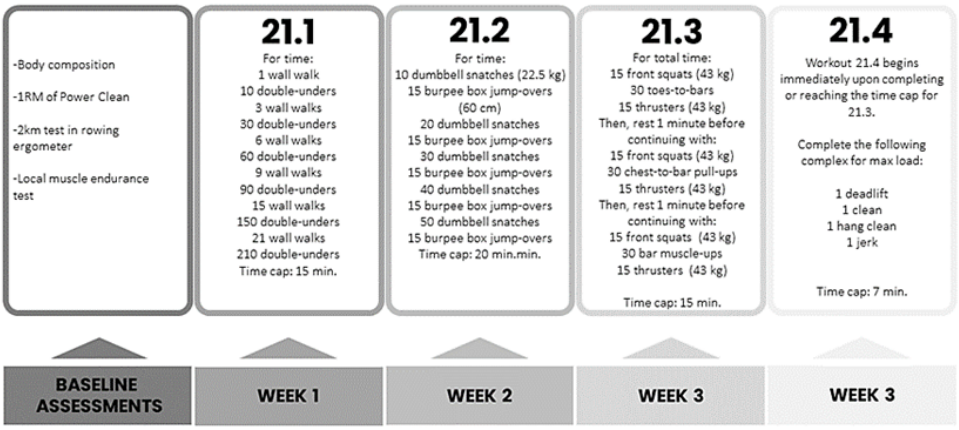

Figure 1. Description of study timeline.

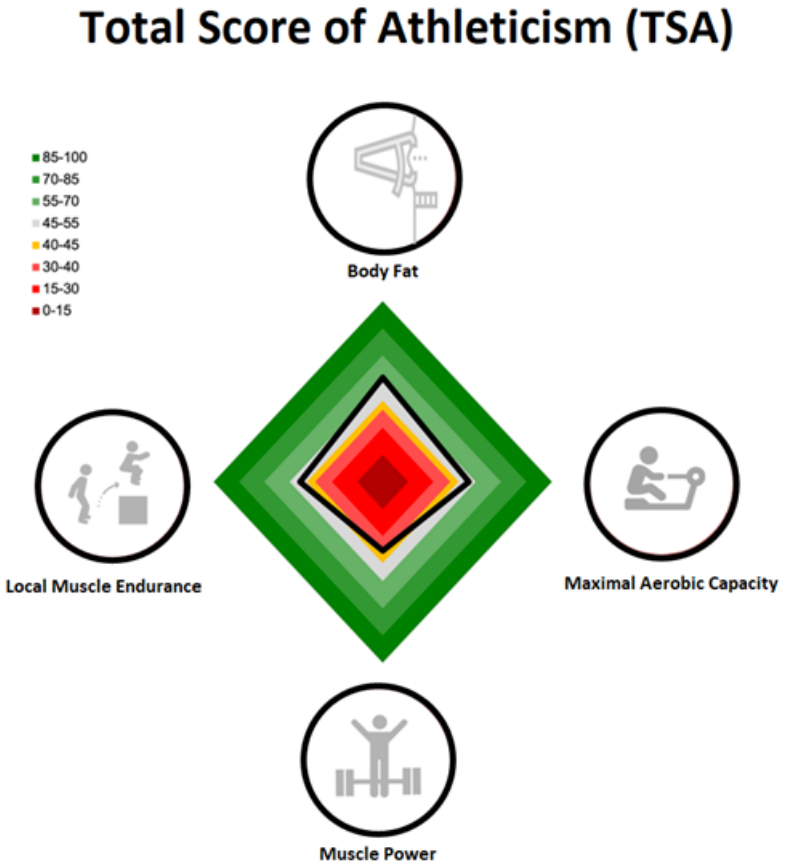

Figure 2. The Total Score of Athleticism was derived by averaging the z-scores of four tests or measures: percentage of body fat, time of 2 km row, power clean weight and Tibana test. To calculate the z-score for each test, the squad's average test score (n = 14) is subtracted from the athlete's test score, then this value is divided by the squad's standard deviation (SD); so, the equation reads as follows: z-score = (athlete score – team mean)/team SD.

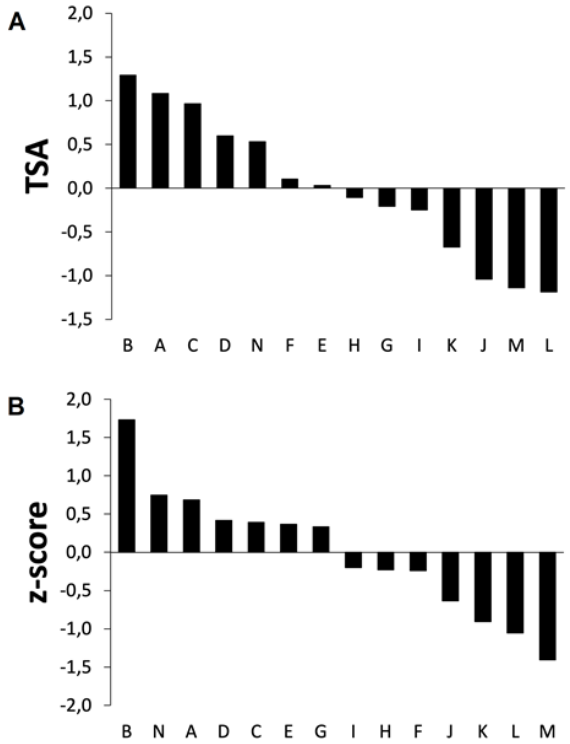

Figure 3. Plotting each athlete's total score of athleticism (TSA) score (A) with the z-score of the CrossFit® Open 2021 (B). The TSA and the z-score have been ranked from highest to lowest.

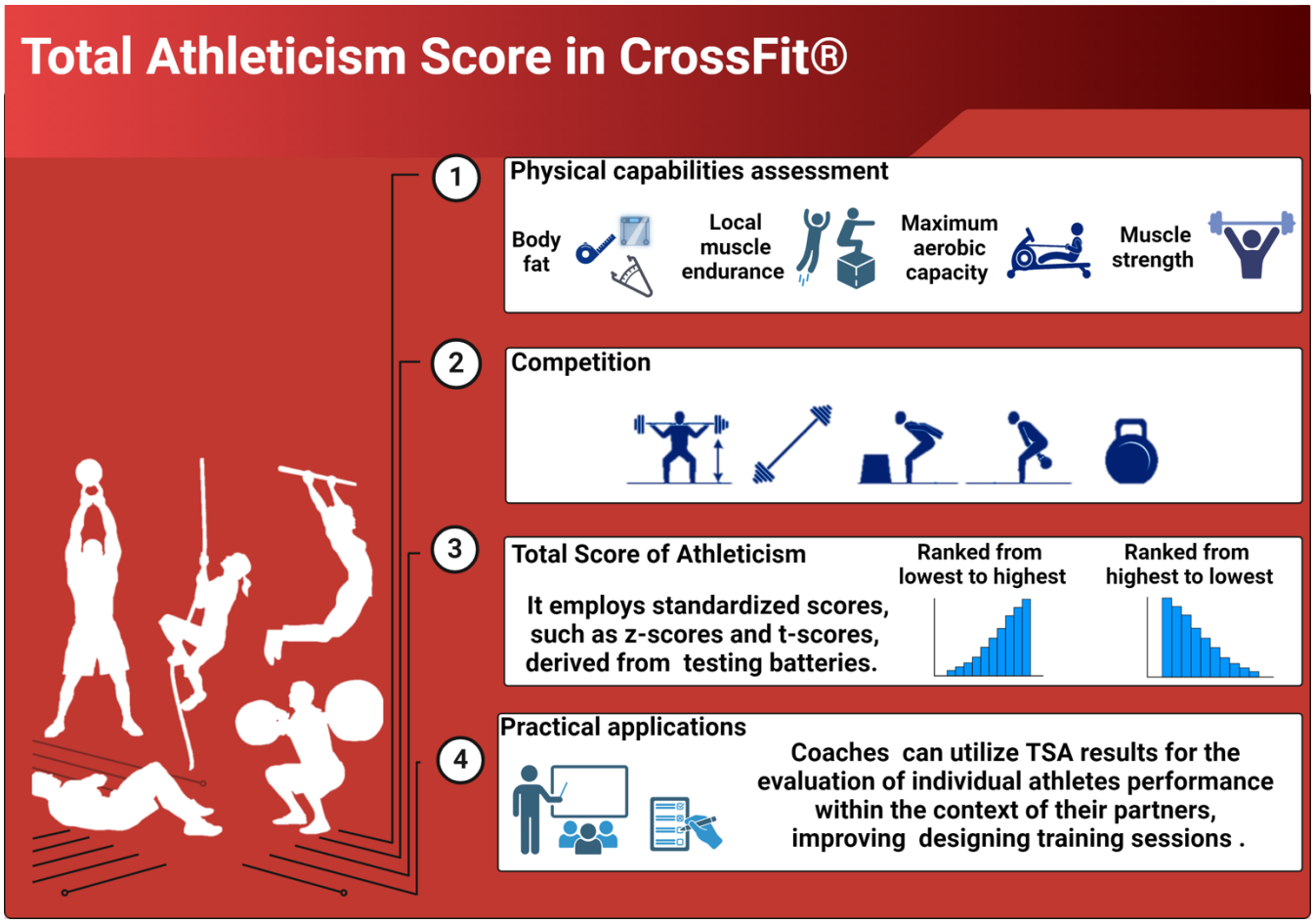

Figure 4. Schematic description of the concept, main outcomes and practical applications of total score of athleticism (TSA) score in CrossFit® context.

Table 1. Anthropometric and performance measurements of the athletes (mean ± SD)

	n = 14
Body weight, kg	84.2 ± 6.2
Body fat, %	8.6 ± 2.0
Maximal oxygen consumption, $L.min^{-1}$	4.49 ± 0.44
Maximal oxygen consumption, $mL.(kg.min)^{-1}$	53.3 ± 2.4
2 km row, time (mm:ss)	07:00 ± 00:21
Power clean, kg	125.2 ± 21.2
Tibana test, repetitions	281.0 ± 35.9

Table 2. CrossFit® Open 2021 results

	n = 14
Open 2021.1, repetitions	407.3 ± 58.4
Open 2021.2, time (mm:ss)	13:55 ± 02:10
Open 2021.3, time (mm:ss)	12:25 ± 02:05
Open 2021.4, kg	113.1 ± 19.1

Table 3 – Correlations between CrossFit® Open 2021 benchmarks and the body fat and performance measures (n = 14)

	2021.1	2021.2	2021.3	2021.4	z-score
Body fat, %					
r (p-value)	-0.27 (0.36)	0.41 (0.15)	0.42 (0.14)	-0.25 (0.40)	-0.40 (0.16)
Power (1-ß)	0.14	0.30	0.31	0.13	0.29
2 km row, time					
r (p-value)	-0.55 (0.04)*	0.76 (<0.01)**	0.78 (<0.01)**	-0.75 (<0.01)**	-0.85 (<0.01)**
Power (1-ß)	0.55	0.96	0.98	0.95	1.00
$VO_{2\ max}$, $L.min^{-1}$					
r (p-value)	0.31 (0.27)	-0.73 (<0.01)**	-0.71 (0.01)**	0.71 (<0.01)**	0.73 (<0.01)**
Power (1-ß)	0.18	0.92	0.89	0.89	0.92
$VO_{2\ max}$, $mL.(kg.min)^{-1}$					
r (p-value)	0.08 (0.78)	-0.37 (0.19)	-0.19 (0.51)	0.14 (0.62)	0.24 (0.42)
Power (1-ß)	0.04	0.25	0.09	0.07	0.12
Power Clean, kg					
r (p-value)	0.25 (0.39)	-0.63 (0.02)*	-0.88 (<0.01)**	0.94 (0.01)***	0.81 (<0.01)**
Power (1-ß)	0.13	0.73	1.00	1.00	0.99
Tibana test, repetitions					
r (p-value)	0.62 (0.02)*	-0.87 (<0.01)**	-0.87 (<0.01)**	0.77 (0.01)**	0.94 (0.01)***
Power (1-ß)	0.71	1.00	1.00	0.97	1.00
TSA					
r (p-value)	0.51 (0.06)	-0.81 (<0.01)**	-0.90 (<0.01)***	0.82 (<0.01)**	0.91; (<0.01)***

Power (1-ß)	0.47	0.99	1.00	1.00	1.00

Note: $VO_{2\ max}$, maximal oxygen consumption; TSA, total score of athleticism; *large correlation; **very large correlation; ***almost perfect correlation

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