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# The influence of flexibility on maximum strength performance in the *overhead squat movement* in crossfit™ practitioners

## Summary

The objective of the present study was to evaluate the influence of ankle, hip and shoulder flexibility on relative maximum strength performance, through the one repetition maximum (1RM) test, in the overhead squat movement (OHS) in CrossFit ™ practitioners. 52 individuals of both sexes who practiced CrossFit ™ were investigated in two boxes based in the cities of Canoas and Gravataí, Rio Grande do Sul, Brazil. The results showed that general flexibility presents a positive, weak and non-significant correlation with the relative strength of OHS (ρ=0.0152; p=0.9159). Stratifying by joint and sex, for women, a weak, positive and non-significant correlation was found between relative OHS strength for the ankle joint (ρ=0.1556; p=0.4477) and weak, negative and non-significant correlations for the hip and shoulder joints (ρ=-0.0256, -0.0369; p=0.9008, 0.8579) respectively. For men, weak, positive and non-significant correlations were found in the ankle, hip and shoulder joints (ρ=0.0395, 0.3012, 0.2523; p=0.8480; 0.1348; 0.2136), respectively. Despite showing slightly greater positive associations for male individuals, linearity cannot be asserted between the variables analyzed.

**Keywords:** flexibility, *overhead squat,* crossfit ™; strength

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**Abbreviations:** 1RM, one repetition maximum; OHS, overhead squat movement; FMS™, functional movement systems; DS, deep squat test; PP, post-pubertal; JPI, young in the initial period; JPC, young in the consolidation period; TMI, mid-life transition; MI, middle age; DF, limited dorsiflexion; ROM, range of motion; FAS, front of the body; PNF, proprioceptive neuromuscular facilitation; MTU, musculotendinous stiffness

## Introduction

CrossFit ™ is one of the fastest growing conditioning programs in terms of number of followers,[1] and aims to create a comprehensive, generalized and inclusive training model. It basically consists of constantly varied functional movements, performed at high intensity. One of the main objectives of the training system is to develop physical fitness. For CrossFit Inc. an individual is physically fit when they are proficient in the ten physical skills, which are: cardiorespiratory endurance, strength, vigor, power, speed, coordination, flexibility, agility, balance and precision.[2]

Generally speaking, flexibility is an important element of general physical conditioning, as it has numerous benefits in different sports, in addition to being essential for functional independence when carrying out daily activities. For example, movements involving joints with limited flexibility tend to be performed with lower mechanical efficiency, greater energy expenditure and a higher incidence of pain.[3] Accordingly, studies have shown that to achieve success in various sports and martial arts it is necessary for the practitioner to be proficient in specific flexibility patterns.[4] In particular, increased dynamic flexibility favors the efficiency of the movement as a whole.[4] When the body is strong in the final range of movement, the chances of success in executing the concentric phase of the exercise increase, as an increased range of movement can allow greater stretching in the muscles involved and, as a result, these are capable of producing forces larger due to the stored elastic energy.[4] CrossFit ™ workouts encompass Olympic weightlifting exercises (such as squats, snatches, clean and presses), aerobic exercises (such as rowing, running and cycling) and gymnastic movements (such as handstands, dips, rings and pull-ups). Among the physical aspects and exercises involved in CrossFit ™, the points of interest in this research were flexibility and the overhead squat (OHS), an Olympic weightlifting movement, in which the subject squats holding the bar above their head.

OHS works on the efficient transfer of energy between large and small parts of the body. Although it seems extremely simple, it requires correct adherence to the movement technique, creating a lot of difficulty and discomfort for the majority of CrossFit ™ practitioners. In the starting position, the feet are kept shoulder-width apart, the arms are extended above the head, with the shoulders flexed at 180° and the elbows in full extension, the hands are positioned so that the grip on the bar is away. The shoulders, at the same time as they push the bar upwards, have a slight medial rotation to favor the activation of the muscles in the dorsal region, which, in turn, help to stabilize the load above the head. During the execution of the movement, it begins with flexing the hips followed by flexing the knees, which must remain aligned with the little toes; in this way, the hips assume a slight lateral rotation. The lumbar curvature must be maintained throughout the movement. The end of the eccentric phase of the movement is reached when the knee joint assumes an angle of less than 90°. The heels must remain in contact with the ground at all times, requiring range of dorsiflexion movement. Finally, the movement is completed with full extension of the hips and knees, returning to the starting position.[5] During the execution of the OHS, the trunk and arms must be kept still, or with as little oscillation as possible.

According to Glassmann,[5] OHS demands and develops functional flexibility and, in the same way, develops the squat by mercilessly amplifying and punishing any error in posture, movement and stability. Swings of the load forward generate a huge and instantaneous increase in torque on the hips and back. When the bar is held perfectly still above the head, the OHS does not cause overload on the hips and back; however, moving too quickly, in the wrong line of action, or swaying makes even the lightest loads challenging and can therefore cause injury to practitioners. Given this, the objective of the present study was to explore the associations between the flexibility of ankles, hips and shoulders in the performance of relative maximum strength, through the one repetition maximum test (1RM), in the OHS movement in CrossFit ™ practitioners.

## Methods

The present study was approved by the Research Ethics Committee of La Salle University, according to opinion nº 4,428,922 of 11/30/2020 and met Brazilian guidelines in accordance with CNS resolution 466/12. A descriptive-correlational method with a quantitative and transversal approach was used, in order to identify and describe the characteristics of a given sample in a single data collection.

The field of study were two CrossFit ™ boxes, located in the cities of Canoas and Gravataí, Rio Grande do Sul, Brazil. An intentional sample was used, chosen according to the availability and accessibility of volunteers of both sexes, aged between 18 and 65 years old, CrossFit ™ practitioners , with any training time, duly registered in the CrossFit ™ boxes who had a medical certificate attached to their registration forms that cleared them to practice physical exercises and who have obtained grades 2 or 3 in the deepsquat test described in the FMS™ (Functional Movement Systems*)* protocol by Sttovia et al.[6] Volunteers who did not sign the written informed consent and who had any physical condition that prevented them from performing any of the procedures during data collection were excluded from the study.

According to those responsible for the two boxes at the time of conducting the study, the population of enrolled students was 230 individuals. According to the sample size calculation proposed by Barbetta,[7] (assuming a sampling error of 5%), the minimum number of subjects tested should be 146 individuals. However, the final sample size was 52 individuals. Because data collection took place on different days, some individuals who participated in the first data collection, which was 1RM back squat, were absent from the following class, in which the 1RM OHS was collected. The Covid-19 pandemic also influenced the final sample size, as the interval between the first and second data collection was long due to the closure of the CrossFit ™ boxes due to municipal decrees. Due to this contingency, in this period of time, some students stopped training, moved, or changed CrossFit ™ boxes. Data collection was carried out throughout classes, between the months of January and May 2021 in the *boxes*, after participants signed the TCLE.

In the first stage of data collection, the deep squat test (DS) was applied as a criterion for inclusion in the sample, on random days, and the participants did not have any type of prior warm-up, in accordance with what was proposed in the FMS manual. Flexibility assessment was carried out using the Flexiteste protocol, described by Araújo and Pável (2005), involving the hip joints (flexion, abduction, adduction and extension), ankles (dorsal flexion and plantar flexion) and shoulders (extension/ posterior adduction of the shoulder, posterior extension of the shoulder, lateral rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, medial rotation of the shoulder with abduction of 90° and flexion of the elbow at 90° and posterior adduction from abduction 180° at the shoulder) tested for maximum passive amplitude. On the same day, body mass and height were measured (using a scale with a stadiometer by Filizola™) in order to characterize the profile of the sample. The sample was classified according to strength levels using the 1RM back squat test (squats with the bar on the shoulders), in order to minimize the interference of pre-existing strength in the analysis of the data obtained.

The second stage of data collection was carried out simultaneously with the CrossFit ™ classes, divided into three moments. At first, on a previously scheduled date, the day's training consisted of 1RM back squat. Secondly, on another day, the 1RM overhead squat was performed in the same way. In these two moments, in the first phase of the class, a joint warm-up and a general warm-up were carried out, focused on the movement that would be performed on the day. In the next phase of the class, there was a technical leveling to adjust the execution of the movements. The back squat and OHS movements followed the execution standard proposed by CrossFit Inc.

The third moment included both tests, which were performed following the protocol proposed by Andrade et al.[8] A specific warm-up was carried out, in which participants performed five to ten repetitions of the proposed movement using around 40% to 60% of the estimated maximum load. This estimate was made by the student himself, based on prior self-knowledge, using the last maximum load recorded, or, for those who did not have previous data, the load was guided by the box coach. Then, three repetitions were performed with around 60% to 80% of estimated 1RM. After this stage, the loads were moderately increased by the performer until he performed just one successful repetition, with maximum load. Each participant had five attempts to find 1RM, and all attempts were monitored full time. The break time between each series was approximately 3 minutes.

The classification of individuals regarding muscular strength levels followed the method proposed by Kilgore,[9] which takes into account the subject's body mass and the maximum load for 1RM back squat, and were characterized as having low, medium strength low, medium, medium high or high. Regarding age, the subjects were classified as post-pubertal (PP) (14 to 20 years old), young in the initial period (JPI) (20 to 30 years old), young in the consolidation period (JPC) (30 to 40 years old), mid-life transition (TMI) (40 to 45 years) and middle age (MI) (45 to 60 years) as proposed by Gallahue et al.[10]

Regarding flexibility levels, the general *score* obtained in the Flexiteste was used, which took into account the sum of the points obtained in the test for each joint divided by the number of tests applied. In this way, individuals were classified as having low flexibility (0 to 1 points), low average (1 to 2 points), high average (2 to 3 points) and high (3 to 4 points). was carried out using descriptive statistics and graphical data visualization techniques to understand the sample, identify *insights* into trends and correlate the data collected. *Python* programming language was used to create the script in the *Jupyter Notebook tool*. Two groups of analyzes were performed: descriptive data analysis and correlational analyses. Distribution analysis allowed a decision to be made regarding the use of parametric or non-parametric instruments. The second and final group of calculations included correlational analyses, in order to obtain the intensity, sign and significance level of the correlations (*Spearman 's ρ*), which analyzes the intensity and direction of the monotonic relationship between two continuous or ordinal variables. Thus, the exploration of the scores obtained by the instruments followed the guiding principles commonly accepted in specialized literature.[11] A p-value of 0.05 was assumed.

## Results

The present study explored the levels of flexibility, muscular strength and maximum load for 1RM OHS in 52 CrossFit ™ practitioners, 26 of whom were women and 26 men, with a mean age of 31 ± 7 years; mean BMI of 26.69 ± 3.71 kg/cm$^2$; average practice time of 3.16 ± 2.08 years, with all individuals having at least 5 months of practicing the modality. All results obtained in the 1RM OHS test were converted to OHS relative strength (percentage of the maximum load obtained in the back squat test) and then called % backsquat. It is reasonable to assume that an individual with greater muscular size has better results in the 1RM tests in both movements, which is why this method was adopted, in order to prevent pre-existing brute strength from interfering with the results obtained when compared with the levels of flexibility.

Given the physiological specificities that characterize and differentiate men from women, classification by sex was adopted in order to obtain more assertive insights in the following analyses.

Figure 1 shows that based on the strength distribution of the sample according to gender, it is possible to infer that women had higher levels of strength than men, within this sample group, for the exercise used for this characterization (back squat).

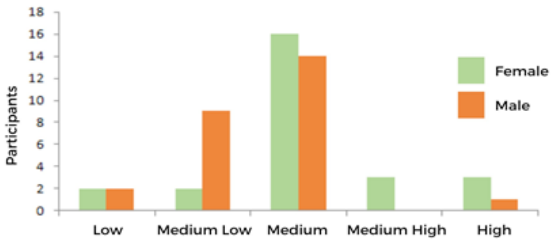


**Figure 1** Distribution of strength according to sex.

Figure 2 presents the distribution of the relative strength of OHS (%backsquat) depending on the sex of the individuals, through which it is possible to verify that men presented higher percentages than women. Women had an average % back squat of 58.6% ± 8.94, while men had an average % back squat of 62.74% ± 10.91 (Figure 3).

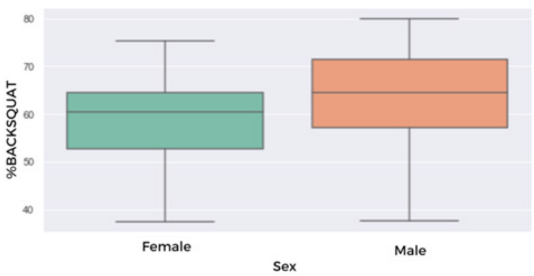


**Figure 2** Distribution of % *backsquat* (kg) by sex.

It can be seen, when comparing Figures 1 and 2, that women obtained better results in terms of strength characterization (Figure 1). For this characterization, the back squat exercise was used, as mentioned previously. However, when analyzing the results of relative strength of OHS we noticed that men obtained better results (Figure 2). From these data it is possible to infer that woman had higher levels of brute strength (back squat) than men, however men had better results in relation to relative OHS strength, which is reasonable,since men had lower proportional back squat results, it would be necessary to lift less weight in OHS to obtain a higher %backsquat.

Regarding flexibility, women obtained higher test scores than men, who had greater variability in this aspect among themselves. Women had an average general flexibility score of 2.48 ± 0.38, while men had an average general flexibility score of 2.09 ± 0.46. Women were around 18.5% more flexible than men for the general flexibility score, with 15.62%, 18.1% and 21.7% more flexible for the ankle, hip and shoulder joints, respectively.

Such results allow us to infer that, since women are more flexible than men, this increased flexibility (i.e., a higher level of flexibility than already presented) does not seem to interfere with the result of relative strength of OHS. On the other hand, men showed lower levels of flexibility, suggesting that if they had greater ranges of movement, perhaps they could obtain better numbers in the %backsquat. Such data are confirmed in the correlation analysis. When crossing the general flexibility score with the %backsquat we found coefficient values ρ = - 0.0031 (p = 0.9880) for women and ρ = 0.2419 (p = 0.2337) for men. Interpreting these data, it is possible to observe that the influence of flexibility on the relative strength of OHS is almost null for the female sample group, however, for the male sample group there is a positive relationship, albeit weak, although without statistical significance.

Figures 3 to 5 show a combination of scattered data points as well as the fitted linear regression line passing through the data. This data shows a reasonable estimate of the relationship between the two variables: the strength of the correlation and the direction (positive or negative correlation). The female data set had a higher overall flexibility score and lower %backsquat than the men. This is evident when analyzing the correlations by sex (Figures 4 and 5). As for men, even though they had a lower overall flexibility score, they managed to achieve higher %backsquat. However, linearity cannot be asserted between the variables general flexibility score and %backsquat (ρ = 0.0152; -0.0031; 0.2419; p= 0.9159; 0.9880; 0.2337; general, women and men, respectively).

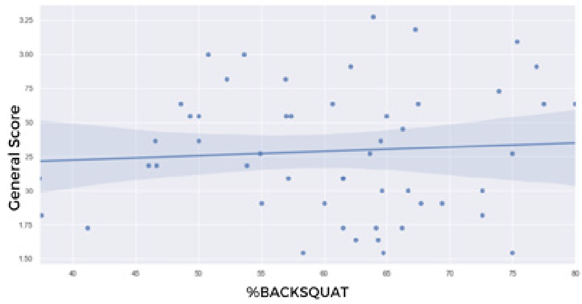


**Figure 3** Correlation between flexibility of the entire sample and % *backsquat.*

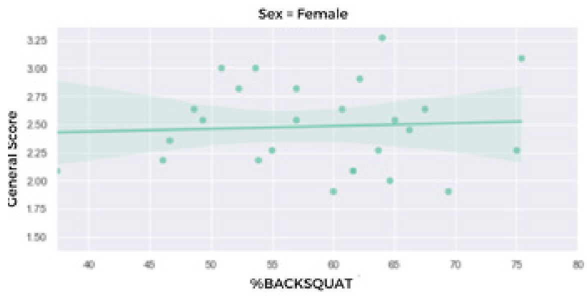


**Figure 4** Correlation between women's flexibility and % *backsquat.*

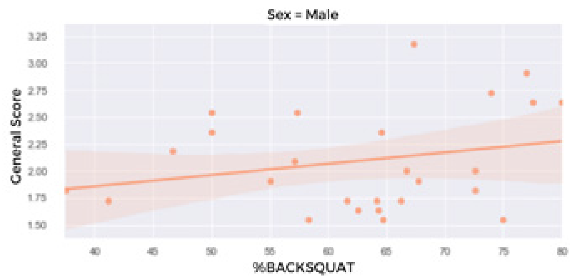


**Figure 5** Correlation between men's flexibility and % *backsquat.*

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In Figure 6, it can be seen that the %backsquat increased considerably over the years of practice time. This behavior is observed in both the women's and men's data sets (Figures 7 and 8). Women had an average practice time of 2.95 ± 0.90 years; men, 3.36 ± 2.20 years. Furthermore, this positive correlation was confirmed in the correlation analysis (ρ = 0.4761, 0.4440, 0.4257; p = 0.0004, 0.0231, 0.0301; overall, women and men, respectively). These results suggest that the relative strength of OHS is more associated with practice time than with flexibility, which seems reasonable, as over the years of practice the individual develops strength, in addition to becoming capable of refining details of the movement, which favors improved performance.

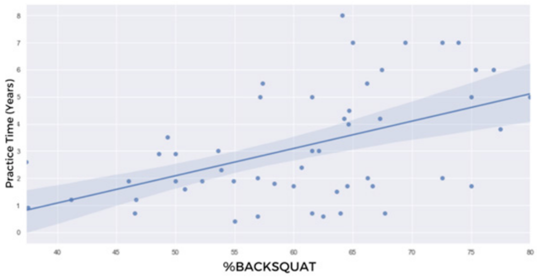


**Figure 6** Correlation between the practice time of the entire sample and the % *backsquat.*


**Figure 7** Correlation between women's practice time and % *backsquat.*

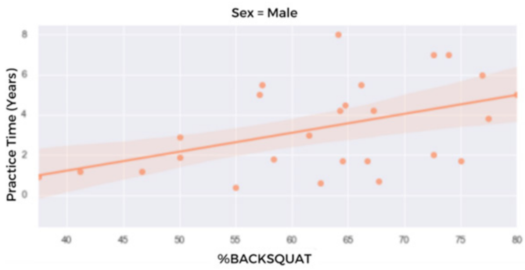


**Figure 8** Correlation between men's practice time and % *backsquat.*

Figures 9 to 11 show that, when stratifying by sex, only male individuals showed a proportional increase in the relationship between practice time and general flexibility score. This result was also evidenced in the correlation analysis (ρ = 0.1599, - 0.0401, 0.3031; p= 0.2574, 0.8460, 0.1323; overall, women and men, respectively). On the other hand, women showed a negative correlation in this regard, although the data presented in Figure 4 shows that they obtained more significant results in terms of flexibility than men. Practice time appears to have a positive relationship with flexibility for men, as all movements tested showed a positive correlation with practice time. For women, the practice time seemed to impair flexibility levels for some body segments, especially for shoulder adduction and posterior extension movements (ρ = - 0.3586, - 0.3716; p = 0.0720, 0. 0615; respectively). This result was not investigated in depth as it was not the objective of this study, however it is possible to speculate that the gain in strength in the pectoral and anterior shoulder region, as a result of many exercises proposed by CrossFit ™ that work these muscle groups, may trigger shortening of the muscles, involved and be the cause of such a negative relationship. In any case, this must be investigated in more depth and could be the subject of future studies, in order to know which body segments or exercises can negatively influence these results, what are the causes of these results and what are the ways to avoid loss of fitness. flexibility over practice time, since the overall flexibility score is an average of all flexibility tests applied.

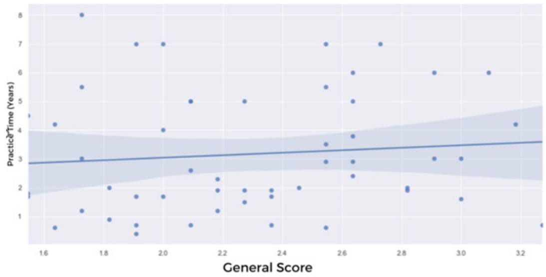


**Figure 9** Distribution of practice time by overall flexibility *score.*

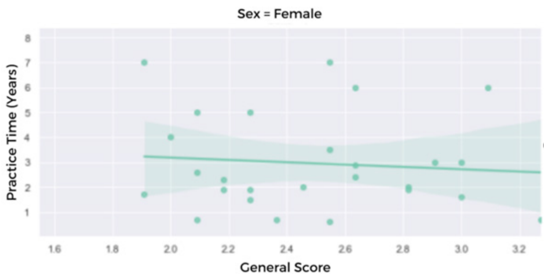


**Figure 10** Distribution of practice time by women's overall flexibility *score.*

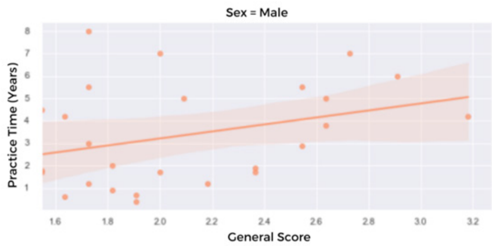


**Figure 11** Distribution of practice time by men's overall flexibility *score.*

Correlation matrices were also created from the data crossing, making it possible to verify the Spearman ρ coefficients and p-value for each crossing (Figures 12 to 14). The greatest relationship was obtained when crossing hip flexion with practice time for all groups analyzed (ρ = 0.5076; 0.4867; 0.5615; p = 0.0001; 0.0117; 0.0028; general, women and men, respectively), followed by crossing practice time and %backsquat, both when the entire sample was analyzed and when the sample was stratified by sex (ρ = 0.4761; 0.4440; 0.4257; p = 0.0004; 0.0231; 0.0301; overall, women and men, respectively). It was possible to consider that the practice time favored the hip flexion movement and the relative strength of OHS.

When analyzing flexibility for the entire sample (Figure 12), it was possible to observe that the movements of dorsal flexion of the ankle, lateral rotation of the shoulder with abduction of 90° and flexion of the elbow at 90° and posterior adduction from abduction of 180 ° on the shoulder were more significantly positively related to the %backsquat (ρ = 0.1135; 0.2042; 0.2206; p = 0.4228; 0.1464; 0.1160; respectively), while the movements of ankle plantar flexion, hip adduction, posterior shoulder adduction and posterior shoulder extension were negatively related to %backsquat (ρ = - 0.2308; -0.0013; - 0.1688; - 0.1952; p = 0.0996; 0.8740; 0.2315; 0.1654; respectively). When stratifying the group by sex, it was possible to observe that for women (Figure 13), the movements that presented a stronger positive relationship with the % back squat were ankle dorsiflexion, hip flexion, shoulder lateral rotation with 90° abduction and elbow flexion to 90° and posterior adduction from 180° shoulder abduction (ρ = 0.3061; 0.2371; 0.1929; 0.2532; p = 0.1283; 0.2436; 0. 3450; 0.2120; respectively). For men, the movements that were most positively related to the % back squat were hip flexion, hip abduction, hip adduction, hip extension, posterior shoulder extension, lateral rotation of the shoulder with 90° abduction and flexion of the shoulder, elbow at 90° and posterior adduction from 180° abduction at the shoulder (ρ = 0.1029; 0.2125; 0.2470; 0.2766; 0.1248; 0.3824; 0.3494; p = 0 .6170; 0.2974; 0.2238; 0.1714; 0.5435; 0.0538; 0.0802; respectively). On the other hand, the movements of ankle plantar flexion, posterior shoulder adduction and posterior shoulder extension were negatively related to the %backsquat for women (ρ= -0.1692; -0.2340; -0.4162; p= 0.4087; 0.2498; 0.0344; respectively) for men, the only movement that was negatively related to %backsquat was ankle plantar flexion (ρ = -0.0426; p= 0 ,8361).

| | Back Squat | %BACK SQUAT | OHS | I | II | V | VIII | VI | VII | XVII | XVIII | XIX | XX | XVI | GENERAL SCORE | ANKLE SCORE | HIP SCORE | SHOULDER SCORE | Practice time (years) | Age | Weight | Height |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Back Squat | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| %BACK SQUAT | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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| XVII | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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| XIX | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XX | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XVI | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| GENERAL SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| ANKLE SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| HIP SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| SHOULDER SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] |
| Practice Time (Years) | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] |
| Age | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] |
| Weight | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] |
| Height | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - |

**Figure 12** Correlation matrix with *Spearman* ρ coefficients and p-value for the complete sample set.

**Note 1:** On the lower diagonal are the *Spearman* ρ coefficients and on the upper diagonal are the p-values.

**Note 2:** I - ankle dorsal flexion, II - ankle plantar flexion, V - hip flexion, VIII - hip abduction, VI - hip extension, VII - hip adduction, XVII - posterior shoulder adduction, XVIII - posterior extension of the shoulder, XIX - lateral rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XX - medial rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XVI - posterior adduction from the 180° shoulder abduction.

| | Back Squat | %BACK SQUAT | OHS | I | II | V | VIII | VI | VII | XVII | XVIII | XIX | XX | XVI | GENERAL SCORE | ANKLE SCORE | HIP SCORE | SHOULDER SCORE | Practice time (years) | Age | Weight | Height |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Back Squat | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| %BACK SQUAT | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| OHS | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| I | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| II | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| V | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| VIII | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| VI | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| VII | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XVII | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XVIII | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XIX | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XX | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| XVI | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| GENERAL SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| ANKLE SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| HIP SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| SHOULDER SCORE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] |
| Practice Time (Years) | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] |
| Age | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] | [illegible] |
| Weight | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - | [illegible] |
| Height | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | - |

**Figure 13** Correlation matrix with *Spearman* ρ coefficients and p-value for the female sample set.

**Note 1:** On the lower diagonal are the *Spearman* ρ coefficients and on the upper diagonal are the p-values.

**Note 2:** I - ankle dorsal flexion, II - ankle plantar flexion, V - hip flexion, VIII - hip abduction, VI - hip extension, VII - hip adduction, XVII - posterior shoulder adduction, XVIII - posterior extension of the shoulder, XIX - lateral rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XX - medial rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XVI - posterior adduction from the 180° shoulder abduction.

**Citation:** da Silva MP, Saldanha RP, Toigo AM. The influence of flexibility on maximum strength performance in the *overhead squat movement* in crossfit™ practitioners. *Int Phys Med Rehab J.* 2023;8(3):195–203. DOI: 10.15406/ipmrj.2023.08.00360

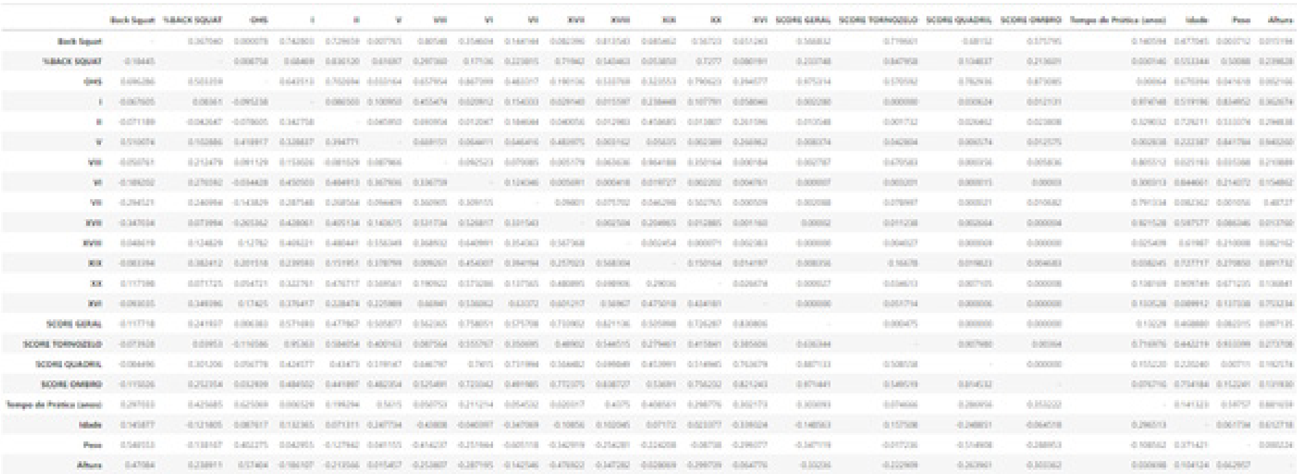

**Figure 14** Correlation matrix with *Spearman* ρ coefficients and p-value for the male sample set.

**Note 1:** On the lower diagonal are the *Spearman* ρ coefficients and on the upper diagonal are the p-values.

**Note 2:** I - ankle dorsal flexion, II - ankle plantar flexion, V - hip flexion, VIII - hip abduction, VI - hip extension, VII - hip adduction, XVII - posterior shoulder adduction, XVIII - posterior extension of the shoulder, XIX - lateral rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XX - medial rotation of the shoulder with abduction of 90° and flexion of the elbow at 90°, XVI - posterior adduction from the 180° shoulder abduction.

Considering the entire sample, the relationship between the relative strength of OHS and the ankle, hip and shoulder scores presented the coefficients ρ = - 0.0529; 0.0087; 0.0178; p = 0.7093; 0.9509; 0.9001; respectively.

The general flexibility score showed a small negative relationship with the % backsquat for women, while for men it was positively related (ρ= -0.0031; 0.2419; p= 0.9880; 0.2337; respectively). For women, the ankle score, which included all tests carried out for ankle flexibility, had a stronger positive relationship than for men (ρ = 0.1556; 0.0395; p = 0.4478; 0.8480; respectively). For men, hip and shoulder scores, which include all tests carried out for hip and shoulder flexibility, respectively, had a stronger positive relationship than for women (ρ = 0.3012; 0.2523; p = 0.1348; 0.2136; ρ= -0.0257; -0.0369; p= 0.9008; 0.8579; respectively).

## Discussion

The present study aimed to explore the associations between ankle, hip and shoulder flexibility in relative maximum strength performance, through the one repetition maximum (1RM) test, in the OHS movement in CrossFit™ practitioners. Rabin et al.,[12] tested two movements with the intention of finding exercises that were capable of effectively screening for limited dorsiflexion (DF) range of motion (ROM), and thus identifying individuals with a tendency to develop lower limb disorders. These same authors evaluated the OHS movement and the squat movement with arms in front of the body (FAS), suggesting that OHS and FAS can be used as complementary tests in screening ankle DF limitation. Due to its excellent sensitivity, OHS should be performed first and, if the result is negative (squatting below the 90° line, keeping both heels flat on the floor), limited dorsiflexion ROM can be safely excluded. However, if a positive result is obtained for the OHS (when the individual needs to squat with an amplitude greater than 90° to keep the heels on the floor), the test should continue with the FAS to more safely classify the DF ROM as limited. In any case, conversely, the study conducted by the aforementioned authors demonstrated that to perform a good OHS, a good dorsiflexion ROM is necessary. These findings support the findings of Bell et al., [13] who point out that the OHS has been shown to be a predictor of injury due to its ability to identify tense and hyperactive or weak and hypoactive muscles, and for identifying joint restrictions. Clifton et al.,[14] suggest that the overhead deep squat (DS*)* test is a predictor of performance in the FMS™ and helps to identify individuals who require additional musculoskeletal assessment, since one of the objectives of the test is to identify possible injury risks. All these studies support the choice of test used to collect data in the present investigation.

Regarding the influence of DF ROM on force production capacity,[15] reported that when squatting with a greater forward lean of the trunk, resulting from a lower DF ROM, the demand for activation of the posterior chain will increase. For this reason, the authors hypothesized that a squat with a greater forward inclination of the trunk would lead to a smaller hypertrophic response in the knee extensors (compared to a more upright squat), and as a consequence, there would be a decrease in strength in the phase concentricity of the movement.

LaRoche et al.*,*[16] observed that four weeks of stretching using the proprioceptive neuromuscular facilitation (PNF) technique contributed to an increase in musculotendinous stiffness (MTU), which occurred simultaneously with gains in ankle joint range of motion. The results confirm that MTU stiffness and joint range of motion measures appear to be separate entities. According to these same authors, the increase in MTU stiffness after the training period is explained by adaptations to maximal isometric muscle contractions, which were a component of PNF. Furthermore, a stiffer MTU system would be associated with an improved ability to store and release elastic energy, therefore, PNF would benefit certain athletic performance due to a reduced contraction time or greater mechanical efficiency. The results of this study suggest that PNF is a useful technique for increasing the range of motion and strength of a joint.

Similarly Ress et al.,[17] observed an increase in isometric test performance for plantar flexors and peak torque when the tests were performed after training combined with stretching exercises. The authors suggest that increases in strength may occur in increments

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in the myotendinous unit as a response to high mechanical stress on tendons and muscles. This mechanical stress contributes to changes in collagen structure and the protein synthesis response necessary for hypertrophic adaptation to occur.

The findings of the studies by Bell et al.,[13–17]support the results obtained in this investigation, which showed a positive relationship (although weak and without statistical significance) between DF ROM and the relative strength of OHS. Assuming that flexibility can affect OHS,[18] maintain that chronic stretching aims to reduce injury and increase performance by increasing muscle compliance and, therefore, reducing the energy required. to move the member. From this perspective, if the subject is more flexible, compensations in the OHS will be less apparent or will not exist, therefore, it seems reasonable to think that individuals with increased flexibility would also have superior performance in issues related to strength.

The present research found a positive relationship (although weak and without statistical significance) between the relative strength of OHS and shoulder lateral rotation movements with 90° abduction and 90° elbow flexion ($\rho$ = 0.3824 , 0.1929 ; p = 0.3450, 0.0538), medial rotation of the shoulder with 90° abduction and 90° elbow flexion ($\rho$ = 0.0717, 0.0521; p = 0.7277, 0.8001) and posterior adduction from 180° shoulder abduction ($\rho$ = 0.3493, 0.2532; p = 0.081, 0.2120) (stronger for men than for women, respectively). When analyzing the general shoulder flexibility score and the %backsquat, a positive relationship was also found for the entire group ($\rho$ = 0.0178; p = 0.9000), and when stratifying the sample by sex, a positive relationship was found only for male individuals ($\rho$ = 0.2523; p = 02136).

In the same direction,[19] carried out a battery of tests that allowed the identification of a select group of potential elite Olympic weightlifting athletes. The study consisted of evaluating elite athletes and non-elite athletes by testing physical dimensions and body composition, muscular strength, power, flexibility and gross motor control. In the flexibility tests, shoulder flexibility and specific flexibility were evaluated during the OHS movement, in which the subjects were filmed. Video analysis allowed identifying the relative angles of the leg and trunk, internal angles of the knee and hip and, again, shoulder flexion. As a result, the authors observed that elite athletes scored better numbers in all flexibility tests and were also able to lift higher loads in the proposed Olympic weightlifting movements. This fact corroborates the idea of Alter et al.,[4] cited previously, who, in general terms, says that an increased ROM can allow the production of greater forces. Although the results of the present study did not present statistical significance, there is an apparent tendency for positive correlations (although very weak) between flexibility and %backsquat in the variables mentioned.

In fact, performing stretching exercises for a long period of time (chronic effect) appears to cause significant increases in strength performance. Kokkonen et al.,[20] observed increases of up to 31% in 1RM test performance after an 8-week static stretching program for the hip, thigh and plantar flexor muscles. These same authors compared strength gains in the lower limbs in physically active individuals in two groups: one that performed only isolated strength training (control group) and the other that performed strength training combined with static stretching exercises (experimental group). Significant increases in lower limb strength were found in both groups. However, the greatest differences were observed in the group that performed strength training in combination with stretching exercises (6, 27 and 31% in the 1RM test for knee flexion, knee extension and leg press, respectively*)*. In the present study, a positive relationship was also found between hip flexibility and relative strength for the proposed movement. The highest positive correlation found between the relative strength of OHS when related to the joints as a whole was for the hip joint in male individuals ($\rho$ = 0.3012; p = 0.1348).

When analyzing the movements tested separately for the hip joint, it was possible to find a positive relationship for male individuals in the four movements: flexion ($\rho$ = 0.1028; p = 0.6169); abduction ($\rho$ = 0.2124; p = 0.7194); adduction ($\rho$ = 0.2469; p = 0.2238) and extension ($\rho$ = 0.2765; p = 0.1713), with flexion being the least representative relationship. For women, a positive relationship was found between the relative strength of OHS and flexion movements ($\rho$ = 0.2370; p = 0.2436) and hip abduction ($\rho$ = 0.0716; p = 0.7281), only and when analyzing hip flexion separately the relationship was more significant for women than for men.

In a similar study Bastos et al.*,*[21] concluded that performing stretching exercises together with specific strength exercises also increased muscle strength, but the results they found were less significant when compared to other authors.[20] Bastos et al.*,*[21] attributed this disparity to methodological differences between the studies cited. Kokkonen et al.*,*[21] proposed a training program that included a total of 15 stretching exercises, divided into two sections per week, for 8 weeks. On the other three days, individuals underwent strength training. Bastos et al.*,*[21] in turn, proposed only 4 stretching exercises and divided their sample into three groups: (a) a group that performed all static stretching exercises before starting strength training exercises; (b) a group that performed static stretching for a specific muscle immediately before strength exercise for that same muscle, between strength training sets; and (c) a group that performed only the strength training program, without any type of stretching exercise. The authors concluded that although all groups showed an increase in muscle strength, strength training performed without any type of stretching exercise, regardless of whether the stretching is performed before or during the training session, can more effectively increase muscle strength. muscle strength. Bastos et al.*,*[21] also found that strength training, with or without the use of stretching exercises, increased muscle strength in the groups studied. Finally, they deduced that the differences between the amount of stretching stimuli and the form/order in which they were applied may have influenced the study responses when compared with the results obtained by Kokkonen et al.[21]

Although stretching is commonly used by many athletes in different sports, some research disagrees with the previously cited findings by establishing an adverse effect of acute static stretching on several different maximal performances. Pre-exercise stretching has demonstrated an inhibitory effect on maximal force or torque production,[22,23] vertical jump performance,[24] running speed,[25] and muscular endurance.[26] It is important to highlight that these studies deal with acute effects, that is, when stretching is performed immediately before training and/or between training sets, which contrasts with the positive effects of a medium/long-term stretching protocol, case of the studies mentioned above.

However, in the present investigation, some negative relationships (although weak and without statistical significance) were also found between the relative strength of OHS and flexibility, both in general scores per joint and in movements analyzed separately. Such relationships appeared less frequently, but with magnitudes similar to the positive relationships, and can be consulted in the correlation matrix presented in Figures 12 to 14. For the general sample, the negative relationships were found in the intersections between % backsquat and plantar flexion ankle ($\rho$ = -0.2308; p = 0.0996); hip extension ($\rho$ = -0.0013; p = 0.9925); posterior shoulder adduction ($\rho$

= -0.2308; p = 0.0996); posterior shoulder extension (ρ = -0.1952; p = 0.1653) and ankle score *(*ρ = -0.0529; p = 0.7092). In women, negative relationships were found in the intersections between % backsquat and ankle plantar flexion (ρ = -0.1691; p = 0.4086); hip extension (ρ = -0.0696; p = 0.7352); posterior shoulder adduction (ρ = -0.2340; p = 0.6473); posterior shoulder extension (ρ = -0.4162; p = 0.0344) and ankle score *(*ρ = -0.0529; p = 0.7092); in the general score *(*ρ = -0.0030; p = 0.9880), hip score *(*ρ = -0.0256; p = 0.9008) and shoulder *score (*ρ = -0.0369; p = 0 .8578). Finally, in men, a negative relationship was found only in hip plantar flexion (ρ = -0.0426; p = 0.8361).

Based on the relationships found in the present research, it is possible to speculate that there is an ideal point of flexibility, and that from this point onwards, flexibility is not positively related to the relative strength of OHS. Men had lower flexibility scores than women, and the relative strength of OHS was positively related to this variable. Unlike the female data set, which presented higher flexibility scores and had an almost null relationship between it and the relative strength of OHS. Although it is not possible to confirm, such a relationship seems reasonable, and it is suggested that studies addressing the topic be conducted.

Finally, there is still no conclusive evidence that flexibility improves the rate of force development or that greater ROM is associated with greater strength levels. Few studies have related such variables,[8,16,17,19–21,27] of which only two specifically investigated CrossFit ™ practitioners.[8,27] The present research, despite suggesting a small positive association, also did not present conclusive results and, therefore, cannot be used to confirm such a relationship.

## Final considerations

The present investigation suggests a small positive association between the relative strength of OHS and general flexibility, especially for male individuals, in CrossFit ™ practitioners for the sample group analyzed. Stratifying the sample set between men and women, and flexibility by joint, ankle ROM seems to show a tendency to positively influence the relative strength of OHS only for the female sample set, and hip and shoulder ROM seems to show a tendency to positively influence the relative strength of OHS only for the male sample set.

It was also observed that women have higher levels of brute strength and flexibility scores than men. On the other hand, men showed higher results for relative strength of OHS. It was found that the practice time seems to favor the hip flexion movement and the relative strength of OHS, both in the complete sample set and when we analyzed men and women separately. It was also possible to observe that the practice time seems to negatively influence shoulder flexibility in some movements, for the female sample group. All correlations obtained in the analyzes carried out in the present study were weak and without statistical significance, which can be justified by the low number of individuals in the sample. Other points that may have interfered with the research results were sensitivity at the time of the Flexitest (since some individuals have lower pain tolerance, which may interfere with the perception of maximum amplitude during the test); thoracic flexibility (which was not evaluated in the study, but which may also interfere with the performance of the OHS movement); the insecurity on the part of individuals to work with high loads in a movement in which the load must be stabilized above the head, and fatigue due to previous training throughout the week since no rest interval was requested between a training session and taking 1RM of the movements tested. Despite suggesting that a flexibility program associated with CrossFit ™ can help gain relative strength for the proposed exercise (OHS), there is no conclusive evidence that this can occur, or how it occurs. For these reasons, given the potential practical significance of these results, additional studies using more robust experimental designs, larger sample sizes, and practical interventions should be conducted with the aim of confirming or refuting these results.

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## Conflicts of interest

None.

## References

1. Tibana RA, Almeida LM, Prestes J. Crossfit Riscos ou Benefícios? O que Sabemos até o Momento?*Brazilian Journal of Science and Movement.* 2015;23(1):182 –185.
2. Glassman G. *Level 1 Training Guide*. Crossfit Inc, 2021.
3. Carvalho ACG. Relação entre flexibilidade e força muscular em adultos jovens de ambos os sexos. *Brazilian Journal of Sports Medicine.* 1998;4(1):2–8.
4. Alter MJ. *Ciência da Flexibilidade*. 2nd edn. Porto Alegre: Artmed Editora, 1999.
5. Glassman G. The Overhead Squat. *Crossfit Journal*. 2005.
6. Sottovia Carla, Guiselini Mauro, Guiselini Rafael. *Functional Movement Systems***.** Instituto Mauro Guiselini. 2005.
7. Barbetta PA. *Estatstica Aplicada s Cincias Sociais.* Florianópolis: Editora da UFSC, 2003.
8. Andrade LN, Teixeira RV, Carlos PS. Relação entre a flexibilidade e a força= entre praticantes de crossfit. *Motricidade.* 2018;14(1):279–283.
9. Kilgore Lon. Back Squat Strength Standards. *British Medical Journal.* 2008**;**92–95.
10. Gallahue DL, Ozmun JC, Goodway JD. *Compreendendo o desenvolviment o motor: bebs, crianas, adolescentes e adultos.* 7th edn Porto Alegre: Artmed, 2013.
11. Anlise de dados para ciências sociais: a complement aridade do SPSS. Lisbon: Edições Sílabo, 2008.
12. Rabin A, Kozol Z. Utility of the overhead squat and forward arm squat in screening for limited ankle dorsiflexion. *Journal Of Strength And Conditioning Research.* 2017;31(5):1251–1258.
13. Bell DR, Padua DA, Clark MA. Muscle Activity and Flexibility in Individuals with Medial Knee Displacement During the Overhead Squ. *Athletic Training & Sports Health Care***.** 2012;4(3):117–125.
14. Clifton DR, Grooms DR, Onate JA. Overhead deep squat performance predicts functional movement screen™ score. *International Journal of Sports Physical Therapy*. 2015;10(5):622–627.
15. Fuglsang EI, Telling AS, Sørensen H. Effect of ankle mobility and segment ratios on trunk lean in the barbell back squat. *Journal of Strength and Conditioning Research.* 2017;3(11):3024–3033.
16. Laroche DP, Lussier MV, Roy SJ. Chronic stretching and voluntary muscle force. *Journal Of Strength And Conditioning Research.* 2008;22(2):589–596.
17. Rees SS, Aron JM, Mark LW, et al. Effects of proprioceptive neuromuscular facilitation stretching on stiffness and force-producing characteristics of the ankle in active women. *Journal of Strength and Conditioning Research*. 2007;21(2):572–577.

18. Bazett Jones DM, Gibson MH, Mcbride JM. Sprint and Vertical Jump Performances Are Not Affected by Six Weeks of Static Hamstring Stretching. *Journal of Strength and Conditioning Research*. 2008;22(1):25–31.

19. Fry AC, Ciroslan D, Fry MD. Anthropometric and Performance Variables Discriminating Elite American JuniorMen Weightlifters. *The Journal of Strength and Conditioning Research.* 2006;20(4):861.

20. Kokkonen J, Nelson AG, Tarawhiti Tina, et al. Early-phase resistance training strength gains in novice lifters are enhanced by doing static stretch. *Journal of Strength and Conditioning Research.* 2010;24(2):502–506.

21. Bastos CLB, Miranda Humberto, Rodrigo GSV, et al. Chronic Effect of Static Stretching on Strength Performance and Basal Serum IGF-1 Levels. *Journal of Strength and Conditioning Research.* 2013;27(9):2465–2472.

22. Kokkonen J, Nelson AG, Cornwell A. Acute muscle stretching inhibits maximal strength performance. *Research Quarterly For Exercise And Sport.* 1998;69(4):411–415.

23. Nelson AG, Kokkonen J, Eldredge C. Strength inhibition following an acute stretch is not limited to novice stretchers. *Research Quarterly For Exercise And Sport.* 2005;7694):500–506.

24. Cornwell A. Acute effects of passive muscle stretching on vertical jump performance. *Journal Of Human Movement Studies*. 2001;307–324.

25. Nelson AG, Dricoll NM, Landin DK, et al. Acute effects of passive muscle stretching on sprint performance. *Journal Of Sports Sciences.* 2005;23(5):449–454.

26. Nelson AG, Kokkonen J, Arnall DA. Acute muscle stretching inhibits muscle strength endurance performance. *The Journal Of Strength And Conditioning Research*. 2005;19(2):338–343.

27. Servo L, Cezar Grontowski, Tahyza Boss Ferreira, et al. Efeito da flexibilidade nos níveis de força máxima dinâmica do exercício clean nos praticantes de crossfit. *Brazilian Journal of Health Review*. 2020;3(3):5705–5714.

28. Araujo CGS, Pavel RC. *Flexiteste: Um método completo para avaliar a flexibilidade.* Barueri: Manole, 2005.