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Relationship between the practice of Crossfit and artery, carotid and vertebral alterations

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ABSTRACT
Introduction: It is known that physical exercise leads to significant cardiovascular changes such as a reduction in stiffness and an increase in arterial diameter, however, studies on this relationship focus predominantly on the arteries of the lower limbs. Objective: Evaluate the influence of crossfit on the cardiovascular system. Methodology: Collected from 20 crossfit athletes and 20 non-athlete participants. Inclusion criteria for the study group were individuals who practiced crossfit more than twice a week, aged over 18, without medical and/or psychiatric pathologies and for the control group aged over 18, without medical and/or psychiatric pathologies and who did not exercise more than twice a week. Results: The study group consisted of 17 individuals aged between 28 and 38, and the control group consisted of participants aged between 22 and 58. No significant vascular adaptive changes were observed when practicing crossfit. Conclusion: This study found that the changes due to adaptation to crossfit at the vascular level did not occur at the level of the cervical arteries.

Keywords: Arterial diameter, Resistance index, Arterial stiffness, Crossfit.

INTRODUCTION

Regular physical exercise leads to cardiovascular changes and consequently to an improvement in aerobic capacity and resistance to exertion. At the cardiac level there is development of the heart muscle, an improvement in contractility, an increase in cardiac output and also an improvement in cardiac perfusion to suppress the increased need for oxygen. At the arterial vascular level, there is an increase in the arterial diameter and a decrease in the thickness of the wall, consequently leading to a decrease in the resistance to the passage of blood, and there may also be an alteration in the vasodilation capacity. At the muscular level, there is an increase in microcirculation, thus increasing the capacity of accessible oxygen if there is a metabolic need for it1.

These and other changes are related to several factors, including the characteristics of the arterial wall, which is composed of three layers, the middle one being the one with the smoothest muscle fibers and is the thickest, being, in turn, the most affected by arterial stiffness, which is defined as a hardening together with a loss of elasticity of the arterial walls. This process occurs naturally, but is also accelerated by

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modifiable factors, such as a sedentary lifestyle, poor eating habits, smoking, and also by non-modifiable factors, such as genetic factors, hypertension and diabetes mellitus. The loss of elasticity on the part of the arteries prevents their proper functioning as it deregulates blood flow and pressure, increasing the appearance of pathologies and complications, such as arterial hypertension, kidney failure, liver disorders, cognitive deficit, neurodegenerative disorders, among others2.

This study aims to evaluate possible vascular alterations in CrossFit athletes, a sport that has become increasingly popular and is based on high-intensity circuits. The type of physical exercise practiced in this modality focuses on three pillars: calisthenics, which consists of the use of one's own body weight to create physical effort, such as push-ups and pull-ups; aerobic exercise such as running and jumping; and in weightlifting, such as weighted squats and deadlifts. In the choice of the type of physical exercise practiced by the study sample, CrossFit was considered because it is a high-intensity sport with potential cardiovascular changes in practitioners of this sport. As this sport is a more recent and non-traditional modality such as soccer, basketball, among others, it has been less studied, which makes this study also very interesting about the cause-and-effect relationship of the practice of the modality and the possible morphological and hemodynamic changes of the extracranial arteries3.

In order to evaluate the anatomical characteristics, such as thickness, morphology, path, diameter of the vessels, and hemodynamic characteristics, such as qualitative parameters and turbulence of the flow of the carotid and vertebral arteries to be studied, arterial Doppler ultrasound is used. This technique is a modality of ultrasonography, which uses sound waves that are produced and received by the piezoelectric crystals that are found in the transducers. In this study, the transducer to be used is the high-frequency linear between 5-10 MHz (low penetration capacity, but good resolution in close proximity)[4].

It is known that the practice of physical exercise leads to significant cardiovascular alterations such as decreased stiffness and increased arterial diameter, however, studies on this relationship focus predominantly on the arteries of the lower limbs. The relationship between the practice of physical exercise on a regular basis and its vascular effects at the level of the carotid and vertebral arteries is still a topic that is little addressed and has a comprehensive space for the development of scientific knowledge.

OBJECTIVE

To evaluate the influence of Crossfit practice on the cardiovascular system.

METHODOLOGY

The present study is prospective, descriptive and correlational. Collected from 20 athletes, CrossFit practitioners and 20 non-athletes. Inclusion criteria in the study group were individuals who practiced

Crossfit more than twice a week, aged over 18 years, without medical and/or psychiatric pathologies and in the control, group aged over 18 years, without medical and/or psychiatric pathologies and who did not practice physical exercise more than twice a week. All subjects agreed to participate in the study.

They were asked about the time of practice of Crossfit, as well as the frequency with which they do it, in the case of the group of athletes, and the frequency in which they practice physical exercise in general in the case of the control group, in addition to the questions that already usually characterize this exam, which are about modifiable and non-modifiable factors in the individual. Next, a carotid Doppler ultrasound study was performed with a high-frequency linear probe. The examination was performed with the individual in the supine position in a quiet and dimly lit environment.

The data obtained were entered, coded, treated and analyzed using the IBM SPSS (Statistical Package for the Social Sciences) version 27, and a quantitative descriptive analysis was performed with the calculation of means, standard deviation, minimum and maximum values and absolute data. In order to test the distribution of the sample, the Kolmogorov-Smirnov normality test was applied.

ETHICAL ISSUES

The Study was authorized by an Ethics Committee codified under number 119/CE-IPCB/2023. The research team declares that it has no conflicts of interest.

RESULTS

Table 1: Descriptive Analysis of the study group. BMI- body mass index

Crossfit Group	N	Minimum	Maximum	Average	Deviation error
Age	17	28	38	33,59	3,104
BMI	17	21,5	34,7	25, 694	3,3598
Valid N (from list)	17				

Analyzing table 1, the group of athletes is aged between 28 and 38 years, taking into account that the average is 33.59±3.104 years.

As for BMI, we can observe in the group of athletes, a minimum BMI value of 21.5kg/m², a maximum value of 34.7kg/m² and a mean value of 25.694±3.3598 kg/m2.

Table 2 shows that the control group was aged between 22 and 58 years and had a mean age of 37.60±9.450 years.

Table 2: Descriptive Analysis of the control group. BMI - body mass index.

Control Group	N	Minimal	Maximum	Average	Deviation error
Age	20	22	58	37,60	9,450
BMI	20	18,8	29,4	24,470	2,9256
Valid N (from list)	20				

As for BMI, in the control group, we can observe a minimum value of 18.8kg/m², a maximum value of 29.4kg/m² and a mean value of 24.470±2.9256kg/m².

Table 3 shows that the participants in the group of athletes practice at least 90 minutes per week and have been practicing the sport for at least 2 years.

Table 1: Practice of crossfit

Crossfit Group	N		Minimal		Maximum		Mean ± Standard Deviation	
	And	D	And	D	And	D	And	D
ACC Resistance Index	17	17	0,68	0,70	0,89	0,88	0,8082±0,06075	0,7947±0,04446
ACC Diameter	17	17	5,20	5,24	6,79	7,71	5,9353±0,54972	6,3435±0,677671
ACI Resistance Index	17	17	0,55	0,42	0,87	0,86	0,7194±0,10491	0,7182±0,10858
ACI Diameter	17	17	3,64	4,56	7,24	6,40	5,1100±0,73231	5,1465±0,46201
ACE Resistance Index	17	17	0,75	0,75	0,92	0,87	0,8224±0,04146	0,8106±0,03832
ACE Diameter	17	17	3,15	3,00	4,80	5,11	3,8853±0,47659	4,1982±0,57783
AV2 Endurance Index	17	17	0,48	0,47	0,83	0,83	0,7347±0,09042	0,7082±0,10424
Diameter AV2	17	17	3,00	2,20	4,20	3,90	3,5176±0,32984	3,1629±0,43266
IIM	17	17	0,40	0,50	0,70	0,70	0,5529±0,08745	0,6059±0,07475
Muscle	17	17	6,30	6,05	12,50	11,70	9,8653±1,58633	9,5429±1,36208
Valid N (from list)	17	17						

As for the maximum value, we can say that there are two athletes who have been practicing Crossfit for 9 years and there are two athletes who practice the modality for 600 minutes per week.

The average number of years of practice is 5.12±2.233 years and the average number of minutes practiced weekly by the participants is 255.88±129.086 minutes.

Table 4: Resistance Index and Vascular Diameters in the *Crossfit Group.* ACC - common carotid artery, ICA - internal carotid artery, ACE - external carotid artery, VA - vertebral artery, IIM - intimate-media index.

Crossfit Group	N	Minimal	Maximum	Average	Deviation error
Years of Practice	17	2	9	5,12	2,233
Min/week	17	90	600	255,88	129,086
Valid N (from list)	17				

As we can see in table 4 presented above, in the group of Crossfit practitioners, the minimum value of the common carotid artery resistance index, both on the left and right sides, is within the normal range. On the other hand, the maximum value on the left side was 0.89 and 0.88 on the right side, both of which are altered higher than the normal range. The average on both sides is increased.

As for the diameter of the common carotid artery, both the minimum, maximum and mean values on both sides are within the normal range.

The minimum value of the resistance index of the internal carotid artery is normal on the left side and inferiorly altered on the right side. The maximum value is superiorly altered on both sides, and it can be concluded that there is a wide disparity of values referring to the resistance index of the internal carotid artery, taking into account that the mean is within the normal range on both sides. The minimum, maximum, and mean values of the diameter of the internal carotid artery are normal on both sides.

With regard to the external carotid artery resistance index value, we can see a normal minimum value on both sides, a maximum value that is superiorly altered on both sides, and we can observe a higher value on the left side compared to the right side. The mean is more altered on both sides, without showing a significant difference.

As for the minimum and maximum values of the vertebral artery resistance index, they are increased, and no significant differences were observed between both sides. The mean value was normal for both the left and right sides. Regarding the diameter of the vertebral artery,

We can observe a minimum value of 3.00 mm on the left side, which is within the normal range, and a minimum value of 2.20 mm on the right side, which is outside the normal range.

The minimum, maximum and mean values of the intima-media index were all within the normal range and with no significant differences between the left and right sides.

In the measurement performed in order to evaluate the muscle, we can observe values that vary between 0.40 mm and 0.70 mm on the left side and between 0.50 mm on the right side, thus resulting in an insignificant difference between both sides.

Table 5: Resistance Index and Vascular Diameters in the Control Group. ACC - common carotid artery, ICA - internal carotid artery, ACE - external carotid artery, VA - vertebral artery, IMI - intimate-media index.

Control Group	N		Minimal		Maximum		Average	
	And	D	And	D	And	D	And	D
ACC Resistance Index	20	20	0,65	0,68	0,87	0,88	0,7780±0,05064	0,7675±0,04153
ACC Diameter	20	20	5,38	8,5	8,90	8,10	6,6965±0,94979	6,5430±1,49826
ACI Resistance Index	20	20	0,56	0,59	0,99	0,88	0,7155±0,09122	0,6900±0,07623
ACI Diameter	20	20	4,70	4,91	7,37	7,52	5,6035±0,93204	5,8975±0,70579
ACE Resistance Index	20	20	0,71	0,68	0,94	0,99	0,8320±0,06412	0,8385±0,07513
ACE Diameter	20	20	3,50	3,54	5,00	5,93	4,2425±0,44238	4,5950±0,58814
AV2 Endurance Index	20	20	0,32	0,60	0,81	0,81	0,7190±0,12540	0,7070±0,5814
Diameter AV2	20	20	2,10	2,00	4,20	4,00	3,2440±0,50482	3,1735±0,50346
IIM	20	20	0,40	0,50	1,00	1,10	0,6250±0,16504	0.67±0.13018
Muscle	20	20	6,40	6,20	11,90	12,40	9,3165±1,36840	9,5395±1,70890
Valid N (from list)	20	20						

Analyzing Table 5, referring to the control group, we can observe a minimum value of resistance index of the normal common carotid artery on both the left and right sides. Referring now to the maximum and average value, both are altered on the left side as well as on the right side. The minimum diameter obtained from this same artery is also normal on both sides. On the other hand, the maximum value is outside the normal range, although the average resulting from these previous values is normal on both sides.

The resistance index of the internal carotid artery is within the limit of normality in terms of its minimum value. As for the maximum value, it is outside the normal standard on both sides, with the left side being higher altered in relation to the right side, and the mean is within the normal standard. As for the diameter of this same artery, it is within the normal range in terms of minimum, maximum and average values on both sides.

In the external carotid artery, a minimum value of normal resistance index was observed on both sides, maximum values increased, and a higher index was observed on the left side compared to the right side and an increased mean on both sides, with no significant differences.

In this same artery, we evaluated the diameters obtained, resulting in normal minimum, maximum and mean values on both sides.

Regarding the vertebral artery, we can observe minimum and maximum values of vertebral artery resistance index that are out of normality, and a significant difference in the minimum value of the left side can be observed, compared to the right side. The averages on both sides are normal. The minimum diameters obtained in this same artery are less altered, although the maximum and mean values are normal.

The intima-mean index is higher than the range of normal values, in its maximum value, although it is normal in its minimum and average values.

As for muscle measurements, no significant differences were observed between the left and right sides.

Table 6: Comparison between pairs of variables from both groups of left cervical arteries. ACC - common carotid artery, ICA - internal carotid artery, ACE - external carotid artery, VA - vertebral artery, IMI - intimate-media index.

Left Side	Variables	Average± Deviation error	*P* Value
By 1	IR ACC IR ACC GC	0,03412±0,07272	0,071
By 2	Diam. ACC Diam. ACC GC	-0,64118±1,17853	0,039
By 3	AND ACI IR ACI GC	0,01353±0,11230	0,626
Set of 4	Diam. ACI Diam. ACI GC	-0,61765±1,18313	0,047
By 5	AND ACE AND ACE GC	-0,00412±0,08086	0,836

Set of 6	Diam. ACE Diam ACE GC	-0,37647±0,58450	0,017
Set 7	AND AV2 AND AV2 GC	0,03000±0,15792	0,445
Set of 8	Diam. AV2 Diam. AV2 GC	0,32471±0,54520	0,026
Set by 9	IIM IIM GC	-0,08235±0,19117	0,095
Set of 10	Muscle GC Muscle	0,60471±1,71819	0,166

As can be seen in Table 6, pairs 2, 4, 6, 8, referring to the resistance index and diameter of the arteries under study, present a significant difference between both groups, as they have a *P* value lower than 0.05, and all pairs that demonstrate significant disparities address variables that evaluate the diameters of the different arteries under study.

Table 7: Comparison of variables, on the right side, between both study groups. ACC - common carotid artery, ICA - internal carotid artery, ACE - external carotid artery, VA - vertebral artery, IMI - intimate-media index.

Right Side	Variables	Average± Deviation error	*P* Value
By 1	IR ACC IR ACC GC	0,02706±0,03738	0,009
By 2	Diam. ACC Diam. ACC GC	-0,52765±0,90806	0,029
By 3	AND ACI IR ACI GC	0,00,02765±0,14524	0,626
Set of 4	Diam. ACI Diam. ACI GC	-0,83294±0,86166	0,001
By 5	AND ACE AND ACE GC	-003471±0,08783	0,123
Set of 6	Diam. ACE Diam ACE GC	-0,43941±0,83733	0,00046
Set 7	AND AV2 IR AV2 GC	0,00706±0,12790	0,823
Par 8	Diam. AV2 Diam. AV2 GC	0.02941±0.0.55847	0,831
Par 9	IIM IIM GC	-0.07059±0.17235	0,111
Par 10	Muscle GC Muscle	-0,1882±2,46222	0,975

On the right side, we can see a significant difference between the group of Crossfit practitioners and the control group in pairs 1, 2, 4 and 6. In pair 1 there is a distinction in relation to the left side, since this inequality of values is found in a variable that studies the resistance index. On the other hand, in pairs 2, 4 and 6 we can observe a significant difference between the practitioner group and the control group in the variables that study the diameter of the common carotid artery, internal and external.

DISCUSSION

Science establishes a relationship that indicates that physical exercise increases blood flow at the arterial level, consequently stimulating vasodilatory factors by endothelial cells, thus gaining a greater capacity for arterial dilation. Exercise is also associated with a remodeling effect on the arteries that causes an increase in vascular elastic capacity, causing both a reduction of arterial stiffness and an increase in the diameter of the vessel or even cause a decrease in the diameter but with a better adaptation to high demands at the hemodynamic level.

In the common, internal and left external carotid artery, we can observe a statistically significant relationship with a negative mean between the diameter of the carotid arteries of the group of athletes and the diameter of the same arteries in the control group, translating into a decrease in arterial diameters in participants who regularly practice Crossfit compared to non-practitioners. According to the study conducted by Patricia Marchio (2018), the carotid arteries can present endothelial dysfunction in response to physical exercise, due to the oxidative stress to which they are exposed due to shear forces.

On the other hand, the diameter of the vertebral arteries in athletes is significantly higher compared to non-athletes because, according to the study carried out by Jane Black (2014), the practice of a sport on a regular basis can lead to an increase in vascular diameters but not necessarily in all arteries in general, as this process is associated with an increase in blood flow in the regions under stress, directly related to the areas of activation, causing an activation of vasodilator factors, thus causing an increase in arterial vascular diameter, as for example in this case, in the vertebral artery.

The study carried out by Yiyan Wang (2022), corroborates the present research because, as we can see, the difference is statistically significant between the intima-mean index of the group of Crossfit practitioners and the control group, and the average difference between these two variables, respectively, is negative. This result translates into a lower IIM in the group of physical exercisers compared to the control group, as supported by the literature, since studies indicate that mainly aerobic physical exercise, but also resistance exercise, is directly related to the decrease in intima-media thickness, thus contributing to cardiovascular health.

Comparing the left and right cervical arteries, we can say that there are no significant differences between both sides, which is expected because the cervical arteries are not vessels directly related to the areas of activation in the practice of physical exercise, such as vessels of the lower limbs, and also due to the fact that Crossfit is a sport that is, and it should always be practiced in a proportional way on both the left and right sides, with no limb or side of the body predominating, going against the development of strength in a symmetrical way.

One of the limitations identified in the present study was the fact that BMI is an ambiguous index, which does not take into account either muscle mass or the percentage of body fat mass, thus obtaining

BMI values that may contain false interpretations. Another limitation identified was the fact that there was an average age difference between the two groups of about 4 years, with the maximum age of a participant in the Crossfit was 38 years, compared to the maximum age of 58 years in the control group. We know that with advancing age, there are several changes at the vascular level, such as increased arterial stiffness, increased thickening of the intima-media layer and decreased endothelial function, so participants may present parameters influenced by advancing age.

The present study aims to explore a gap still present in the scientific literature that is due to the fact that the Crossfit be recent, high-intensity sport, on the rise and with potential vascular changes in its participants.

FINAL THOUGHTS

This study found that the changes due to the adaptation to the practice of Crossfit at the vascular level, they did not occur at the level of the cervical arteries.

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