PODIUM
Journal of Science and Technology in Physical Culture

UNIVERSITY EDITORIAL

Volume 18
Issue 1
2023

University of Pinar del Río "Hermanos Saíz Montes de Oca"

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ISSN: 1996–2452 RNPS: 2148
PODIUM Journal, January-April 2023; 18(1):

Translated from the original in Spanish

Original article

Relationship between flexibility, strength and VO2max of athletes from Imbabura

Relación entre flexibilidad, fuerza y VO2max de los deportistas de Imbabura

Relação entre flexibilidade, força e VO2max dos atletas Imbabura

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Received**:** 25/09/2022.
Approved**:** 07/12/2022.

ABSTRACT

The qualities of the physical condition such as flexibility, strength and VO2max in the athlete, are fully manifested in any sporting activity. The objective of the research was to evaluate the level of flexibility and the existing relationship with the level of explosive strength and VO2max. One hundred thirty-seven athletes from the province of Imbabura were selected in the disciplines of soccer, basketball, climbing, athletics and taekwondo and were evaluated through the sit and reach test, vertical jump (VERT) and Queen College test. The results showed that 81.8 % were of mixed ethnicity, 56 % of the sample male. The taekwondo and climbing disciplines were more flexible (31 cm), the average explosive strength that stood out was climbing (48cm) of jumping capacity, followed by basketball (45cm); the VO2max of the basketball players was excellent (57 ml*kg-1*min-1). Soccer presented an average VO2max (52.8 ml*kg-1*min), with significant differences between the means (p=<0.05). The flexibility of the sports disciplines had a moderate direct relationship

(p=<0.00) with strength and a moderate inverse relationship (p=<0.01/ rho =-0.4) with VO2max. Flexibility was directly proportional to strength, that is, if flexibility increased, strength also increased; however, flexibility was inversely proportional to VO2max, that is, flexibility decreased and VO2max increased.

Keywords: Athletes, flexibility, strength, VO2max.

RESUMEN

Las cualidades de la condición física como la flexibilidad, fuerza y VO2max en el deportista, se manifiestan en su totalidad en cualquier actividad deportiva. El objetivo de la investigación fue evaluar el nivel de flexibilidad y la relación existente con el nivel de fuerza explosiva y VO2max. Se seleccionaron 137 deportistas de la provincia de Imbabura en las disciplinas de fútbol, basquetbol, escalada, atletismo, ciclismo y taekwondo y se evaluaron mediante la prueba de sit and reach, salto vertical (VERT) y test de Queen College. Los resultados mostraron que el 81,8% fueron de etnia mestiza, el 56 % de la muestra de género masculino. Las disciplinas taekwondo y escalada fueron más flexibles (31 cm), la fuerza explosiva promedio que destacó fue la escalada (48cm) de capacidad de salto, seguido del basquetbol (45cm); el VO2max de los basquetbolistas fue excelente (57 ml*kg-1*min-1). El fútbol presentó un VO2max promedio (52,8 ml*kg-1*min), con diferencias significativas entre las medias (p=<0,05). La flexibilidad de las disciplinas deportivas tuvo una relación (p=<0,00) directa moderada con la fuerza e inversa moderada (p=<0,01/ rho =-0,4) con el VO2max. La flexibilidad fue directamente proporcional a la fuerza, es decir, si aumentó la flexibilidad también aumentó la fuerza; sin embargo, la flexibilidad fue inversamente proporcional a el VO2max, es decir, la flexibilidad disminuyó y el VO2 max aumentó.

Palabras clave: Atletas, flexibilidad, fuerza, VO2max.

RESUMO

As qualidades de aptidão física como flexibilidade, força e VO2max no atleta se manifestam em sua totalidade em qualquer atividade esportiva. O objetivo da pesquisa era avaliar o nível de flexibilidade e a relação existente com o nível de força explosiva e VO2max. Um total de 137 atletas foram selecionados da província de Imbabura nas disciplinas de futebol, basquete, escalada, atletismo, ciclismo e taekwondo e foram avaliados usando o teste sit and reach, salto vertical (VERT) e o teste Queen's College. Os resultados mostraram que 81,8% eram de etnia mista, 56% da amostra era masculina. As disciplinas de taekwondo e escalada eram mais flexíveis (31 cm), a força explosiva média que se destacava era a capacidade de saltar (48 cm), seguida do basquetebol (45 cm); o VO2max dos jogadores de basquetebol era excelente (57 ml*kg-1*min-1). O futebol tinha um VO2máx médio (52,8 ml*kg-1*min-1), com diferenças significativas entre os meios (p=<0,05). A flexibilidade das modalidades esportivas teve uma relação direta moderada (p=<0,00) com força e uma relação inversa moderada (p=<0,01/ rho =-0,4) com o VO2max. A flexibilidade foi diretamente proporcional à força, ou seja, se a flexibilidade aumentou, a força também aumentou; entretanto, a flexibilidade foi inversamente proporcional ao VO2máx, ou seja, a flexibilidade diminuiu e o VO2máx aumentou.

Palavras-chave: Atletas, flexibilidade, força, VO2max.

INTRODUCTION

Flexibility is defined as the mobility and capacity of the joint to generate a movement of a specific range that is performed without the presence of pain and restrictions. (Morales & González, 2015) and also as a capacity included in processes to reduce the risk of injury, which is why many people stretch before or after sports activity. However, this capacity does not produce clinically important reductions in muscle soreness, these changes may only be short-term (Thomas *et al.*, 2018). Although the quality of the evidence on long-term effects is less rigorous, there is no theoretical basis on which to believe that stretching can have long-term effects on joint mobility in the absence of a short-term effect (Katalinic *et al.*, 2010).

It is known that stretching interventions do not seem to change the properties of the muscle or the tendon, although extensibility and tolerance to greater traction strength are increased, due to viscoelastic characteristics and to the fact that the changes and adaptations to the protocols seem to occur mainly at the sensory level (Freitas *et al.*, 2018).

Clinical trials show that stretching interventions, both acute and chronic, can increase maximum range of motion in the absence of changes in the passive torque-angle curve; they argue that these results are partly explained by the influence of non-muscular structures that contribute only marginally to passive torque (Steinfeld *et al.*, 2015). When stretching passively, an increase in the range of movement is generated that does not explain the structural changes in the muscle-tendon unit; probably these are produced due to a greater tolerance to stretch in adaptations of the nociceptive nerve endings that abound in these tissues (Konrad & Tilp, 2014).

Faelli & *et al.* (2021) in their study state that including static and dynamic stretching in the warm-up improves running economy and decreases the perception of effort in endurance sports. Static stretching leads to a decrease in elastic energy potential and strength capacity that is even associated with a decrease in running economy and sports performance; it is for this reason that the authors recommend crossed strength training or planned intervals and adequate recovery times, as a necessary tool to reduce injuries (Baxter *et al.*, 2017).

Strength training is essential to guarantee adequate physical performance in any sport and includes mobility, the functioning of the locomotor system and functional independence (Muñoz *et al.*, 2021). Some authors recommend research with different training modalities and mention that it is still uncertain whether training with combined exercises between strength and flexibility has long-term effects (Kim *et al.*, 2019).

Strength training has significant performance benefits that are even appreciated by athletes (Mon-López *et al.*, 2019). It includes: heavy endurance training, explosive endurance, plyometric training for runners and as a complementary capacity, in sports with relatively few demands on muscular strength, such as Olympic shooting (Mon-López, *et al.*, 2019). In this direction, a documentary review became necessary, considering it as an important

attribute in a well-planned training program for middle and long distance athletes of all levels (Alexander *et al.,* 2020).

Simultaneous training of aerobic capacity and intense strength can increase running speed and power output, it is suggested that the improvement in endurance performance may be related to the delayed activation of fibers that improve neuromuscular efficiency (Rønnestad & Mujika, 2014 and Sagarra-Romero *et al.,* 2017). By understanding the importance of physical qualities and the presence of flexibility, strength and VO2max in training, it was considered to establish the relationship between flexibility and its variables in sports disciplines in the province of Imbabura.

By considering flexibility, strength and VO2max as important parameters in sports training, this study seeks to analyze the behavior of each one and relate the study variables to analyze if one influences the other. The research was implemented in the province of Imbabura, in which the general state of athletes in different disciplines was diagnosed, with a physiotherapeutic approach. By understanding the importance of physical qualities in training and with the aforementioned background, it became necessary to study the relationship of flexibility on strength and VO2max in sports disciplines in the province of Imbabura.

MATERIALS AND METHODS

Type and study population

A descriptive, quantitative, non-experimental and correlational study was carried out in a population made up of 211 (N) senior athletes from clubs in the province of Imbabura, who were selected by means of unrestricted random sampling in the sports disciplines: soccer, basketball, climbing, athletics and taekwondo. The sample was calculated with a margin of error of 5 % and a confidence level of 95 %, delimiting a sample of 137(n) people, who were informed of their participation and signed the consent.

Techniques and instruments

1. Sit and reach test: this test was designed to measure the flexibility capacity of the hamstring and lower back muscles, it was of great relative intra-examiner reliability of r= 0.95-0.99 regardless of the sex of the evaluated person; it was explored with the patient seated, knees extended and feet flexed at 90º, both placed against a drawer specially built for carrying out this test. From this position, the subject was urged to slowly and progressively flex the trunk to the maximum, with legs and arms extended, and maintain the final position for approximately two seconds. This final position reached was considered the result of the test, where at that moment, the distance between the tips of the fingers and the tangent to the soles of the feet was assessed. The values that exceed the soles of the feet (zero of the rule) were considered positive and those that did not reach them were considered negative. The measurement of this test was made in centimeters.

2. Queen Collage Endurance Test: is a test based on recovery time as a reliable index of VO2max assessment, which consisted of going up and down a step that presented a height of 16.25 inches (41.3cm) for three minutes, at a rate of 24 runs/min for men. After completing the three minutes, the participant had to remain standing for five seconds and after this the pulse was taken for 15 seconds, multiplied by four and thus converted into beats per minute. This value was called recovery heart rate (FCR), which was used to estimate maximum oxygen consumption using the following formula: Men VO2max. (ml/kg/min) = 111.33 (0.42 x FCR). The Pearson correlation coefficient found a validity of the Queens College test of r=0.95 and an SEE=1.0 in young males. In 2005, they obtained the same characteristics for women with r= 0.95 and SEE = 0.344.

3. Strength test vertical jump test: The application and the Vert brand device were used to assess the explosive strength, this allowed to identify the initial speed and the final impact of the fall, with an accuracy greater than 95%; the device was placed in the elastic of the athlete's pants and he was asked to execute the jump, this value was recorded in cm.

Statistical analysis

A database was established in Microsoft Excel 2016 (v16.0), the results were analyzed using the SPSS version 21 package (Statistical package for Social Sciences). Qualitative data were expressed in frequencies and percentages for the variables gender, ethnicity, and quantitative data in mean, maximum, minimum, and standard deviation values for the variables age, flexibility, strength, and VO2max. To determine normality, the Kolmogorov Smirnov test was applied; tests of descriptive statistics and parametric inferential statistics ANOVA One way were applied (one factor) and post hoc studies (Tukey test) were developed. This was used as a categorical classifier for sports disciplines. For the correlation of the parametric variables, the Pearson coefficient was used.

RESULTS AND DISCUSSION

In this section, the statistical studies that classified the sample were included (Table 1), including ethnicity and gender by discipline (Table 2, Table 3 respectively), means and Anova test (Table 4), multiple comparisons with post hoc of Tukey (Table 5) and the relationships of flexibility capacity with strength and VO2max, through Spearman's Rho test (Table 6).

Table 1. *- Distribution of the average age according to sports discipline*

Sport	Means	Minimum	Maximum	Dev . typ .
Cycling	15.4	14.0	17.0	1.0
Climbing	17.3	13.0	25.0	3.8
Basketball	21.0	16.0	27.0	3.4
Football	21.3	16.0	32.0	4.2
Athletics	17.2	13.0	39.0	5.4
taekwondo	13.6	12.0	16.0	1.4
Total	18.0	12.0	39.0	4.6

The youngest group with an average age of 13 years corresponded to taekwondo and this age was considered the initiation stage of this sport (Villalba *et al.,* 2018). Cycling had an average age of 15 years and that was considered the initiation age; the results in climbing averaged 17 years and it was recognized as the age of specialization in this discipline. At 17 years old, athletics and at 21 years old, basketball and soccer, were considered appropriate ages to achieve maximum sports performance (Cañadas, 2021).

Table 2. *- Distribution of ethnicity according to sports discipline*

Sport		Ethnicity		
		Mestizo	Afro-descendant	Indigenous
Cycling	F	20	0	0
	%	14.6%	0.0%	0.0%
Climbing	F	15	0	0
	%	10.9%	0.0%	0.0%
Basketball	F	17	2	0
	%	12.4%	1.5%	0.0%
Football	F	29	10	0
	%	21.2%	7.3%	0.0%
Athletics	F	14	6	0
	%	10.2%	4.4%	0.0%
taekwondo	F	17	6	1
	%	12.4%	4.4%	.7%
Total	F	112	24	1
	%	81.8%	17.5%	.7%

In the sports disciplines studied, the ethnic group that prevailed was the mestizo type with 81.8 %, followed by the Afro-descendant ethnic group with 17.5 %; data that coincided with the population issue of the province of Imbabura according to the INEC. From this it was concluded that the ethnic group with the greatest predominance in the locality was the mestizo type, values that could be verified in other related researches, such as the case of Flores *et al.,* (2014).

Table 3. *- Gender distribution according to sports discipline*

Sport		Gender	
		Male	Feminine
Cycling	F	13	7
	%	9.5%	5.1%
Climbing	F	9	6
	%	6.6%	4.4%
Basketball	F	16	3
	%	11.7%	2.2%
Football	F	20	19
	%	14.6%	13.9%
Athletics	F	10	10
	%	7.3%	7.3%
taekwondo	F	9	15
	%	6.6%	10.9%
Total	F	77	60
	%	56.2%	43.8%

The male gender stood out minimally, with 56 % over the female gender, with 43 %; the inequality gap between genders was increasingly shorter, since inclusion policies threaten participation between genders (Conde Pascual, 2022; Zitlally Flores, 2020).

Table 4. *- Distribution of means and ANOVA test by sport discipline*

	Cycling	**Climbing**	**Basketball**	**Football**	**Athletics**	**taekwondo**	**Next.**
Flexibility/cm	28.8 ±4.9	31.9 ±10.7	20.9±4.1	24.4±6.6	25.05±8.9	31.3±7.7	0,000
Strength /cm	30.1 ±6.7	48.8±8.6	45±9.8	43.5±10.9	41.8±8.9	33.2±8.2	0,000
VO2max/ ml*kg-1*min-1	52.9±11.7	41.5±5.6	57.1±9.2	52.8±11.9	43.7±7.1	43.7±10.8	0,000

± Standard deviation; sig <0.05

Climbing and taekwondo were considered the most flexible, averaging 31cm; in both disciplines it was required to perform specific gestures and postures that implied a greater amplitude of movements. They had adequate amplitude and skill in execution that allowed for faster and more precise movements (Morenas *et al.,* 2021; Paramitha *et al.,* 2020).

The average strength that stood out in the different disciplines was climbing with 48 cm of jumping capacity, since fast and explosive movements were required to reach the climbing wall press in the execution of the gesture that involves the impulse in the lower limbs and the hand grip strength. Basketball reached an average of 45 cm in jump height, data higher than those found in young Colombian basketball players where the average was 37 (Rojas *et al.,* 2019). This sport involved jumps, sudden changes of direction and deceleration actions, which demonstrated a leading use of this type of strength (Aksoviæ *et al.,* 2020).

The VO2max of the basketball players obtained an average of 57 ml*kg-1*min-1 and was awarded the category of excellent, this denoted superiority in values, coinciding with different studies where the average of young basketball players was between 45 and 50 ml*kg-1*min-1. (Rozi, 2020; Husairi et al., 2021). In soccer, a VO2max of 52.8 ml*kg-1*min-1 was presented, with approximate values to the studies carried out in young soccer players where the average of their VO2max was between 51 and 55 52.8 ml*kg -1*min-1 considered an indicator of the aerobic fitness necessary to be able to sustain the 90 minutes of play that this discipline demands (Modric *et al.,* 2020; Hardiansyah, 2020).

After performing the ANOVA test of one factor, to compare the groups studied, a difference was observed between the means of both flexibility, strength and VO2max in the different sports disciplines, with a significance p<0.05.

Table 5. *- Multiple comparisons between sports disciplines through Tukey's post hoc test*

Flexibility		**P**
Cycling	Basketball	0.012
Climbing	Basketball	0
	Football	0.012
Basketball	Cycling	0.012
	Climbing	0
	taekwondo	0
Football	Climbing	0.012
	taekwondo	0.005
taekwondo	Basketball	0
	Football	0.005
Strength		P
Cycling	Climbing	0
	Basketball	0
	Football	0
	Athletics	0.001
Climbing	Cycling	0
	taekwondo	0
Basketball	Cycling	0
	taekwondo	0.001
Football	Cycling	0
	taekwondo	0
Athletics	Cycling	0.001
	taekwondo	0.029
taekwondo	Climbing	0

	Basketball	0.001
	Football	0
VO2max		P
Cycling	Climbing	0.017
	taekwondo	0.011
Climbing	Cycling	0.017
	Basketball	0
	Football	0.005
Basketball	Climbing	0
	Athletics	0.001
	taekwondo	0
Football	Athletics	0.018
	taekwondo	0.002
Athletics	Basketball	0.001
taekwondo	Cycling	0.011
	Basketball	0
	Football	0.002

Tukey post hoc test p<0.05

Post-hoc comparisons made it possible to establish that these differences were significant between the disciplines: in flexibility, basketball had a lower value and a significant difference ($p<0.05$) with respect to cycling, climbing and taekwondo. Regarding strength, taekwondo and cycling presented the lowest averages, being different ($p<0.05$) from soccer and basketball. VO2max for rock climbing differed significantly from cycling, basketball, and soccer.

Determining the profile of the athletes through the main conditioning physical capacities (flexibility, explosive strength and VO2max), made it possible to quantify and analyze the improvement in physical and technical performance, by facilitating the adjustment of intensities and volumes in their training plans (Cejudo Palomo, 2015). Maintaining flexibility training allowed sustaining the condition of the athlete, which were similar to the movements and technical gestures of each discipline (Ubaque, 2019).

Table 6. *- Relationship of flexibility with strength and VO2max through Spearman's Rho test*

Flexibility/strength	**Next.**	**0.0000**
	Rho Spearman	0.462
Flexibility/resistance	Next.	0.001
	pearson	-0.423

Flexibility had a moderate direct relationship (p<0.05.) (0.462) with explosive strength, that is, if flexibility increased, so did strength; in sport, strength training can contribute to the development and maintenance of flexibility (Simão *et al.,* 2011)

Flexibility had a moderate inverse relationship (p<0.05.) (-0.423) with VO2max, that is, if flexibility increased, VO2max decreased. VO2max and flexibility are essential bimotor components for athletes; however, they differ from the study conducted by this author Zhan k. where flexibility is directly proportional to aerobic capacity (Candrawati *et al.,* 2019).

CONCLUSIONS

The explosive strength with the highest level corresponds to the average that stands out was climbing (48cm) of jumping capacity, followed by basketball (45cm); the VO2max of the basketball players was excellent (57 ml*kg-1*min-1); soccer presented an average VO2max (52.8 ml*kg-1*min), with significant differences between the means (p=<0.05). The flexibility of the sports disciplines had a moderate direct relationship (p=<0.00) with strength and a moderate inverse relationship (p=<0.01/ rho =-0.4) and with VO2max.

In the study, the disciplines taekwondo and climbing were the most flexible and the level of average explosive strength that prevailed was that of climbing, followed by basketball; soccer presented an average VO2max level that exceeded the other disciplines.

Flexibility was directly proportional to strength, that is, if flexibility increased, strength also increased; however, flexibility was inversely proportional to VO2max, that is, flexibility decreased and VO2max increased.

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Conflict of interests:
The authors declare not to have any interest conflicts.

Authors' contribution:
The authors have participated in the writing of the work and analysis of the documents