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EFFECT OF THE IMPLEMENTATION OF A FLEXIBILITY PROGRAM ON JOINT RANGE OF MOTION AND THE SPEED OF STRAIGHT FIST BLOWS IN BOXING AND MUAY THAI ATHLETES

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Abstract. The objective of this research was to determine the results of the implementation of a program for the development of Flexibility in Boxing and Muay Thai athletes, on the joint range of motion (ROM) and the production of Speed of straight fist blows. A quantitative methodology was used with a pre-experimental research design. From the evaluation of Flexibility in 10 Boxing and Muay Thai athletes using the Flexitest method, and after evidencing the lowest levels of this capacity in the ankle, shoulder and wrist areas, a 6-week training program was developed using the dynamic, static and FNP methods for the training of these areas. Peak speeds achieved by participants in straight fist blows thrown into the air were also assessed. Statistically significant differences were observed when comparing the joint ranges pre and post program training of Flexibility in the ankle and shoulder joints. With respect to Speed, no statistically significant differences were observed in any of the gestures evaluated. The strength of association was low to zero when correlating the Flexibility and Speed production of the gestures. Although the flexibility of shoulders and ankles was improved, the speed of the striking gestures was not modified and could not be considered an association between both variables.

Keywords: flexibility, range of motion, boxing, muay thai, fist blow.

EFECTO DE LA IMPLEMENTACIÓN DE UN PROGRAMA DE FLEXIBILIDAD SOBRE LOS RANGOS DE MOVILIDAD ARTICULAR Y LA VELOCIDAD DE LOS GOLPES RECTOS DE PUÑO EN ATLETAS DE BOXEO Y MUAY THAI

Resumen. El objetivo de esta investigación fue determinar los resultados de la implementación de un programa para el desarrollo de la Flexibilidad en atletas de Boxeo y Muay Thai, sobre la rangos de movilidad (ROM) articulares y la producción de Velocidad de los golpes rectos de puño. Se utilizó una metodología cuantitativa con un diseño de investigación preexperimental. A partir de la evaluación de la Flexibilidad en 10 atletas de Boxeo y Muay Thai utilizando el método Flexitest, y tras evidenciar los niveles más bajos de esta capacidad en las zonas de tobillo, hombro y muñeca, se desarrolló un programa de entrenamiento de 6 semanas de duración utilizando los métodos dinámico, estático y FNP para el entrenamiento de estas zonas. También se evaluaron las Velocidades pico alcanzadas por los participantes en golpes de puño rectos lanzados al aire. Se observaron diferencias estadísticamente significativas al comparar los rangos articulares pre y post programa de entrenamiento de la Flexibilidad en las articulaciones de tobillo y hombro. Con respecto a la Velocidad no se observaron diferencias estadísticamente significativas en ninguno de los gestos evaluados. La fuerza de asociación resultó de baja a nula al correlacionar la Flexibilidad y producción de Velocidad de los gestos. Si bien se mejoró la Flexibilidad de hombros y tobillos, la Velocidad de los gestos de golpeo no se vio modificada y no se pudo considerar una asociación entre ambas variables.

Palabras clave: flexibilidad, rango de movimiento, boxeo, muay thai, golpe de puño.

Introduction

Flexibility, along with Strength, Endurance, and Speed, is one of the biomotor capacities that condition sports performance (Hohmann et al., 2005). However, throughout history, its development has been disadvantaged because of studies that generated a poor perception about the effects of its implementation (Chaabene et al., 2019). In this context, it becomes important to reconsider the benefits of the use of stretching work in the preparation of athletes.

In Combat Sports, the development of Flexibility exercises, besides being proposed due to a custom of historical nature (Chaabene et al., 2019), would be considered as a conditioner of performance in most of its modalities (Basar et al., 2014; El-Ashker, 2018; Franchini & Herrera-Valenzuela, 2021; Lima, 2017; Lenka & Shah, 2019; Sánchez-Sánchez et al., 2014; Saraiva et al., 2014; Schwartz et al., 2015; Slimani et al., 2016; Wongputthichai & Ketchatturat, 2017).

Several authors have postulated about the benefits of having adequate levels of this capacity, from its positive impact on the strength-velocity productions during muscle contractions (Del Rio Valdivia et al., 2015; Hunter & Marshall, 2001; Kokkonen et al., 2007 and 2010), which is why it was determined to know the levels of this capacity in a group of Boxing and Muay Thai athletes.

After evaluating the Flexibility from the Flexitest method (Araujo, 2005 and 2008) in a sample composed of 10 competitors of these disciplines, and after the analysis of the results, the lowest levels of range of motion (ROM) in the ankle, wrist and shoulder areas were evidenced.

According to the problems encountered, the implementation of a program for the development of flexibility with the sample of athletes mentioned was determined and the results obtained were analyzed in order to evaluate its effect on ROM and speed of execution of straight fist strikes.

Flexibility and sports performance

In the field of sport, improvements in Flexibility could be related to increases in the ability to apply muscular force and achieve more powerful actions (Kokkonen et al., 2007 and 2010; Shrier, 2004).

Sporting gestures, and particularly those of a ballistic nature, involve muscular chaining actions in which a series of shortening and lengthening reactions of various muscles are combined to varying degrees, which occur in different planes of movement at the same time following a spiral-diagonal activation pattern (McAtee & Charland, 2010). Thus, when the athlete moves by activating his antagonist musculature to accumulate energy to be used later in the agonist action, he can thus achieve a greater ROM and travel for his acceleration, which may allow him to apply a greater amount of Force (Weineck, 2005).

Taking the above into consideration, improvements in the Flexibility of athletes could offer benefits on the production of Strength-Speed, from its incidence on the stretch-shortening cycle (SSC).

The SSC, present in most sports actions, makes it possible to link an eccentric muscle stretching action with a concentric muscle shortening action performed at high intensity, so as to develop a large amount of force in a very short period of time from the use of the potential energy stored in the elastic components (Copoví Lanusse, 2015).

Improved Flexibility could have a positive impact on SSC due to a reduction in passive *stiffness* or resistance of structures to deformation, allowing optimal stretching with a greater reserve of potential kinetic energy by a reflex accumulation of a greater number of muscle fibers in the motor sequence (Gleim & McHugh, 1997; Kim, 2006; Medeiros & Lima, 2017; Rodriguez Casallas & Gracia Diaz, 2015; Weineck, 2005).

The benefits of improved flexibility on SSC performance would be in contrast to the role of active muscle *stiffness* in isolated isometric or concentric actions. This is so since in these cases a higher *stiffness* would have been shown to be positively related to isometric force production, rate of isometric, and concentric force development (See Figure 1), which would be explained by a more efficient contractile force transmission in the muscle-tendon units.

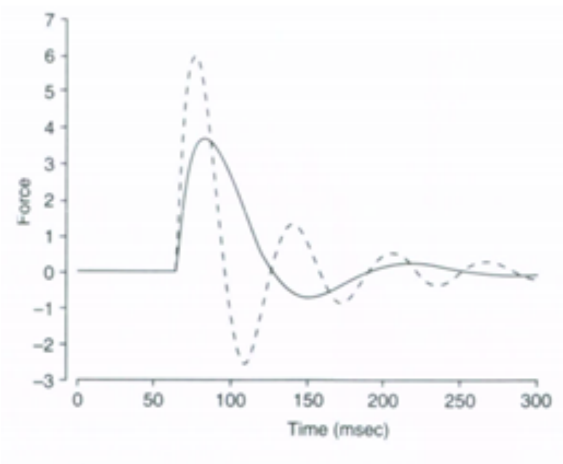

Figure 1. Force-time curve and muscle stiffness.

Note: representation of the oscillations generated by applying forces on two systems. A system with higher stiffness (dotted line) would allow a higher initial force transmission to occur and will oscillate at a higher frequency. Taken from Gleim, G. W. & McHugh, M. P. (1997). Flexibility and Its Effects on Sports Injury and Performance (p. 290). *Sports Medicine*.

Following the research work carried out by Rees et al. (2007), Flexibility training through the PNF (Proprioceptive Neuromuscular Facilitation) method, not only could generate improvements on ROM but also an increase in muscle-tendon *stiffness* with improvements on Strength development.

According to Medeiros & Lima (2017), another viscoelastic property that has an influence on the improvement of muscle performance is the reduction of hysteresis or loss of energy as heat. According to these researchers from a stretching regimen, this parameter can be positively influenced allowing a reduction in energy dissipation in the muscle-tendon unit.

Data acquired on punch kinematics from studies by Cheraghi et al. (2014) indicated that boxers partially flex their upper extremity joints, especially the elbow joint, at the onset of the gesture. Piorkowski et al. (2011) also found from the analysis of video recordings, that during the onset of a fist strike the performers performed knee flexion/extension counter movements. Apparently, these athletes would intuitively be using the SSC to throw punches, allowing to think that the development of Flexibility could be related to improvements in the ability to throw fist punches in a faster and more powerful way.

Method

The methodology used for this research was quantitative since it was based on the collection and analysis of data composed of a score for twenty passive joint movements and the peak velocity in different combinations of straight fist strikes.

Research Design

The research design was pre-experimental and action-research type, considering that it was a problem evidenced in a specific group of athletes and for whom an intervention proposal was carried out, which was included as part of their daily training.

The development presented a longitudinal character since the data were collected in a pre-test and after the conditioning activity (of 6 weeks duration) in a post-test.

Population and Sample

The study was carried out with a non-probabilistic sample composed of 6 boxing athletes (1 woman and 5 men) and 4 Muay Thai athletes (4 men), who carried out their training together at the Integral Fitness training center located in the Autonomous City of Buenos Aires, Argentina. The inclusion criteria consisted of having more than one year of training experience in these activities and having participated in some *amateur* or professional competition. In addition, they should not be recovering from any injury that could compromise the results of the *tests*.

Variables

The dependent variable was composed of the participants' levels of flexibility and the speed achieved in straight fist strikes, while the independent variable was the conditioning activity, that is, the training program for this physical capacity (see Figure 2).

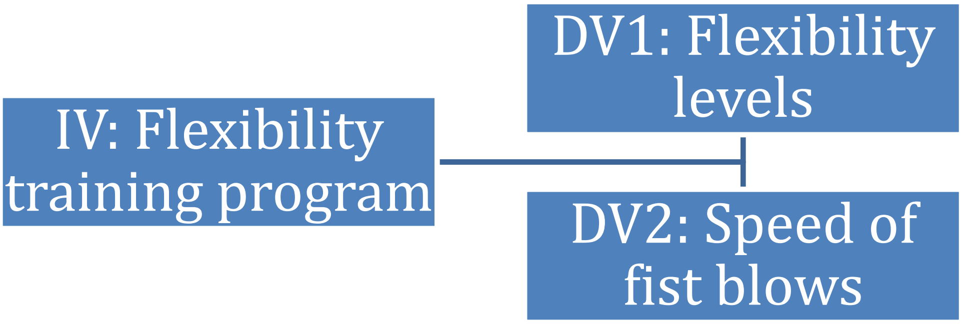

Figure 2. Study variables.

Note: IV - independent variable, DV - dependent variable.

Measuring Instruments and Techniques

The Flexitest method (Araujo, 2005) was used to evaluate the flexibility levels of the participants. This tool allows the measurement of 20 joint movements performed passively and has been used in athletes from different disciplines (Farinatti et al., 2014; Marinho et al., 2011; Montealegre Suárez & Vidarte Claros, 2019; Roa López, 2009). The maximum ROM achieved by each joint was compared with a list of images showing different positions, allowing a score to be assigned for each one according to its amplitude. According to the score given, the following rating scale was established: 0 very poor, 1 poor, 2 average, 3 good, and 4 very good. In addition, the sum of the results of all the movements provided an indicator of the overall Flexibility level of the subject called flexindex. As there were no significant differences between the two sides of the body except for pathological conditions (Braganca de Viana et al., 2008), the measurement of the limbs was carried out only on the right side of the participants. Regarding the reliability of this test, high intra- and inter-observer levels were determined for Flexitest (Araujo, 2005 and 2008).

Hykso Punch Trackers accelerometers were used to determine the speed of execution of isolated straight punches and in combinations. These devices are placed on the wrists of the athletes and allow knowing the peak velocity developed during specific punching gestures (Omcirk et al., 2021). Its design is specifically prepared for this task, allowing data collection from remote synchronization with mobile devices such as *smartphones* or *tablets*. A good level of intra-tool reliability of these sensors was determined by comparing them with the data obtained from the analysis of gestures through the Kinovea software (López et al., 2020).

Procedures

Initial evaluation

First of all, the flexibility levels of the athletes were evaluated through the Flexitest method (Araujo, 2005). For this, a session was organized specifically for this purpose in the morning hours and distanced with a minimum of thirty minutes from any physical exercise, considering that in the early hours of the day flexibility levels are higher (Rodríguez Casallas & Gracia Díaz, 2015), and that the increase in body temperature could modify muscular and joint resistance (Bishop, 2003).

Once all the individual scores were obtained, they were also grouped according to body zones; thus, forming seven averages: ankle, knee, hip, trunk, wrist, elbow, and shoulder.

After analyzing the results, it was concluded that the lowest levels of flexibility were in the ankle, shoulder, and wrist areas.

During the evaluation day, the peak velocities achieved in straight punches thrown in the air with both hands (jab and direct) and in combinations of these movements (jab-direct and jab-direct-jab-direct) were also recorded using *Hykso Punch Trackers*. The objective of this was to obtain a performance indicator of straight punches, and then compare them after the application of the program for the development of Flexibility.

Training periodization

Considering the results of the evaluations, a plan for flexibility training was developed, focusing only on the 3 areas where the lowest ROMs were observed: ankle, wrist, and shoulder.

This periodization was based on the model presented in the work of Lima et al. (2019), where the training load was dosed following an incremental staggering throughout the weeks. The work was programmed with a frequency of three weekly stimuli, located at a time of the day immediately after the strength training was developed (Leite et al., 2017); thus, to ensure greater adherence and achieve completion.

The macrocycle, with a duration of 6 weeks (Franchini & Herrera-Valenzuela, 2021), was divided into two mesocycles of three weeks each (See Tables 1 and 2). During the first mesocycle, exercises under the dynamic and static stretching methods were used. When moving to the second mesocycle, dynamic work was maintained, but with the objective of increasing the intensity of the work, static exercises were developed under the FNP modality in its two variants: agonist tension-relaxation and antagonist tension-relaxation (Franchini & Herrera-Valenzuela, 2021; Hohmann et al., 2005; Kim, 2006; McAtee & Charland, 2010; Peck et al., 2014; Weineck, 2005).

Table 1

1st Mesocycle

No.	Exercise	Method	MICROCYCLE 1		MICROCYCLE 2		MICROCYCLE 3	
			Reps/Seg	Series	Reps/Seg	Series	Reps/Seg	Series
1	Ankle rotations	Dynamic	12c/l	3	12c/l	4	15c/l	4
2	Dorsiflexion of ankles	Static	20"	3	30"	3	30"	4
3	Plantar flexion	Static	20"	3	30"	3	30"	4
4	Shoulder circles with elastic bands	Dynamic	12c/l	3	15c/l	4	15c/l	4
5	Internal rotation of shoulders	Static	20"	3	30"	3	30"	4
6	External shoulder rotation	Static	20"	3	30"	3	30"	4
7	Posterior shoulder abduction	Static	20"	3	30"	3	30"	4
8	Posterior shoulder adduction	Static	20"	3	30"	3	30"	4
9	Wrist rotations	Dynamic	12c/l	3	12c/l	4	15c/l	4
10	Wrist flexion	Static	20"	3	30"	3	30"	4
11	Wrist extension	Static	20"	3	30"	3	30"	4

Note: model of the first mesocycle of the periodization of the Flexibility training.

Table 2

2nd Mesocycle

No.	Exercise	Method	MICROCYCLE 1		MICROCYCLE 2		MICROCYCLE 3	
			Reps	Series	Reps	Series	Reps	Series
1	Ankle rotations	Dynamic	15c/l	4	15c/l	4	20c/l	4
2	Dorsiflexion of ankles	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Plantar flexion	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
3	Shoulder circles with elastic bands	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Internal rotation of shoulders	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
4	External shoulder rotation	Dynamic	15c/l	4	15c/l	4	20c/l	4
5	Posterior shoulder abduction	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Posterior shoulder adduction	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
6	Wrist rotations	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Wrist flexion	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
7	Wrist extension	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Ankle rotations	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
8	Dorsiflexion of ankles	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	Plantar flexion	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
9	Shoulder circles with elastic bands	Dynamic	15c/l	4	15c/l	4	20c/l	4
10	Internal rotation of shoulders	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
	External shoulder rotation	FNP antagon	5 "x20"	1	5 "x20"	2	5 "x20"	3
11	Posterior shoulder abduction	FNP agonist	5 "x20"	1	5 "x20"	2	5 "x20"	3
		FNP antagon	5 "x20"	4	5 "x20"	2	5 "x20"	3

Note: model of the second mesocycle of the periodization of the Flexibility training.

Final evaluation

For proper control of exercise intensity, athletes were asked to reach moderate pain levels during their execution (See Figure 3), equivalent to 5-6 points on a perceived exertion scale (Apostopoulos, 2015).

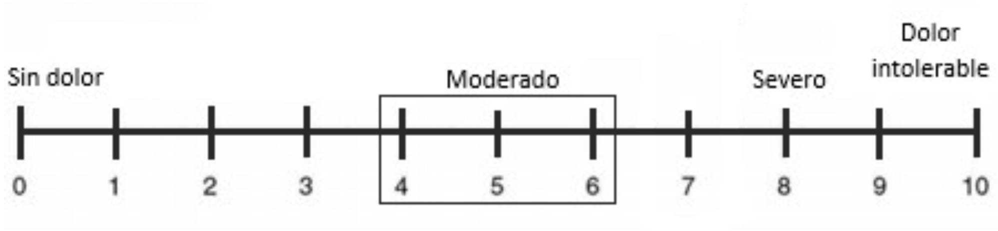

Figure 3. Perceived exertion scale.

Note: pain level that athletes should aim for (4 to 6) when performing the Flexibility exercises.

Once the six weeks of periodization were completed, the athletes were summoned again following the same criteria established for the initial evaluation: morning schedule and prior to the development of their training sessions.

The twenty joint movements corresponding to the Flexitest protocol were evaluated, as well as the speed of execution of straight strokes.

Statistical Analysis

Categorical variables were reported as number of presentation and percentage. Continuous variables that assumed a normal distribution were reported as mean and standard deviation (SD). Otherwise, median and interquartile range (IQR) were used. Statistical tests (Shapiro-Wilk test) and graphical methods (histograms and quantile-quantile) were used to determine the sampling distribution of continuous variables.

Pre- and post-implementation changes in the flexibility program were explored using statistical inference tests. For this purpose, the Student's t-test for paired samples or the Wilcoxon signed-rank test was used.

On the other hand, the strength of association between changes in Flexibility and changes in Velocity production in straight fist strikes was evaluated. For this purpose, Pearson's r correlation coefficient or Spearman's rho correlation coefficient was used, as appropriate. The magnitude of correlation was considered very high (0.9 to 1.0), high (0.7 to 0.89), moderate (0.5 to 0.69), low (0.3 to 0.49), and null (< 0.3) (Mukaka 2012). A p value <0.05 was considered significant. IBM SPSS Macintosh software, version 24.0 (IBM Corp., Armonk, NY, USA) was used for data analysis.

Results

Flexibility

At baseline, the median total score on the flexindex was 46.5 (RIQ 40.75 - 52) points, with a minimum and maximum of 36 and 56 points, respectively (Figure 4). After the training program, the median flexindex score was 54 (RIQ 50.75 - 58.25) points.

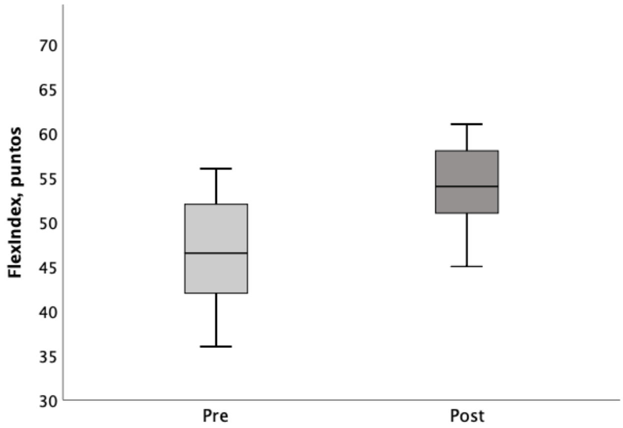

Figure 4. Box plot for the variable flexindex pre- and post-training.

When determining the changes between the beginning and end of the program, a mean difference of 7.9 (SD 5.28) points was observed, with a minimum of 1 and a maximum of 15 points. These differences were statistically significant (p=0.001). Figure 5 shows the individual scores on the flexindex variable pre- and post-program.

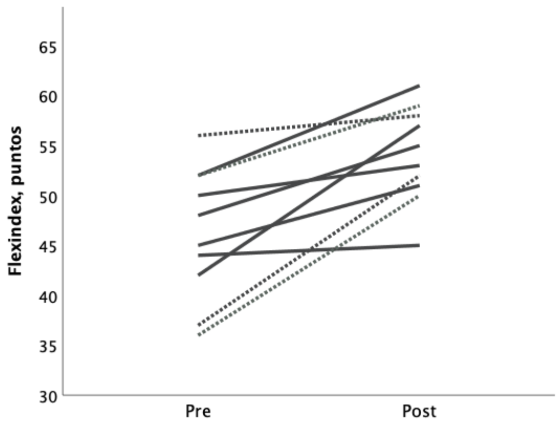

Figure 5. Individual scores in the flexindex variable pre- and post-training.

Note: the sport of the participants is represented by solid (Boxing) and dotted (Muay Thai) lines.

Table 3 presents the pre- and post-program comparisons of the flexibility of the different movements evaluated.

Table 3

Comparison of pre- and post-training flexibility

Variables	Pre	Post	p-value
Ankle dorsiflexion	2 (1.75 - 2)	2 (2 - 3)	0.014
Ankle plantar flexion	2 (1 - 2)	3 (2 - 3)	0.008
Knee flexion	3 (3 - 4)	3 (3 - 4)	0.56
Knee extension	2 (1.75 - 2)	2 (2 - 2)	0.32
Hip flexion	3 (2 - 3)	2.5 (2 - 3)	0.56
Hip extension	3 (2 - 3)	3.5 (2 - 4)	0.014
Hip adduction	3 (3 - 3.25)	4 (3 - 4)	0.18
Hip abduction	3 (2.75 - 3)	3 (3 - 3)	0.32
Trunk flexion	3 (2 - 3)	3 (3 - 3)	0.046
Trunk extension	2.5 (2 - 3.25)	3 (3 - 3.25)	0.034
Lateral trunk flexion	3 (2 - 4)	3 (2.75 - 4)	0.48
Wrist flexion	2 (2 - 2)	2 (2 - 3)	0.083
Wrist extension	2 (2 - 2)	2 (2 - 2.25)	0.32
Elbow flexion	3 (2 - 4)	3 (3 - 3.25)	0.41
Elbow extension	2 (2 - 2)	2 (2 - 2)	0.99
Posterior adduction of the shoulder from abduction to 180º	2.5 (1.75 - 3)	3 (2 - 4)	0.034
Posterior adduction or shoulder extension	1 (1 - 2)	2 (1 - 2.25)	0.059
Posterior shoulder extension	1 (0.75 - 2)	1 (1 - 2)	0.18
Lateral rotation of the shoulder with 90° abduction and 90° elbow flexion	1.5 (1 - 2)	2.5 (1.75 - 3)	0.024
Medial shoulder rotation with 90° abduction and 90° elbow flexion	2.5 (2 - 3.25)	4 (3 - 4)	0.014

Note: n=10, all numerical values are expressed as median and interquartile range (IQR).

Range of Motion

Table 4 presents the pre- and post-flexibility program comparisons for the ROM of the different joint groups evaluated. Statistically significant differences were only observed when comparing the values in the ankle and shoulder joints (p=0.006 and p=0.005, respectively).

Table 4

Comparison of pre- and post-training range of motion.

Variables	Pre	Post	p-value
Ankle	1.75 (1.5 - 2)	2.5 (2.5 - 3)	0.006
Knee	2.5 (2 - 3)	2.5 (2.5 - 3)	0.41
Hip	2.88 (2.31 - 3)	3.13 (2.69 - 3.5)	0.12
Trunk	2.5 (2 - 3.33)	3 (3 - 3.33)	0.06
Wrist	2 (2 - 2.38)	2 (2 - 2.63)	0.32
Elbow	2.5 (2 - 3)	2.5 (2.5 - 2.63)	0.41
Shoulder	1.7 (1.2 - 2.5)	2.4 (1.95 - 2.85)	0.005

Note: n=10, all numerical values are expressed as median and interquartile range (IQR).

Figure 6 shows the medians of each joint group evaluated pre- and post-flexibility training program.

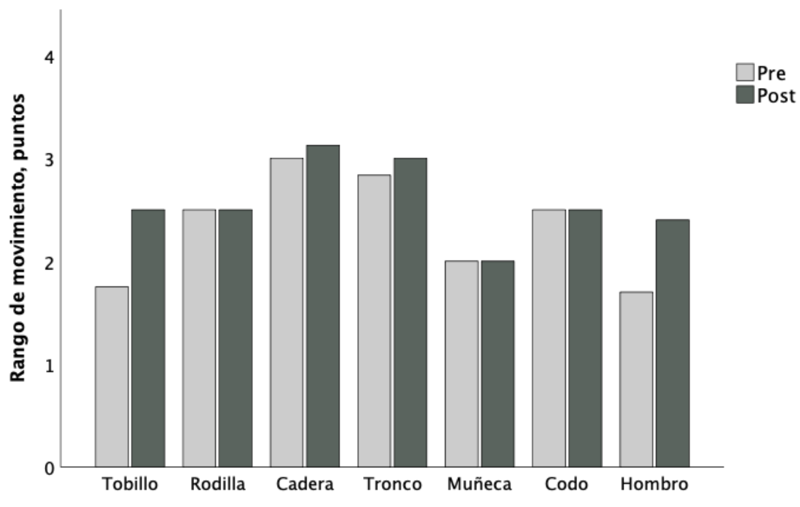

Figure 6. Range of motion pre- and post-training.

Note: bar graph of the range of motion variable for the different joint groups evaluated pre- and post-training program.

Speed Production

Table 5 presents the comparisons in the Speed pre- and post-Flexibility program. No statistically significant differences were observed in any of the evaluated gestures.
Table 5

Comparison of Speed pre- and post-Flexibility program.

Note: all numerical values are expressed as mean and standard deviation (SD).

Variables	Pre	Post	Average of the differences	p-value
Jab (m/s)				
1	4.69 (0.7)	4.54 (0.6)	-0.15 (0.60)	0.45
1.2	4.13 (0.73)	4.32 (0.62)	0.19 (0.89)	0.52
1,2,3,4	5.43 (1.3)	5.88 (1.4)	0.46 (1.01)	0.18
Direct (m/s)				
1	5.41 (0.68)	5.82 (0.85)	0.41 (0.84)	0.16
1.2	4.48 (0.62)	4.67 (0.82)	0.19 (0.80)	0.47
1,2,3,4	5.06 (1.66)	5.12 (1.32)	0.06 (1.08)	0.86

Correlation between changes in Flexibility and Speed

To correlate the change in the Flexibility variable (flexindex) and the changes in the Velocity production of the different straight stroke gestures (Jab and Direct, 1, 1,2 and 1,2,3,4), Spearman's rho correlation coefficient was used (See Table 6). The strength of the association was low when correlating Flexibility and Speed production of Jab 1, Direct 1, and Direct 1,2 gestures. The strength of the association was null when correlating Flexibility and Speed production in *Jab 1*,2, *Jab* 1,2,3,4, and Direct 1,2,3,4 gestures (Table 6).

Table 6

Correlation between changes in flexindex and Speed in Jab and Direct

	Spearman's rho	p-value
Jab (m/s)		
1	-0.426	0.22
1.2	-0.257	0.47
1,2,3,4	-0.120	0.74
Direct (m/s)		
1	-0.363	0.30
1.2	-0.309	0.38
1,2,3,4	-0.171	0.64

Note: all numerical values are expressed as mean and standard deviation (SD).

Discussion and conclusions

Discussion

Several researches have mentioned the benefits in the performance of different gestures after the implementation of programs for the improvement of Flexibility (Del Río Valdivia et al., 2015; Hunter & Marshall, 2001; Kokkonen et al., 2007 and 2010), but in none of the cases specific parameters of punching gestures in combat sports have been evaluated. For this reason, in the present study, we investigated the relationship between improvements in Flexibility and Speed productions of straight punching gestures.

Despite the fact that in the development of the intervention program Flexibility exercises were performed under the FNP method, in contrast to the results evidenced in the research work of Rees et al. (2007), this would not seem to have had a direct impact on the production of Strength of the evaluated gestures. Although it has been considered that the speed of execution of fist strikes influences the Force and Power developed (Mack et al., 2010; Tiwari et al., 2020), the use of a device that specifically measured the latter variables, such as the one employed by Dunn et al. (2019) in their research which had a load cell to measure the applied Force, would have been very useful in order to obtain a greater amount of data on the performance of the specific gestures evaluated.

The analysis of the results of the present research showed a considerable improvement in the flexindex levels. Since this is an indicator of the Flexibility of the subjects at a global level (Araujo, 2008), a positive impact on this capacity can be glimpsed. At the moment that it has not been possible to evidence an improvement in the productions of straight stroke speed, this prevents the possibility of proposing that there is any positive impact on the SSC from the increase in the levels of Flexibility as proposed by some authors (Gleim & McHugh, 1997; Kim, 2006; Medeiros & Lima, 2017; Rodríguez Casallas & Gracia Díaz, 2015; Weineck, 2005).

Taking into account that the 6-week Periodization program for flexibility training applied on Boxing and Muay Thai athletes, showed statistically significant improvements on the ROM of the shoulder and ankle joints of the participants, this could serve as a reference for use in similar populations of athletes with whom we seek to optimize this capacity. In addition, this Periodization is aligned with the proposals of researchers such as Lima et al. (2019), who mentioned the importance of systematization to obtain positive results.

It should be noted that although the periodization of the flexibility training only contemplated the work on the shoulder, wrist and ankle areas, the comparison of the passive ROM pre- and post-training also showed improvements on the trunk and hip areas, and this could be attributed to the effect of the interconnection of the muscles through the kinetic chains of movement (McAtee & Charland, 2010). This could promote a more efficient functioning of the different body segments during the performance of sporting gestures, so it would be appropriate to consider the analysis of its relationship with the incidence of injuries.

Although it has not been possible to establish a relationship between improvements in the levels of flexibility and speed in specific gestures, the findings of research that have positively related these two variables make it necessary to further investigate this possible association in hitting athletes. This requires abandoning the stereotypes unfounded by the traditionality generated after thousands of years of history in these sports (Balmaseda, 2009; Trial & Wu, 2013), and openness on the part of coaches to encourage this type of research work.

Conclusions

In light of the results of the present research, it has been possible to investigate the effect of the implementation of a flexibility program on joint ROM and speed of execution of straight punches in a sample of ten Boxing and Muay Thai athletes.

After the evaluation of the Flexibility from the Flexitest method in 20 passive joint movements, and having evidenced the lowest levels of this capacity in shoulders, wrists, and ankles, a 6-week periodization program was carried out for its improvement.

When determining the changes between the beginning and end of the program, a statistically significant difference was observed in the levels of global flexibility (flexindex) of the participants.

With respect to the joint groups in which changes in ROM were determined, statistically significant differences were only observed when comparing the values in the ankle and shoulder joints, demonstrating that the wrists did not follow the same trajectory.

Finally, no statistically significant differences were observed in Speed productions in any of the evaluated gestures. The strength of the association between the changes in the levels of Flexibility and the Speed productions of the striking gestures was low when correlating the isolated Jab (1) and Direct (2) strikes, and the Direct throwing 1,2. The strength of the association was null when correlating Flexibility and Speed production in the Jab throwing 1,2 and 1,2,3,4 gestures and the Direct hit by throwing

1,2,3,4. These results prevent the generation of any association between the improvements obtained in Flexibility and Speed production of straight fist strikes.

Because the sample of participants was small, this has generated two limitations to the study: the impossibility of having a control group and its respective randomization.

On the other hand, working with athletes who are in the competitive calendar generates a difficulty for the longitudinal projection of a research, because in many cases the training loads must be modified when a competition is approaching, interfering with the development of the work.

Future research should consider the evaluation of other performance variables in these athletes, such as the application of punching strength, agility, and endurance, as well as other strikes (*cross*, *uppercut,* and kicks in the case of Muay Thai). In addition, working with a control group and a randomized sample would allow a more robust conclusion on the evidence of the results obtained in the research.

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