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TRAINING FOCUSED ON DEEP CERVICAL MUSCLES TO PREVENT NECK PAIN

ENTRENAMIENTO CENTRADO EN LA MUSCULATURA CERVICAL PROFUNDA EN PREVENCIÓN DEL DOLOR DE CUELLO

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ABSTRACT

The objective of the study was to create a training program for deep cervical muscles and help physical activity and sports professionals when exercising them.

There are very few guidelines related to exercising these muscles, but at the same time, scientific literature demonstrates its close connection with neck pain.

Therefore, previous research is used in order to develop a training program focused on deep cervical muscles, as well as its corresponding evaluation methods, including a new cervical extensor test aimed at achieving a more accurate estimation of strength and resistance.

Finally, a case study is presented; a woman not suffering from neck pain but having associated risk factors, who follows the program as a means of preventing it, showing clear progress after its completion.

KEYWORDS: Prevention, semispinalis cervicis, longus colli, longus capitis, isometric strength.

RESUMEN

El objetivo del estudio fue crear un programa de entrenamiento de la musculatura cervical profunda, para orientar a los profesionales de la actividad física y del deporte en el trabajo con ella.

Hay muy pocas pautas relacionadas con el trabajo de ésta, al mismo tiempo que la literatura científica nos muestra su estrecha relación con el dolor cervical.

Por ello, se utilizan las investigaciones previas para crear un programa de entrenamiento centrado en la musculatura cervical profunda. Así como sus correspondientes métodos de evaluación, entre los que se incluye un nuevo test de extensión cervical con el que se pretende conseguir una valoración de la fuerza y la resistencia más adecuada.

Finalmente se presenta un estudio de caso de una mujer sin dolor cervical, pero con factores de riesgo asociados, que sigue el programa como forma de prevención, mostrando un claro progreso tras la finalización de este.

PALABRAS CLAVE: Prevención, semiespinosos cervicales, largo del cuello, largo de la cabeza, fuerza isométrica.

1. INTRODUCTION

Nowadays we are all very familiar with neck pain, since it affects approximately 300 million people in the world, becoming one of the main causes of disability (James et al., 2018). Its annual average prevalence rate is around 26%, with a higher incidence in women and mainly aged between 35 and 49 (Hoy et al., 2010). It is estimated that half of the world population will suffer at least one episode of neck pain throughout their life (Pérez-Fernández et al., 2020). In addition, the prognosis for recovery is not very promising, given that between 50% and 75% of the people who have suffered from neck pain will experience similar symptoms once again within one to five years (De Araujo et al., 2020; Pierobon et al., 2017; Tsang et al., 2021).

According to clinical practice guidelines, the practice of physical activity is of the utmost importance to reduce neck pain. Keeping an active lifestyle and training both mobility and neck strength are established as fundamental (Zadro et al., 2019).

This is what the exercises mainly focus on in physiotherapy centres when helping people suffering from neck pain, as well as the good performance of connected regions such as the shoulder girdle, the upper extremities (Im et al., 2016; Kay et al., 2012; Lin et al., 2018; Murray et al., 2015) or the abdominal wall (He et al., 2019). Thus, interventions on this matter are found (De Campos et al., 2018; Lin et al., 2018; Villanueva et al., 2020). However, when focusing on the cervical muscles (Ludvigsson et al., 2020), we can see that the interventions tend to focus on the superficial cervical muscles (Alpayci & Ilter, 2017; De Campos et al., 2018; Murray et al., 2015), disregarding the deep muscles. Research on the latter is scarce and rare, especially when related to the field of physical activity and sport.

Therefore, with the aim of guiding professionals in physical activity and sport, we decided to research deep cervical muscles. The first thing to do was to gather information about their importance in relation to neck pain and apply it to training in order to prevent and treat the pain.

Likewise, the information obtained was used in order to develop a training program focused on the deep cervical muscles, as well as evaluation methods for estimating the progress of the participants. The program was designed aimed at people who did not suffer from pain but presented associated risk factors and therefore intended to prevent its appearance.

The objective of this study is to present a workout routine for the prevention of neck pain focused on the training of the deep muscles, and show the evaluations needed.

2. RESEARCH CONTEXT AND METHODOLOGY

Focusing on those interventions that pursue a proper functioning of the cervical muscles (Gross et al., 2015; Kay et al., 2012; O'Riordan et al., 2014), we realize that the intention is generally to reach a muscular balance that allows a neutral neck position when resting (Hrysomallis, 2016), since people suffering from neck pain commonly present low neck flexion and craniocervical extension postures (Silva et al., 2009).

Another common feature among people suffering from neck pain is the change in muscle activation patterns. In this population, it is common to find an increased activation of the superficial neck muscles, thus leading to a lower activation of the deep muscles (Bonilla-Barba et al., 2020; Deborah Falla et al., 2004; Schomacher, Farina, et al., 2012; Schomacher & Falla, 2013). This situation is due to a lack of synchronization between the corresponding motor neurons (Pierobon et al., 2017), which is also reflected in a retarded activation of the deep muscles. This exposes the cervical region to a greater force of disturbance originating mainly from the movement of the upper extremities (Deborah Falla et al., 2004; Pierobon et al., 2017).

This inhibition of the deep musculature forces the superficial muscles to carry out tasks for which they are not prepared (Jull & Falla, 2016), so that eventually they become overloaded, usually causing pain. It is not clear whether, in some cases,

these changes in the activation patterns could be the consequence of pain instead of the cause (O'Leary et al., 2011).

As mentioned above, interventions related to cervical pain usually focus on the superficial musculature. But this does not imply that the deep cervical muscles are completely ignored in this field. Research on the subject is increasing, finding even interventions in the field addressed.

A significant fact was found by Martínez de Haro et al. (1995), i.e, in 15-year-old boys, the best values in the sit-up test were related, among other factors, to neck circumference. A larger neck girth indicates greater muscle mass, and therefore, greater strength in those muscles. This fact was explained as the need to keep the head always in a balanced position and therefore gain strength with each exercise performed.

2.1. CRANIOCERVICAL FLEXION

The deep cervical flexors, mainly the longus colli and the longus capitis, directly influence the craniocervical flexion, although distorted muscle activation patterns are found in people suffering from neck pain, resulting in the inhibition of these muscles (O'Leary et al., 2011). This causes the muscles in the superficial cervical area to tend to become excited (Jull & Falla, 2016).

As a response to this situation, there are some exercises which selectively activate these muscles, such as the craniocervical flexion exercises (De Araujo et al., 2020) when the subjects, in the supine position, perform controlled craniocervical flexions. This way, they are able to perform the movement using the deep flexors. At the same time, the trainer can easily detect if the superficial flexors are being activated by palpating them. This last aspect is fundamental since a reduced activation of the superficial flexors implies a higher activation of the deep flexors (Jull & Falla, 2016). If the examiner perceives an excessive activation of the superficial flexors, this is associated with a decrease of the deep activation and the exercise concludes (De Araujo et al., 2020).

In these exercises, a sphygmomanometer (Stabilizer Pressure Biofeedback, Chattanooga Group) is placed under the participant's nape. This way, the person can instantly know the pressure he is exerting during the exercise and is able to voluntarily control it (De Araujo et al., 2020). The craniocervical flexion reduces the space between the stretcher and the cervical curvature while pressing the device, so the participant can perform isometric craniocervical flexion with different pressures.

This way of training the deep flexors has become popular mainly due to the creation of a craniocervical flexion test that follows this same protocol, and which allows us to easily identify the strength of the deep muscles (O'Leary et al., 2011). The tests that were used initially were cervical flexion tests with resistance on the forehead, but these increased the activation of the superficial flexors (O'Leary et al., 2007). There are different versions of this test, but most of them coincide in dividing the protocol into phases that measure the pressure that can

be generated by the deep muscles, and others that calculate resistance (Pierobon et al., 2017).

This training, aimed at the deep neck flexors, can be found in different interventions, both for people suffering from neck pain and for asymptomatic patients, showing its effectiveness to strengthen those specific muscles, reduce neck pain and improve posture (Deborah Falla et al., 2004).

Some authors (Pierobon et al., 2017) argue that given the malfunctioning of certain muscle groups it is necessary to start with exercises for selective activation (O'Leary et al., 2011), first low-load exercises, and later switch to high-load and strength training exercises (O'Leary et al., 2011; Schomacher & Falla, 2013).

Among the different interventions on deep neck flexors are those that use exercises similar to the craniocervical flexion test, that is, isometric contractions generally spanning 10 seconds, with different pressure levels, standing out those by Suvarnato et al. (2019), Lin et al. (2018) and Chung and Jeong (2018). We should also pay attention to the extensive review by Price et al. (2020) of different interventions on people with chronic nonspecific neck pain, among which reference is made to those of Yildiz et al. (2018), Falla et al. (2013) and Kim and Kwag (2016), for using exercises similar to those described so far. Exercises also used by Ludvigsson et al. (2015) in their intervention. However, it is important to highlight that both, the exercises using tape and those carried out on inclined planes, do not work specifically on the deep neck flexors, since there is too much superficial activation (Peolsson et al., 2013).

2.2. CERVICAL EXTENSION

Research related to deep neck extensors aims, for the most part, to detect in what way the semispinalis cervicis can be activated without activating too much the superficial extensors such as the splenius capitis, since this condition is essential if you want to modify the activation pattern.

For this, the activation of the extensors was evaluated with exercises using both resistance bands and different inclinations, finding that none of these managed to specifically activate the deep musculature (Peolsson et al., 2013).

On the other hand, the studies by Schomacher, Petzke and cols. (2012) and Schomacher et al. (2015), evaluated this activation relationship in different situations, concluding that a great selective activation of the semispinalis cervicis is achieved (ratio close to 2.5) when applying manual resistance in the direction of the flexion on the dorsal side of a cervical vertebra, while the person is offering resistance by isometric contraction in the opposite direction in order to maintain a neutral position of the cervical vertebrae.

This can be explained taking into consideration the mechanical advantage of the examined muscles, since the splenius capitis has a greater influence on the craniocervical junction, whereas the semispinalis cervicis have a greater

influence on the caudal region. Subsequently, Schomacher et al. (2015), following a similar protocol, concluded that the greatest activation occurs in the fascicles with an immediate distal insertion to the applied resistance, that is, if the resistance towards the flexion is applied on C3, the fascicle with the greatest activation is the one inserted in C4, and the fascicles distal to this one present gradually reduced activation. All this is supported by the results of a previous study (Schomacher, Dideriksen, et al., 2012) which explained that the activation of each of the fascicles of the semispinalis cervicis varied depending on their mechanical advantage in a certain demand.

This fact is a fundamental finding in relation to the subject addressed, since research by Schomacher and Falla (2013) indicates that the weakness or malfunctioning of the deep muscles is not necessarily present in all the fascicles, but can occur in some to a greater extent than in others. Therefore, when training someone, the training must be adapted to their individual conditions, focusing on some specific fascicles more than on others.

As mentioned above, one of the main goals when studying the activation of the semispinalis cervicis is to know in what way their selective activation can be achieved, in order to use them in the future as interventions, such as the exercises with manual pressure towards flexion that have been described in the studies by Schomacher, Petzke, et al. (2012) and Schomacher et al. (2015).

Another study related to this subject is the one by Elliott et al. (2010). In it, they calculated the isometric craniocervical extension, keeping the cervical region neutral from the prone position, and they found a great activation of the superficial muscles, so this exercise cannot be considered a specific exercise for the deep musculature.

Schomacher et al. (2015) analyzed muscle activation during different neck exercises. In those exercises, they exerted manual resistance on a subject who responded with maximum isometric contractions in the opposite direction in order to keep the head and cervical vertebrae in a neutral position. In one of the exercises, the subject is standing and leaning on a stretcher so that the trunk, neck and head are aligned and the forearms are resting on the stretcher, pushing against a resistance towards flexion, while in the other exercises, the subject is seated and receiving resistance towards extension, to traction or compression. The muscle activation ratios obtained between splenius capitis and semispinalis cervicis were close to 1, so these exercises cannot be considered as specific for the deep cervical muscles, although their use in the final phases of training is considered.

Finally, in research by Rivard et al. (2017), instead of using exercises with manual resistance, a tape was placed around the head at the forehead, and a rope with a light weight was attached at its end. The subject remained standing and the position of the rope indicated the level of muscle activation. In the sagittal plane, a greater activation of the semispinalis cervicis was found compared to the splenius capitis in the different directions, all having ratios close to 1.5. The study of the resistance to rotation was also included, placing a rope on the frontal plane,

but ratios were slightly lower than 1. This implies a greater activation of the splenius capitis than of the semispinalis cervicis, which is why these exercises are not used as a way of training the deep cervical musculature.

The training proposals for the deep cervical muscles that include the work of the semispinalis cervicis are very scarce. One of them is the intervention by Suvarnato et al. (2019). In order to work on cervical extension, they use isometric exercises of isometric cervical extension against a manual resistance applied towards flexion on C2, following the protocol of Schomacher, Petzke, et al. (2012), and obtaining an increase of the cervical force extension, as well as improving the posture of the head, reducing pain and achieving greater functionality.

To evaluate the cervical extension resistance, the extension test is generally used in the prone position (Sebastian et al., 2015), and a dynamometer is also added on the occipital when the aim is to calculate strength (Suvarnato et al., 2019). However, this exercise activates both the deep and the superficial musculature equally (Elliott et al., 2010), so it is not appropriate if our intention is to calculate the strength of the semispinalis cervicis. At the same time, in these types of tests, there are other factors that can radically influence the final result, such as the weight of the head. That is why, in the intervention proposal addressed in this study, a new way of calculating the strength of the semispinalis cervicis is proposed, following current scientific literature.

3. TRAINING PROGRAM

The intervention was designed including an assessment phase and four training phases. Each of these phases is made up of two sessions held on separate days, within the same week. However, the two assessment sessions were carried out one at the beginning and the other at the end of the phases of the intervention, including, in each session, the five tests that enable to know both the initial condition of the subjects who are going to start the training, and also their situation at the end of the intervention.

3.1. EVALUATION TESTS

Four tests are introduced, pre-and post-tests, plus a fifth one that will be carried out by physiotherapy professionals, since physical activity and sports professionals will work, initially and unless a medical prescription allows it, always with no pain.

3.1.1. CRANIOVERTEBRAL ANGLE

This angle indicates how far forward the head is in a relaxed standing position. And although there is great controversy about its connection with neck pain, its evolution is registered here, since it allows us to compare it with a multitude of other studies.

This angle is measured between the horizontal line that passes through C7 and the line that passes through the tragus and C7 from a lateral view (Lee et al., 2017). Therefore, a smaller angle shows a more anteriorized position of the head. The measurement protocol was based on the one used in the article by Silva et al. (2009), locating the vertebrae by palpation of the spinous processes (Schomacher et al., 2013), and taking a lateral view picture of the subject facing forward and in a comfortable standing position with feet shoulder-width apart (see Figure 1).



Figure 1:Craniocervical angle measurement

Note: The picture on the left represents the measurement prior to the intervention and the picture on the right represents the measurement after the intervention.

3.1.2. CRANIOCERVICAL FLEXION TEST

To assess the strength and resistance of the deep craniocervical flexors, that is, the longus capitis and the longus colli, the craniocervical flexion test was used, as it is recommended in a wide variety of articles and clinical guides (De Araujo et al., 2020; Pérez-Fernández et al., 2020). As explained above, this test is carried out using a Stabilizer Pressure Biofeedback, Chattanooga Group, placed under the person's nape, who is in supine position, and pre-inflated to 20mm Hg. The examiner remains beside, palpating the superficial cervical musculature and showing the device to the examinee. In Figure 4 we can see a picture of the craniocervical flexion test representing the craniocervical flexion exercise with the Stabilizer Pressure Biofeedback.

This craniocervical flexion test has three different stages.

The first stage is devoted to the instruction of the examinees, helping them to become familiar with the movement requested, so contractions of 2-3 seconds are performed, reaching pressure levels 22, 24, 26, 28 and 30mm Hg.

The second stage is the assessment of maximum pressure, that is, the examinee performs controlled repetitions of 10 seconds, going through each different pressure level, with 45-second rests between the repetitions. The activation pressure is the maximum pressure held for 10 seconds without generating compensations (Pierobon et al., 2017).

The third stage focuses on resistance. In it, 10-second isometric contractions are performed at the maximum pressure level reached in the previous stage (activation pressure), with a 30-second rest between them. Once again, the test ends when compensations appear, such as an excessive activation of the superficial muscles of the neck, when more than 20% of the target pressure is lost (generally 2mm Hg) or when 10 repetitions are performed. Once this stage is finished, the performance index is calculated multiplying the number of repetitions by the increase in pressure, that is, if 5 repetitions of 26mm Hg have been performed, the index would be 30 (5 repetitions x 6 mm Hg = 30).

3.1.3. CERVICAL EXTENSOR ENDURANCE TEST

With the aim of assessing the strength and resistance of the deep cervical muscles in charge of extension, specifically the semispinalis cervicis, a test is proposed based on what was previously mentioned in the cervical extension section regarding how to achieve a selective activation of the semispinalis cervicis.

This test is carried out with the examinee seated on a chair, feet flat on the floor, knees and hips at 90 degrees and hands on knees. The back must be leaning against the back of the chair to avoid compensations due to the movement of the body, a 1.5 cm wide tape is placed around the examinee's neck, making contact on the sides and back of the subject. The starting position is a slight low cervical flexion, subsequently performing a controlled isometric low cervical extension until a neutral cervical position is reached while encountering the resistance of the tape.

This isometric contraction is performed against a tape offering resistance towards flexion, horizontally, and connected to a fixed resistance. To measure the force exerted, a dynamometer (Suiff Pro, Grup Estel) is placed between the tape and the fixed resistance. The examiner is in charge of detecting and preventing the subject from generating compensations by moving the trunk or shoulders.

The proposed cervical extensor test is divided into three phases.

The first phase is devoted to explaining and familiarizing the examinee with the movement, so that he gets used to it and is able to perform it with no compensations such as thoracic or shoulder movements. The subject is instructed on the way he must perform a low cervical extension and once he understands how to do it, he is told that in the test he must carry out a similar isometric contraction against a tape that will offer resistance horizontally towards flexion. The examinee is allowed to perform isometric contractions of 2-3 seconds, exerting little force and placing the tape on different cervical vertebrae.

The second phase aims to evaluate the strength of the deep cervical extensors. In order to do this, the examinee performs isometric extensions of the low cervical region, without experiencing pain, in order to measure the peak force reached in that space of time. Two maximum isometric contractions of five seconds are

performed on the spinous process of C1, C3 and C6 (see Figure 2). Since in this phase our aim is to detect the maximum peak force, the intention is that the measurements are carried out with the least possible fatigue. Therefore, between the repetitions, the subject must rest for 30 seconds and between each cervical level for 3 minutes. The test is interrupted if unwanted compensations appear such as movements of the trunk or shoulders.



Figure 2: CERVICAL EXTENSOR ENDURANCE TEST

Note: In the top left picture the initial position on C1 is represented, in which the examinee presses with her index finger against her cheekbones in order to keep the tape in a correct position before exerting force; in the top right picture the contraction on C1 is represented; in the bottom left the contraction on C3; and in the bottom right the contraction on C6.

To locate each of the spinous processes, C2 is considered as the first bone detectable by palpation caudal to the occipital and C1 as the area immediately proximal to C2; in order to detect C3 and C6, the vertebrae are counted caudally to C2 and checked by counting in the opposite direction from C7, C7 being the most prominent spinous process and therefore easy to identify (Schomacher et al., 2013).

By applying force on different vertebral levels, we manage to selectively activate the different fascicles and thus assess the force of each of them (Schomacher, Dideriksen, et al., 2012), since the loss of functionality can occur irregularly among them. However, the test is not performed on all the vertebrae because it would fatigue the examinee extremely, thus distorting the results obtained in the last repetitions.

The third phase focuses on resistance. In this case, painless maximum isometric contractions of 5 seconds are performed, with 20-second rests between them. The objective is to perform as many repetitions as possible for five seconds with the peak force never below 80% of the maximum force, that is, if more than 20%

of the maximum force is lost, the exercise concludes. The test finishes when five repetitions are performed fulfilling the marked requirements or when they do not comply with the requirements. Once again, this is carried out on C1, C3 and C6 with a 4-minute rest between levels.

Figure 3 shows two examples of the graphical representation provided by the dynamometer (Suiff Pro, Grup Estel) when measuring both maximum force and resistance in the extension test.



Figure 3:Graphic representation provided by Suiff Pro

Note: An example of a maximum strength test is represented on the left and an example of an endurance test on the right.

3.1.4. NECK DISABILITY INDEX

In order to evaluate how neck pain affects the life of each subject, the *Neck Disability Index test* is used. This test is one of the most popularly used in contexts such as the one addressed in this study (Young et al., 2018) and in this specific case the version translated into Spanish will be used, its validity proved by Andrade Ortega et al. (2010). It complements the three previous tests and is used to evaluate whether there is any kind of functional limitation.

3.1.5. NUMERIC PAIN RATING SCALE

To calculate the intensity of neck pain perceived by each subject, physiotherapists use the *Numeric Pain Rating Scale* test, a scale validated for its use in clinical contexts by Young et al. (2018). In this test, pain intensity is measured on an 11-point scale, ranging from 0 to 10. Being 0 no pain at all and 10 unbearable pain.

WORKOUT ROUTINE

3.2. WARMUP

The warmup is performed at the beginning of each session of the intervention, and it involves joint mobility and a massage of the superficial cervical muscles. More details in table 1.

Although there is some controversy concerning the use of massages for warming up, different studies (MacDonald et al., 2013; Sullivan et al., 2013; Wiewelhove et al., 2019) conclude that a massage prior to the practice of physical activity on a certain muscle group can improve flexibility, without reducing the ability of contraction. Therefore, including it in the warmup is advisable. In this specific case, not being in a clinical setting and not having the help of a physiotherapist, the performer will do a self-massage.

WARMUP		
Exercise	Description	Observations
JOINT MOBILITY	Craniocervical flexion-extension	Perform all the movements slowly and in a controlled way.
	Low cervical flexion-extension	
	Right and left lateral separation (in anatomical nomenclature there is no lateral flexion)	Perform the lower limb and upper limb circumduction separately to avoid risk of injury.
	Rotation	
	Circumduction	
Superficial musculature massage	Head and neck extensors: Upper trapezius Levator scapulae Splenius capitis Sternocleidomastoid	Use a ball and massage gently in circles.
	Neck flexors: Anterior scalene Neck cutaneous	

Table 1: WARMUP

3.3. PHASES OF TRAINING

The training focuses on achieving a greater activation and the subsequent strengthening of the deep cervical muscles, specifically, the ones responsible for high cervical or craniocervical flexion and low cervical extension, as it is what most of the population suffering from neck pain lack in (Mahmoud et al., 2019; Silva et al., 2009).

When structuring the phases of a training program for the deep cervical musculature, the reason for the weakness of these muscles must be taken into account, since it is useless to apply heavy loads to inhibited muscles. Before that, it is necessary to increase their activation (O'Leary et al., 2011), in this way, in the initial phases (phase 1 and phase 2) it will be essential to perform exercises aimed at facilitating the activation of the inhibited muscles, so light-load exercises with high activation ratios will be used on the target muscles, since it is necessary

to focus on the neuromuscular component (O'Leary et al., 2011; Schomacher & Falla, 2013), although the transition from the first to the second phase shows an increased workload, with long breaks to avoid the fatigue that would lead to the use of superficial muscles.

However, in more advanced phases of the program, when the subject is able to activate the deep muscles more easily, the exercise load could be increased because at that moment, strength and resistance will take on a fundamental role in the training according to a muscular morphological point of view (O'Leary et al., 2003; Pierobon et al., 2017; Schomacher & Falla, 2013). That is the reason why in phase 3 the load continues to increase and there is an exercise that still generates a greater deep activation instead of superficial, but with a lower ratio, since at this point of the intervention the objective is to strengthen those muscles at each different level and in different everyday life situations (Pierobon et al., 2017), such as when we tend to look down (Yoon et al., 2020). Along the same lines, the exercises used in phase 4 have similar activation ratios for superficial and deep muscles because in this phase the objective is to highly activate the deep muscles, as well as perform synergistic contractions that stabilize the movement. The phases of training are represented in detail in tables 2 to 5.

PHASE 1	
OBJECTIVE	Activate the deep cervical muscles selectively.
CONTENTS	Craniocervical flexion and low cervical extension.
Craniocervical flexion	
EXERCISE	Craniocervical flexion with sphygmomanometer
DESCRIPTION	The initial position is similar to the one required in the craniocervical flexion test (20mm Hg). Craniocervical flexions are performed reaching 22mm Hg in each repetition and returning to the initial position. The same is repeated for levels 24, 26, 28 and 30mm Hg.
LOAD/ VOLUME/ REST	- 3 series x 10 repetitions. One series includes the performance of the repetitions at each of the different pressure level. - Rest: 30 " between pressure levels, 2 'between series.
Low cervical extension	
EXERCISE	Low cervical extension against manual resistance.
DESCRIPTION	The initial position is similar to the one required in the low cervical extension test, isometric contractions of this same movement are performed against the resistance offered by the trainer. The trainer offers resistance towards flexion, exerting pressure with the thumb and middle finger on one vertebra in each series (perform on C1, C3 and C6). The trainer responds with the same amount of force that the subject is generating, in order to keep the cervical vertebrae in a neutral position.
LOAD/ VOLUME / REST	- Isometric force of 50% on the maximum voluntary painless contraction. - 3 series x 10 isometric repetitions of 5". One series includes the performance of the repetitions at each of the different cervical levels. - Rest: 30 " between cervical levels, 2 'between series.

Table 2:Phase 1

PHASE 2	
OBJECTIVE	Strengthen the deep cervical muscles selectively.
CONTENTS	Craniocervical flexion and low cervical extension.
Craniocervical flexion	
EXERCISE	Craniocervical flexion with sphygmomanometer
DESCRIPTION	Similar to the craniocervical flexion exercise with sphygmomanometer in phase 1, but holding the isometric contraction at the target pressure in each repetition.
LOAD/ VOLUME/ REST	- 3 series x 10 isometric contractions of 5". One series includes the performance of the repetitions at each of the different pressure levels. - Rest: 1' between pressure levels, 3' between series.
Low cervical extension	
EXERCISE	Low cervical extension against manual resistance.
DESCRIPTION	Similar to the exercise of low cervical extension against manual resistance in phase 1.
LOAD/ VOLUME / REST	- Isometric force of 50% on the maximum voluntary painless contraction (first series), second and third series at 75%. - 3 series x 10 isometric repetitions of 10". One series includes the performance of the repetitions at each of the different cervical levels. - Rest: 1' between cervical levels, 2' between series.

Table 3:Phase 2

PHASE 3	
OBJECTIVE	Strengthen the deep cervical muscles selectively.
CONTENTS	Craniocervical flexion and low cervical extension.
Craniocervical flexion	
EXERCISE	Craniocervical flexion with sphygmomanometer
DESCRIPTION	Similar to the exercise of craniocervical flexion with sphygmomanometer in phase 2
LOAD/ VOLUME/ REST	- 3 series x 10 isometric contractions of 10". One set includes the performance of the repetitions at each of the different pressure levels. - Rest: 2' between pressure levels, 4'between series.
Low cervical extension	
EXERCISE 1	Low cervical extension against manual resistance.
DESCRIPTION	Similar to the exercise of low cervical extension against manual resistance in phases 1 and 2.
LOAD VOLUME / REST	- Isometric force of 75% on the maximum voluntary painless contraction. - 2 series x 10 isometric repetitions of 5". One series includes the performance of the repetitions at each of the different cervical levels. - Rest: 1' between cervical levels, 2 'between series.
EXERCISE 2	Cervical extension with headband on forehead

DESCRIPTION	<p>The starting position is standing with a band around the head and forehead. The band is attached to a rigid tape connected to a dynamometer with a fixed origin. The trainer holds the dynamometer so that the subject does not have to support its weight.</p> <p>The subject performs isometric cervical extension contractions against the resistance offered by the tape. The inclination of the tape changes:</p> <ul style="list-style-type: none"> - 30 degrees above horizontal (inclined) - Horizontal - 30 degrees below horizontal (declined) - Vertical
LOAD/ VOLUME/ REST	<ul style="list-style-type: none"> - Isometric force of 0.6 kg in the first series and 1 kg in the second series. - 4 flexion series x 10 isometric repetitions of 10" - The flexion is changed after 2 series. - Rest: 2' between series, 3' between different inclinations




Table 4: Phase 3

PHASE 4	
OBJECTIVE	Strengthen the deep cervical muscles and generate their synergistic contractions together with the superficial muscles and flexors with extensors.
CONTENTS	Craniocervical flexion and low cervical extension.
Cervical flexion	
EXERCISE	Cervical flexion against manual resistance.
DESCRIPTION	<p>From a sitting position, feet flat on the floor, back against the back of the chair, hands on thighs, and hips and knees at 90 degrees, isometric cervical contractions are performed. In this case, cervical flexion instead of extension, against the resistance offered by the trainer, who resists the movement towards extension, exerting pressure with the palm of the hand on a different part of the body in each of the different series (on the forehead, the ventral area of C1 or C6).</p> <p>The trainer responds with the same amount of force that the subject is generating, in order to keep the cervical vertebrae in a neutral position.</p>
LOAD/ VOLUME/ REST	<ul style="list-style-type: none"> - Isometric force of 50% on the maximum voluntary painless contraction. - 3 series x 10 isometric contractions of 10". One series includes the performance of the repetitions on each of the indicated parts (front, C1, C6). - Rest: 1' between designated parts, 2' between series
Low cervical extension	
EXERCISE	Low cervical extension against manual resistance, with forearms resting on a support.
DESCRIPTION	<p>For the initial position, the subject flexes the hips and knees until the forearms are resting on a stretcher, keeping the spine position neutral. Once in place, he performs isometric low cervical extension contractions against the resistance offered by the trainer, who resists the movement towards flexion, exerting pressure with the thumb and middle finger on one vertebra in each series (perform on C1, C3 and C6).</p> <p>The trainer responds with the same amount of force that the subject is generating, in order to keep the cervical vertebrae in a neutral position.</p>
LOAD/ VOLUME / REST	<ul style="list-style-type: none"> - Isometric force of 50% on the maximum voluntary painless contraction. - 3 series x 10 isometric repetitions of 10". One set includes the performance of the repetitions at each of the different cervical levels. - Rest: 1' between cervical levels, 2' between series.

Table 5: Phase 4

3.4. TRAINING EXERCISES

The exercises performed throughout the different phases of training are represented in Figure 4.

EXERCISE	PICTURE
<p>Craniocervical flexion with sphygmomanometer</p>	
<p>Low cervical extension against manual resistance</p>	
<p>Cervical extension with headband on forehead</p>	

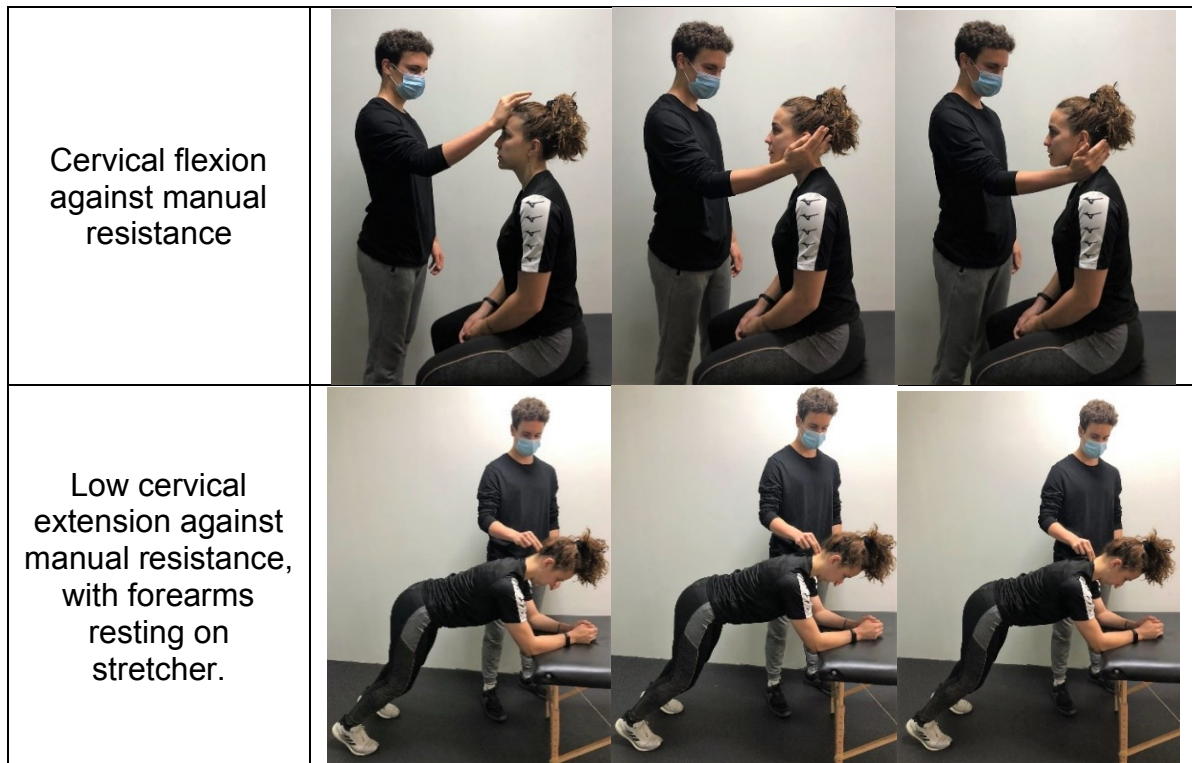


Figure 4: Training exercises

4. CASE STUDY

The training program was applied to a 23-year-old woman, not suffering from neck pain at the moment of the intervention, but having suffered some episodes of pain over the previous year, and also presenting forward head projection. As previously explained, both situations pose risk factors for the development of cervical pain in the future (Blanpied et al., 2017; Mahmoud et al., 2019). In this way, the proposed training program is applied, with the intention of preventing possible neck pain.

The training sessions were carried out on Mondays and Wednesdays for 5 consecutive weeks, making a total of 10 sessions.

The results obtained in the tests *Numeric Pain Rating Scale*, *Neck Disability Index* and craniocervical angle are presented in table 6. The measurements of the latter are also presented in more detail in table 1. The results of the craniocervical flexion test are in Table 7.

Table 6: Results of NPRS, NDI and craniocervical angle

NPRS (0-10)		NDI (0-50)		CV Angle (degrees)	
Pre	Post	Pre	Post	Pre	Post
0	0	3	2	42	51

Note: NPRS = Numeric Pain Rating Scale; NDI = Neck Disability Index; CV = Craniocervical

Table 7: Results of the craniocervical flexion test

Activation pressure (mm Hg)		Performance Index	
Pre	Post	Pre	Post
30	30	4 repetitions = 40	8 repetitions = 80

In the maximum force phase of the extension test, two measurements were registered in order to reduce the influence of possible unsuccessful attempts. The results are presented in table 8.

Table 8. Results of the maximum force phase of the cervical extension test

Cervical level	Force measurement (kgforce)			
	Pre		Post	
C1	4.3	5.3	6.9	7.1
C3	5.1	5.6	6.3	6.5
C6	5.3	5.5	5.8	6.8

Once both results are known, the highest is used as the maximum force value of each of the cervical levels to evaluate the evolution of the subject analysed. These results are represented in Table 9, along with the results for resistance, although it is necessary to highlight the importance of knowing the values that represent 80% of the maximum force in each of the cervical levels, since this is essential if we want to decide how many repetitions of the endurance test conform to what is established (see Table 10).

Table 9: Total results of the cervical extension test

Cervical level	Maximum force (kgforce)		Resistance (0-5)	
	Pre	Post	Pre	Post
C1	5.3	7.1	3	5
C3	5.6	6.5 (6.8)*	3	5
C6	5.5 (5.8)*	6.8	5	5

Note:* Maximum force value obtained in the endurance test

Table 10. Minimum force value considered valid in the endurance test

Cervical level	80 % Maximum force (kgforce)	
	Pre	Post
C1	4.24	5.68
C3	4.48	5.44
C6	4.64	5.44

To analyse the results obtained, it is necessary to consider each of the different tests in the phase of assessment.

The craniovertebral angle is specially important when assessing the evolution of the participant, since, having implemented the training program as a means of preventing neck pain, its evolution is usually very poorly reflected in pain and disability tests.

In this case, the initial value of the craniovertebral angle is 42 degrees, such a low result may seem surprising coming from a person who does not usually suffer from pain, however, it can be understood by virtue of the great variability found by some authors (Ghamkhar & Kahlaee, 2019) regarding this variable and neck pain. Likewise, considerable evolution is found, reaching 51 degrees in the final assessment, improving the cervical posture and getting close to the mean values found by Silva et al. (2009) and Suvarnato et al. (2019), and far from the forward head projection found at the beginning. However, this significant change along the intervention should not be explained solely by taking into account the increase in strength, since other factors can also influence considerably, such as the proprioception or the postural control of the area.

Regarding the strength of the longus colli and the longus capitis, the craniocervical flexion test also shows a positive evolution, since the activation pressure remains at the maximum possible (30mm Hg), above the mean value of asymptomatic people, which is close to 28mmHg (Chiu et al., 2005; Fernández-De-Las-Peñas et al., 2007). In the endurance test, we started with 40 points, value lower than expected, which was close to 60 (Fernández-De-Las-Peñas et al., 2007; Jull et al., 1999, as cited by Lin et al., 2018), thus representing the weakness of the deep cervical muscles, and justifying to a greater extent the subject's participation in the program. The intervention was completed with a performance index of 80, exceeding by far the average values.

In this way, an increase in the strength of the deep cervical flexors was found, fulfilling one of the objectives of the program.

Finally, analysing the results of the extension tests, a clear increase in both strength and endurance is found. The maximum force ranges from values close to 5.5 kgforce, to values around 7 kgforce. In terms of resistance, the number of repetitions is increased at each of the different cervical levels. In this way, having carried out the assessment of the strength of the deep cervical extensors by means of a test of our own creation, we have no previous studies with which to compare our results, but the progress of the subject is evident.

5. CONCLUSIONS:

As a conclusion for this article, the great importance of the deep cervical muscles must be emphasised due to its close relationship with cervical health, since a malfunction of this musculature is associated with the appearance of neck pain and its corresponding disability.

Likewise, current literature on the subject shows different ways of intervening by means of physical activity in order to achieve a better functioning of the deep cervical musculature. That is the reason why this study uses this information to

create a training program that responds to professionals in the physical activity sector, given their need for guidance in the exercising of the deep cervical muscles, with the intention of preventing and reducing neck pain as well as suggesting a new method for the evaluation of the strength and endurance of the semispinalis cervicis, in accordance with recent discoveries.

Finally, the case study presented provides results in line with what was expected, showing a positive evolution of the subject, and therefore emphasising the usefulness of the program.

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