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Effects of Eccentric Exercise on Muscle Architecture in Adults: A Systematic Review

Efectos del Ejercicio Excéntrico en la Arquitectura Muscular en Adultos: Una Revisión Sistemática

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SUMMARY: The purpose of this systematic review was to determine the effects of eccentric training on muscle architecture in the adult population. Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statements were followed using keywords associated with architecture muscular and eccentric training. Four databases were used: PubMed, Scopus, SPORTDiscus and Web of Science. Methodological quality was assessed using the PEDro scale. A total of 1260 articles were retrieved, 18 included in this review. The parameters most frequently evaluated in the studies consulted were pennation angle (PA), fascicle length (FL), and muscle thickness (MT). These were assessed mainly in lower limb muscles such as biceps femoris long head (BFlh), vastus lateralis (VL), medial gastrocnemius (MG) and lateral gastrocnemius (LG), respectively. Eccentric training for at least four weeks generates adaptations in these parameters, mainly by increasing MT with FL and decreasing PA, determining muscle function. These results provide evidence on the effects of eccentric training on muscle architecture, which could be helpful to prevent injuries and favor muscle recovery processes.

KEY WORDS: Muscular architecture; Eccentric training; Muscle power; Pennation angle; Muscle thickness; Fascicle length; Muscle quality.

INTRODUCTION

To understand in greater depth the situation of skeletal muscle in sports or injury rehabilitation contexts, it is necessary to know the characteristics of muscle tissue in a broader and more functional sense (Suchomel *et al*., 2016). One of the most objective and global concepts that contemplate this tissue's physiological and functional capacity is muscle quality (MQ) (Fragala *et al*., 2014). Muscle quality is composed of four dimensions (muscle composition, architecture, ultrastructure, and functional unit) and two indexes (relative strength and muscle quality index) with architecture being one of the least explored factors (Fragala *et al*., 2015). Its evaluation can provide us with the muscle's capacity to generate strength, power, or functionality (Jerez-Mayorga *et al*., 2020).

Muscle architecture (MA) is defined as the arrangement of muscle fibers within a muscle about the axis of force generation, becoming one of the most determinant components of muscle function, which can be associated with functional and health components in individuals (Lieber & Fridén, 2000; Lieber & Ward, 2011; Naimo *et al*., 2021). Therefore, MA is a fundamental element to be considered in assessing MQ (Naimo *et al*.). There is variability in the architecture of a muscle; however, generally, two types of architectural arrangements are described, longitudinal muscles (muscle fibers are arranged parallel to the force-generating axis) and pennate muscles (fibers are oriented at one or more angles concerning the force-generating axis) (Lieber & Fridén; Lieber & Ward). Several parameters can

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be considered; however, these are often conditioned by the assessment method used; these parameters include muscle thickness (MT); muscle length (ML), fascicle length (FL), pennation angle (PA), and physiological cross-sectional area (PSCA, the latter two being most closely related to muscle force generation (Lieber & Fridén; Lieber & Ward).

Understanding the architectural adaptations of skeletal muscle to different types of training has not yet been established by the scientific community. Several studies have attempted to determine the modifications of the architectural parameters in reference to different exercise programs; however, it is still not clear which is the best type of exercise to produce effective changes in these parameters (Narici *et al*., 2016). Recently, Gerard *et al*. (2020), through a meta-analysis, determined the effects of eccentric exercise on the muscular architecture of the long head of the biceps femoris, concluding that it produces adaptations by increasing its MT, FL and decreasing the PA, as well as producing adaptations in the strength of the hamstring muscles. This could favor the recovery processes in the face of muscular injuries or even prevent them (Blazevich & Sharp, 2005).

However, the effects of eccentric training on other muscles have not been systematically reviewed. Therefore, this review aimed to assess the effects of eccentric training on muscle architecture in the adult population.

MATERIAL AND METHOD

PRISMA guidelines were used (The Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The protocol for this review was registered in INPLASY (2021120094).

Search strategy. The search was performed by two authors (RL-P and DJ-M). The databases used were Pubmed, Scopus, SPORTDiscus and Web of Science. The search was performed from inception until March 2021. The following keywords were included: “eccentric training”, “eccentric contraction", “eccentric exercise”, “lengthening contraction”, “negative work”, “muscle architecture”, “pennation angle”, “fibre length”, “fiber length”, “fascicle length”, “cross-sectional area”, “muscle thickness”. The search was not limited in years.

Inclusion criteria. Articles that met the following criteria were included in this review: (I) subjects >18 years old, (II) Eccentric training program longer than four weeks (III) Studies with randomized clinical trial design, (IV) studies reporting measures of muscle architecture: “pennation angle”, “fascicle length”, “muscle thickness”, (V) full text available, and (VI) articles in English. In addition, we excluded all those articles that (I) Eccentric training programs of less than four weeks (II) conference presentations, theses, books, editorials, review articles and expert opinions, (III) duplicate articles, and (IV) articles in which the principal or secondary authors did not respond to e-mail requests.

Study selection. The articles retrieved from the search were entered into the Rayyan QCRI application (Ouzzani *et al*., 2016). This app assists the article selection process, optimizing review time and allowing collaborative work among researchers. (Available for free at http://rayyan.qcri.org (accessed on 27 March 2021)).

Duplicate articles were eliminated, and two investigators (RL-P and DJ-M) independently reviewed titles and abstracts to identify articles that met the eligibility criteria. A third investigator (LC-R) was consulted and resolved by consensus in case of discrepancies. Finally, the selected articles were read in total, and the reference list was reviewed for relevant articles that could be included.

Data extraction. An Excel template will be used for data extraction for each manuscript selected for review. The following information will be considered: author, year, aim, architectural parameter, sample size, age, population, physical activity level, number of participants, eccentric training protocol, results, and conclusions.

Methodological quality. The quality of the evidence of the articles included in this review was assessed using the PEDro scale, which is based on criteria that identify whether the RCTs have sufficient internal validity and statistical information to interpret the results (external validity (item 1), internal validity (items 2-9) and statistical reporting (items 10-11). Each item is classified as yes or no (1 or 0) according to whether the study met the criterion. The total score is from item 2 to 11, so the maximum score is 10 (Cashin & McAuley, 2020). Two independent investigators (RL-P and DJ-M) evaluated the articles using this scale. In case of discrepancy, a third evaluator (LC-R) was consulted. About the quality of evidence, it has been suggested that scores < 4 are considered poor quality, 4 - 5 moderate, 6 - 8 good and 9 - 10 excellent (Cashin & McAuley).

RESULTS

Article Selection. From the initial search, 1260 articles were retrieved, of which 726 were eliminated because they were duplicates. One additional article was identified from another source. After evaluating titles and abstracts, 512 articles were excluded because they did not meet the inclusion criteria, leaving 23 articles for full-text analysis. All the assessed articles presented a control group in this systematic review.

Of the 23 articles, four were eliminated because they did not evaluate the results and one article did not evaluate the target population. Thus, 18 articles were selected, their reference lists were checked, and no new articles were found (Fig. 1). In addition, related studies were included in the drafting of the text.

Study Characteristics. In total, 506 subjects participated in the studies, with a mean of 29.7 of total participants for each study. The number of participants ranged from 12 to 49. The mean age of participants ranged from 18 to 29 years old with a mean of 23.4 ± 2.9 years. Only one study did not mention the age of subjects (Mendiguchia *et al*., 2020). Some participants engaged in recreational physical activity (Coratella *et al*., 2015; Timmins *et al*., 2016; Bourne *et al*., 2017; Seymore *et al*., 2017; Alonso-Fernandez *et al*., 2020; Marusic *et al*., 2020; Presland *et al*., 2020) moderate physical activity (Ribeiro-Alvares *et al*., 2018; Abián *et al*., 2020), and others were physically active (Cadore *et al*., 2014; Marzilger *et al*.; 2019, 2020; Mendiguchia *et al*.; Timmins *et al*., 2021). In four studies, the subjects' physical activity level is not mentioned (Guilhem *et al*., 2013; Franchi *et al*., 2014; Sanz-López *et al*., 2016, 2017). The characteristics of the studies are summarized in Table I.

In this review, the evaluation of the methodological quality was assessed between the two reviewers in the totality of the articles (100 %). The results show that 89 % of the reviewed studies have a "Good" methodological quality, with PEDro 6-8 scale values. The results of this evaluation are shown in Table II.

Effect of Eccentric Strength Training on muscle architecture. Fifteen studies evaluated the effects of eccentric training on PA. Eleven studies found a decrease in PA; of these, in five (Mendiguchia *et al*.; Ribeiro-Alvares *et al*.; Marusic *et al*.; Timmins *et al*., 2016, 2021), NHE strength training was performed in two (Sanz-Lopez *et al*., 2016, 2017), eccentric overload training was conducted, in one (Presland *et al*.) eccentric training with flywheel was performed and in three others (Guilhem *et al*.; Franchi *et al*.; Marzilger *et al*., 2020) isokinetic eccentric training. Four studies found an increase in PA, in one eccentric training with heel drop exercise (Alonso Fernández *et al*.), one eccentric resistance training with workload (Guilhem *et al*.), one declined squat training with one leg at two speeds (Abián *et al*.) and one isokinetic unilateral eccentric training (Coratella *et al*.)

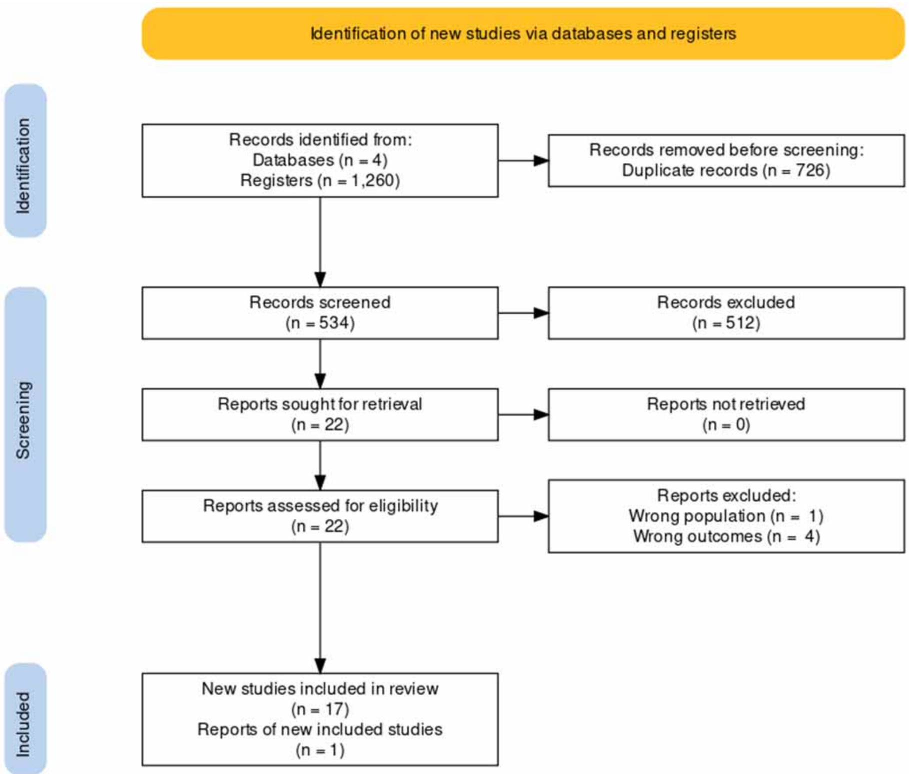

Fig. 1. Flow Chart for the systematic review.

Table I. Characteristics of individual studies.

Study	Group	N	Age (Mean ± SD)	Activity Level
Alonso- Femández *et al.* (2020)	Control	20	26.7 ± 2.8	Recreational physical Activity
	Eccentric training with heel drop exercise	25	25.2 ± 3.1	
Bourne *et al.* (2017)	Control	10	21.3±3.7	Recreational physical Activity
	Nordic hamstring exercise	10	21.6±3.2	
	Hip extensión exercise	10	23.1±4.1	
Cadore *et al.* (2014)	Concentric training	11	22.9 ± 7.8	Physically active
	Eccentric training	11	21.3 ± 3.3	
Coratella *et al.* (2015)	Control	17	20.5 ± 2.3	Recreational athletes
	Isokinetic unilateral eccentric training	16		
	Dynamic constant external resistance unilateral eccentric training	16		
Guilhem *et al.* (2013)	Control	10	20 ± 1	Not mentioned
	Work-matched isoload eccentric resistance training	11		
	Isokinetic eccentric resistance training	10		
Mendiguchia *et al.* (2020)	Sprint training	10	Not mentioned	Soccer players
	Nordic hamstring exercise	12		
Ribeiro-Alvares *et al.* (2018)	Control	10	26± 2.7	Moderately physically active
	Nordic hamstring exercise	10	23.7 ± 3.3	
Sanz- López *et al.* (2017)	Control	10	22,8 ± 4,2	Not mentioned
	Eccentric Overload Training	10		
Sanz- López *et al.* (2016)	Control	10	22,8 ± 4,2	Not mentioned
	Eccentric Overload Training	10		
Seymore *et al.* (2017)	Control	10	19.9±1.2	Recreational physical Activity
	Nordic hamstring exercise	10	18.3±0.5	
Timmins *et al.* (2016)	Concentric strength training	14	22,3 ± 4,2	Recreational physical Activity
	Eccentric strength training	14		
Marusic *et al.* (2020)	Control	16	23.0 ± 2.8	Recreational physical Activity
	Eccentric hamstring exercises in a lengthened position	18	24.2 ± 2.1	
Marzilger *et al.* (2020)	Control	13	27.2 ± 4.1	Young active
	Four isokinetic eccentric training	28	27.1 ± 4.4	
Marzilger *et al.* (2019)	Control	14	27.2 ± 4,1	Young active
	Four isokinetic eccentric training	33	27.1 ± 4,4	
Timmins *et al.* (2021)	Hip-dominant flywheel exercise	13		Soccer players
	Nordic hamstring exercise	14	22 ± 3	
Abián *et al.* (2020)	Control	13	20,8 ± 1,9	Moderately physically active
	Single-leg decline squat exercise (3s)	12	20,8 ± 1,9	
	Single-leg decline squat exercise (6s)	11	21.1 ± 1,2	
Presland *et al.* (2020)	Control	10	26.4 ± 4.1	Recreational physical Activity
	Flywheel training with an additional eccentric-bias	10	29.2 ± 6.2	
Franchi *et al.* (2014)	Concentric strength training	6	25 ± 3	Not mentioned
	Eccentric strength training	6		

Fourteen studies evaluated the effects of eccentric training on FL. Significant increases in FL were found in 12 studies, six of which (Bourne *et al*.; Mendiguchia *et al*.; Ribeiro-Alvares *et al*.; Timmins *et al*., 2016, 2021; Marusic *et al*.) performed NHE strength training, five performed isokinetic eccentric strength training (Franchi *et al*.; Cadore *et al*.; Coratella *et al*.; Marzilger *et al*., 2019, 2020) and one completed flywheel training with an additional eccentric bias (Presland *et al*.).

Eleven studies evaluated the effects of eccentric training on MT. Only in one study, no change in MT was found after flywheel training with an additional eccentric bias (Presland *et al*.). In five studies, there was a significant increase in MT compared to baseline and after performing eccentric training with heel drop exercise (Alonso-Fernandez *et al*.), unilateral isokinetic eccentric training (Cadore *et al*.; Coratella *et al*.), work-matched isoload eccentric resistance training (Guilhem *et al*.), and unilateral constant external resistance dynamic eccentric training (Coratella *et al*.). Only one study assessed muscle quality through echo intensity (Cadore *et al*.), where they found a significant increase in muscle quality, decreasing its echo intensity. PSCA was evaluated in two studies (Sanz-Lopez *et al*., 2017; Marzilger *et al*., 2020), showing an increase in this parameter. The exercise modalities, the muscles tested and their effects on muscle architecture are summarized in Table III.

Table II. Methodological quality of the studies included (Y= yes; N= no).

Studies	*Items*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*Score (/10)*
Alonso- Fernández *et al.* (2020)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Bourne *et al.* (2017)	N	Y	N	N	N	N	Y	N	N	Y	Y	4/10
Cadore *et al.* (2014)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Coratella *et al.* (2015)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8/10
Guilhem *et al.* (2013)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Mendiguchia *et al.* (2020)	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	6/10
Ribeiro-Alvares *et al.* (2018)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Sanz- López *et al.* (2017)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Sanz- López *et al.* 2016	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Seymore *et al.* (2017)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Timmins *et al.* (2016)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Marusic *et al.* (2020)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Marzilger *et al.* (2020)	N	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Marzilger *et al.* (2019)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Timmins *et al.* (2021)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Abián *et al.* (2020)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Presland *et al.* (2020)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Franchi *et al.* (2014)	Y	N	N	Y	N	N	N	Y	Y	Y	Y	5/10

Items considered for rating: 1. Eligibility criteria were specified (This item is not used to calculate the PEDro score.); 2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received); 3. Allocation was concealed; 4. The groups were similar at baseline regarding the most important prognostic indicators; 5. There was blinding of all subjects; 6. There was blinding of all therapists who administered the therapy; 7. There was blinding of all assessors who measured at least one key outcome; 8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"; 10. The results of between-group statistical comparisons are reported for at least one key outcome; 11. The study provides both point measures and measures of variability for at least one key outcome.

DISCUSSION

The present study aimed to evaluate the effects of eccentric training on muscle architecture. The parameters most frequently evaluated in the studies consulted were PA, FL, and MT. These were assessed mainly in lower limb muscles such as BFlh, VL, MG, and LG. Eccentric training for at least four weeks generates adaptations in these parameters, mainly by increasing MT with FL and decreasing PA, determining muscle function. These results provide evidence on the effects of eccentric training on muscle architecture, which could be helpful to prevent injuries and favor muscle recovery processes.

NHE was the most used eccentric training in this review. This type of training targeted the hamstring muscles, being widely used in the literature (Llurda-Almuzara *et al*., 2021), perhaps because it is easy to perform and reproduce, as it requires only a partner and no dynamometric equipment is necessary (Gerard *et al*.), is efficient in reducing injury risk (Al Attar *et al*., 2017), increasing eccentric strength (Ishøi *et al*., 2018) and potentially modifying muscle architecture by increasing fascicle length (Medeiros *et al*., 2020). The latter is repeated in all the studies that used NHE for this review, showing a significant increase in FL after performing their protocols, except as described by Seymore *et al*. who found no significant changes, possibly due to the joint positions assumed during training. A different situation is seen when reviewing the effects of this exercise on PA, showing a decrease in all the studies, except for those described by Seymore *et al*., where there was an increase in PA without significant changes. Concerning MT, this exercise caused a variable increase in all the studies used.

Concerning the other eccentric training modalities included in this review, the second modality used was eccentric isokinetic exercises using a technological tool to control angular velocity. It has already been possible to determine the effects of isokinetic eccentric exercise on quadriceps muscle mass and strength in a population before or after ACL reconstruction or meniscectomy (Zhang *et al*., 2017; Vidmar *et al*., 2019, 2020), its effect on neural adaptations has also been seen (Barrué-Belou etal., 2016). The results of this review support its use as a potential way

Table III. Exercise interventions.

Study	Type of exercise	weeks	Procedure	Assessed parameters	Muscle	Results FL	MT	PA	QM	PSCA or CSA
Alonso- Fernández *et al.* (2020)	Eccentric training with heel drop exercise	8	2 sets x 10-12 repetitions (week 1)3 x/ week, 3 x 12-15 (week 2) 3x/ week, 3 sets x 15 repetitions (week 3 and 4)4x/ week, 4 sets x 15 repetitions (+2kg load) (week 5) 4x/ week, 4 sets x 15 repetitions (week 6)4x/ week, 4 sets x 15 repetitions (week 7) 5x/ week, 4 sets x 10-12 repetitions (week 8) 5x/ week, 4 sets x 10-12 repetitions (week 8) 5x/ week.	FL; MT; PA	MG; LG	_**	_**	_**	**N/A**	**N/A**
Bourne *et al.* (2017)	NHE	10	2-6 sets x 5 -10 repetitions, rest 3 min between sets, 2x /week (alternate legs)	FL	BFlh	_#**	N/A	N/A	N/A	N/A
Cadore *et al.* (2014)	Isokinetic unilateal Eccentric training	6	2 sets x 8 repetitions, 2x/ weeks	MT; QM	VL	**N/A**	_**	**N/A**	_**	**N/A**
Coratella *et al.* (2015)	Isokinetic unilateral eccentric training	8	5 sets x 8 repetitions; 2 x/week	FL; MT; PA	VL	_**	_**	_	**N/A**	**N/A**
	Dynamic constant external resistance unilateral eccentric training	8	5 sets x 8 repetitions; 2 x/week			_**	_**	_	**N/A**	**N/A**
Guilhem *et al.* (2013)	Work-matched isoload eccentric resistance training	9	3 sets x 8 repetitions (week 1) 4 sets x 8 repetitions (week 2-3) 5 sets x 8 repetitions (week 4, 6-9)	FL; MT; PA	VL	_**	_**	_**	**N/A**	**N/A**
	Isokinetic eccentric resistance training	9	3 sets x 8 repetitions (week 1) 4 sets x 8 repetitions (week 2-3) 5 sets x 8 repetitions (week 4, 6-9)			_	_	_	**N/A**	**N/A**
Mendiguchia *et al.* (2020)	NHE	6	3 sets of 12, 10 and 8 repetitions respectively, 1x/week	FL; MT; PA	BFlh	_**	_**	_**	**N/A**	**N/A**
Ribeiro-Alvares *et al.* (2018)	NHE	4	3 sets 3 6–10 repetitions, 1-min rest between sets, 2x/week	FL; MT; PA	BFlh	_#**	_	_#**	**N/A**	**N/A**
Sanz- López *et al.* (2017)	Eccentric Overload Training	6	4 sets x 7 repetitions with 2 minutes of rest	PA	MG	**N/A**	**N/A**	_**	**N/A**	_** **(PCSA)**
Sanz- López *et al.* (2016)	Eccentric Overload Training	6	5 sets x 7 repetitions with 2 minutes of rest	PA	VL	**N/A**	**N/A**	_**	**N/A**	**N/A**
Seymore *et al.* (2017)	NHE	6	2 sets x 5 repetitions (week 1) 1x /week, 2 sets x6 repetitions (week 2) 2x/ week, 3 sets x6-8 repetitions (week 3) 3x/ week, 3 sets x 8 -10 repetitions (week 4) 3x/ week, 3 sets x12 -10-8 repetitions (week 5- 6)	FL; PA; PSCA	BFlh	_	**N/A**	_	**N/A**	_**
Timmins *et al.* (2016)	NHE	6	4 sets x 6 reps (week 1) 2x/week, 4 sets x 6 reps (week 2) 3x/week, 5 sets x 6 reps (week 3) 3x/week, 5 sets x 8 reps (week 4) 3x/week, 6 sets x 6 reps (week 5) 3x/week, 6 sets x 8 reps (week 6) 3x/week.	FL; MT; PA	BFlh	_**	_	_**	**N/A**	**N/A**
Marusic *et al.* (2020)	NHE in a lengthened position	6	2 sets x 5 repetitions (week 1), 2 sets x 6 repetitions (week 2), 3 sets x 6 repetitions (week 3), 3 sets x 8 repetitions (week 4-6) / all 2x / week	FL; MT; PA	BFLH	_#	_	_#	**N/A**	**N/A**
Marzilger *et al.* (2020)	Four isokinetic eccentric training (45°/s, 120°/s, 210°/s and 300°/s)	11	5 sets x 3, 8, 14 and 20 repetitions per-training set respectively (45°/s, 120°/s, 210°/s and 300°/s), 3x/ week	FL; PA; PSCA	VL	_**	**N/A**	_	**N/A**	**_(PCSA) p210/p300**
Marzilger *et al.* (2019)	Four isokinetic eccentric training (45°/s, 120°/s, 210°/s and 300°/s)	11	5 sets x 3, 8, 14 and 20 repetitions per-training set respectively (45°/s, 120°/s, 210°/s and 300°/s), 3x/ week	PSCA	VL	**N/A**	**N/A**	**N/A**	**N/A**	**_ (CSA)**
Timmins *et al.* (2021)	NHE	39	2 sessions per week after field training	FL; MT; PA	BFlh	_**	_	_**	**N/A**	**N/A**
Abián *et al.* (2020)	Single-leg decline squat exercise (3s)	6	3 sets x 8 repetitions, 3x/ week	FL; MT; PA	VL	_	_#	_#**	**N/A**	**N/A**
	Single-leg decline squat exercise (6s)	6	3 sets x 8 repetitions, 3x/ week			_	_**	_	**N/A**	**N/A**
Presland *et al.* (2020)	Flywheel training with an additional eccentric-bias	6	4 sets x 6 repetitions (week 1 and 2), 5 sets x 6 reps (week 3), 5 sets x 8 reps (week 4), 6 sets x 8 repetitions (week 5), 5 sets x 6 reps (week 6)	FL; MT; PA	BFlh	_#**	**NC**	_	**N/A**	**N/A**
Franchi *et al.* (2014)	Isokinetic eccentric training	10	4 sets x 8-10 repetitions, 3x/ (week)	FL; PA	VL	_#**	**N/A**	_#	**N/A**	**N/A**

FL= fascicle length; MT= muscle thickness; PA=pennation angle; QM= muscle quality BFlh= biceps femoris long head; MG= medial gastrocnemius; LG= lateral gastrocnemius; VL= vastus lateralis; CSA= cross section; PCSA= physiological cross section área; NC: no changes. # = Significant changes vs. control group ** = Significant changes vs. baseline

of modifying muscle architecture parameters generating an increase in FL and MT, and a decrease in PA (Guilhem *et al*.; Marzilger *et al*., 2020; Abián *et al*.; Coratella *et al*.; Cadore *et al*.).

On the other hand, when reviewing the effects of eccentric exercise on the architecture of different muscles, only studies that measured muscle architecture parameters in the lower limb muscles were found in this review. These were BFlh, VL, GM, and GL, respectively. Usually, the assessment of muscle architecture parameters is measured using a B-mode ultrasound machine, which has already been validated in lower limb muscles for this type of measurement (Van Hooren *et al*., 2020; Turton *et al*., 2019), which could explain the preference in choosing these muscles to assess. However, it is advisable to investigate the effects of eccentric exercise on upper limb muscles.

It is known that muscles with higher FL have a greater advantage in speed movements (Lieber & Ward), on the other hand, muscles with higher PA are muscles that can generate more force (Blazevich & Sharp). In this context, and according to the results obtained in this review, eccentric training could favor muscle function in speed situations, however, it could disfavor it in strength situations. For this, it is important to distinguish the type of strength we refer to, so it is suggested to include the association with strength in future studies that attempt to resolve this research question. This review only considered the effects of eccentric training on architectural parameters, but not its association with strength or speed.

The population's average age included in the studies of this review ranges between 18 and 29 years of age. This prevents us from having a clearer picture of the general population; there is a lack of studies that evaluate the effects of eccentric training in the elderly population since the changes produced in skeletal muscle function with age are indisputable (Tieland *et al*., 2018)

CONCLUSION

The results of this review show that there are adaptations in muscle architecture to eccentric training of at least four weeks duration. This will allow health and sports professionals to understand in greater depth the adaptations of skeletal muscle to this type of exercise, and in this way, prevent injuries, favor the muscle repair process, and improve sports training. However, although this review includes a universe of more than 500 participants, the adaptations in muscle architecture in the upper limb musculature or the population of older adults and their association with muscle strength are still not known with certainty. In this context, it is suggested to conduct studies that include this population and the upper limb muscles.

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LIZAMA-PÉREZ, R.; CHIROSA-RIOS, I.; CHIROSA-RIOS, L.; OLAVE; E.; FERRAGUT, C.; VILA, H. & JEREZ-MAYORGA, D. Efectos del ejercicio excéntrico en la arquitectura muscular en adultos: Una revisión sistemática. *Int. J. Morphol., 40(2)*:425-432, 2022.

RESUMEN: El propósito de esta revisión sistemática fue determinar los efectos del entrenamiento excéntrico sobre la arquitectura muscular en la población adulta. Se siguieron las recomendaciones del Ìtems de referencia para publicar Revisiones Sistemáticas y Metaanálisis (PRISMA) utilizando palabras clave asociadas con la arquitectura muscular y el entrenamiento excéntrico en cuatro bases de datos: PubMed, Scopus, SPORTDiscus y Web of Science. La calidad metodológica se evaluó mediante la escala PEDro. Se encontró un total de 1260 artículos, del los cuales, 18 fueron incluidos en esta revisión. Los parámetros más frecuentemente evaluados en los estudios fueron el ángulo de penación (AP), la longitud del fascículo (LF) y el grosor muscular (Gm). Estos fueron evaluados principalmente en músculos de los miembros inferiores como la cabeza larga del bíceps femoral (CLBf), el vasto lateral (VL), el gastrocnemio medial (GM) y el gastrocnemio lateral (GL), respectivamente. El entrenamiento excéntrico durante al menos cuatro semanas genera adaptaciones en estos parámetros, principalmente aumentando el GM con la LF y disminuyendo el AP, determinando de esta manera la función muscular. Estos resultados aportan evidencias sobre los efectos del entrenamiento excéntrico en la arquitectura muscular, que podrían ser útiles para prevenir lesiones y favorecer los procesos de recuperación muscular.

PALABRAS CLAVE: Arquitectura muscular; Entrenamiento excéntrico; Potencia muscular: Longitud del fascículo, Angulo de penación; Grosor muscular; Calidad muscular.

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Aberrant Branches of the Subclavian Artery and their Relationship with the Phrenic Nerve and the Brachial Plexus

Ramas Aberrantes de la Arteria Subclavia y su Relación con el Nervio Frénico y el Plexo Braquial

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ZHENG, Y.; WANG, H.; LIU, Y.; ZHAO, A.; PAN, X.; GUO, Y. & LEI, Y. Aberrant branches of the subclavian artery and their relationship with the phrenic nerve and the brachial plexus. *Int. J. Morphol., 40(2)*:433-435, 2022.

SUMMARY: Variations in subclavian artery branches are relatively common and may impact surgical procedures and effects. During educational dissection of a male cadaver, we encountered an extremely rare variation of the right subclavian artery branches. The internal thoracic artery, the thyrocervical trunk, and the costocervical trunk arose from the third part of the right subclavian artery. In addition, the phrenic nerve displaced remarkably laterally by the thyrocervical trunk, and the course of the costocervical trunk was between the upper trunk and the middle trunk of the brachial plexus. These variations may pose a potential risk for nerve compression and increase the risk of arterial and nerve puncture. This case report would bring attention to the possibility of other similar cases, and early detection of these variations through diagnostic interventions is helpful to reduce postoperative complications.

KEY WORDS: Transverse cervical artery; Costocervical trunk; Internal thoracic artery; Phrenic nerve; Brachial plexus.

INTRODUCTION

The subclavian arteries supply blood to the upper limbs and send branches to the neck, thorax, and brain. According to anatomical textbooks and the previous studies, each subclavian artery is divided into three parts, The first part extends from the origin of the subclavian artery to the medial margin of the anterior scalene muscle, the second part lies behind the anterior scalene muscle, and the third part extends from the lateral margin of the anterior scalene muscle to the lateral margin of the first rib (Bean, 1905). Generally, there are five branches of the subclavian artery: the vertebral artery, the internal thoracic artery, and the thyrocervical trunk, the costocervical trunk (Takafuji & Sato, 1991).

The variations of the subclavian branches are known to influence clinical operation (Andreou *et al*., 2011). Based upon previously reported cases, all branches arise from the first part of the subclavian artery, except in the case of the costocervical trunk on the right subclavian artery (Takafuji & Sato). In this report, the internal thoracic artery, the thyrocervical trunk, and the costocervical trunk arose from the third part of the right subclavian artery, the phrenic nerve displaced laterally to the thyrocervical trunk, and the brachial plexus encircled the costocervical trunk. We report this case to bring attention to the possibility of other similar cases, it is helpful to understand the anatomic variants of the subclavian branch, and decrease the risk of iatrogenic injury during neck procedures.

CASE REPORT

During a routine educational dissection in the Human Body Course, a male cadaver of unknown age was presented with aberrant subclavian branches which were carefully dissected to identify their courses and photographed.

The first part of the right subclavian artery gave off the vertebral artery. At the second part, the subclavian artery gave off no branch. The costocervical trunk (75.3 mm from the origin of the subclavian artery, with a 2.6 mm diameter),

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