TÍTULO

ACUTE EFFECTS OF STRENGTH TRAINING ON INTRAOCULAR PRESSURE

A SYSTEMATIC REVIEW WITH TRAINING GUIDELINES FOR GLAUCOMA PATIENTS

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ACUTE EFFECTS OF STRENGTH TRAINING ON INTRAOCULAR PRESSURE: A SYSTEMATIC REVIEW WITH TRAINING GUIDELINES FOR GLAUCOMA PATIENTS

Trabajo de Fin de Máster presentado para optar al Título de Máster Universitario en Actividad Física y Salud por Juan de Dios Cobo Font, siendo el tutor del mismo el Dr. D. Amador García Ramos

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RESUMEN:

El objetivo de esta revisión sistemática fue evaluar los efectos agudos de diferentes protocolos de ejercicios de fuerza sobre la presión intraocular (PIO) durante y después del entrenamiento.

Esta revisión se realizó usando el término de búsqueda “Intraocular Pressure" en combinación con "Strength" y "Resistance training" en las bases de datos Pubmed, Scopus, BMC, Science Direct, y Cochrane (desde el origen hasta el 31 de Diciembre de 2021). Dio como resultado 7143 artículos y tras la selección incluimos 13 artículos y 7 más en una búsqueda secundaria.

Parece que el trabajo de fuerza isométrico produce elevaciones agudas de la PIO, no siendo claro el efecto de la fuerza dinámica. De todos modos son diversos los factores que influyen, como nivel de condición física, volumen e intensidad del entrenamiento, momento de medida de la PIO, etc., lo que puede variar los resultados.

PALABRAS CLAVE:

Presión Intraocular– Entrenamiento Contraresistencia – Entrenamiento de Fuerza – Glaucoma –Prevención.

ABSTRACT.

The objective of the present systematic review was to evaluate the acute effects of different resistance training protocols on IOP values recorded during and after training~~.~~

This review has been carried out under the terms "Intraocular Pressure" AND "Strength" (1) "Intraocular Pressure" AND "Strength Exercises" (2) and Intraocular Pressure" AND "Resistance training" (3), in Pubmed, Scopus, BMC, Science Direct, and Cochrane (all time to 31 December 2021). This show 7143 articles, and after selected we included 13 and 7 more y the secondary research.

Seems that the isometric strength increased acute IOP effect, but it is not clear the effect of dynamic strength. In any case, there are many influential factors as fitness level, volume and intensity of training, IOP time of measure, etc. that results in different values.

KEYWORDS:

Intraocular Pressure– Resistance Training - Strength Training – Glaucoma – Prevention.

ÍNDICE

ACUTE EFFECTS OF STRENGTH TRAINING ON INTRAOCULAR PRESSURE: A SYSTEMATIC REVIEW WITH TRAINING GUIDELINES FOR GLAUCOMA PATIENTS

INTRODUCTION

Glaucoma is an eye disorder characterized by elevated intraocular pressure (IOP), hardness of the eyeball, optic disc atrophy and blindness (1). Investigating about glaucoma is important because it is an irreversible risk blindness factor, with a 76 million people prevalence in the world (2). It is well know that an elevate IOP is an important factor to appearance and progression of glaucoma (3–5). For this reason, it is interesting to know more about what happens during exercise and physical activity. Nowadays, the only strategy that has demonstrated to be effective to mitigate the glaucoma progression is the reduction and stabilization of IOP level (6,7) as it happens with medical laser treatments and surgeries (8), so is important to go deeper about IOP reduction during physical exercise practice, specially resistance (strength) training.

Physical exercise is associated with multiple health benefits (9), in fact is recommended for all people even for people with disorders (10) with minor exceptions. The level of physical activity is an important health factor and specially in ocular affection, like glaucoma, age-related macular degeneration, diabetic retinopathy (11) and in the management and prevent of different ocular disorders (12,13). It is also widely accepted that physical fitness due to an exercise regimen results in lower baseline IOP; although, in fit individuals the acute IOP-lowering effect of exercise may be diminished (14–16).

However there is controversial about if the dynamic exercise or isometric exercise acutely affect IOP levels, although Risner et al (17) said that isometric exercise produces an acute decrease in IOP, but dynamic exercise (all studies analysed aerobic exercise no resistance training) produces more pronounced decrease IOP but of more short duration. In contrast, Zhu et al (18) showed that IOP transiently increased during isometric exercise. Aleman (19) said that the aerobic exercise is beneficial to healthy and glaucoma individuals, but it is not consistent to affirm nothing about resistance training; while another studies showed increase IOP after supervised exercise programme for 6 week, which was composed by a combination of aerobic and strength training (20). Another review (18) suggested that dynamic exercise is effective at reducing IOP in healthy, myopic subjects, and in patients with glaucoma. Instead many exercises present potential risk, as extreme exercises, such as scuba diving and bungee jumping, should be warned in glaucoma patients (18). Zhu et al (18) suggest that high-intensity exercise involving breath-holding or head-down position, which could cause sudden IOP elevation, should be avoided in these patients. Instead another studies reported a IOP reduction after submaximal strength test in young healthy individuals (21). One study evaluated IOP during daily life activities (walking/cycling; resistance training, yoga/meditation, emotional stress, and alcohol consumption in a real life) in people with open-angle glaucoma or suspect. They used a contact lens sensor to measure the IOP, and they showed that all activities elevating IOP (except alcohol consumption), but only resistance training or emotional stress will be associated with persistent IOP elevation (120 min after activities) (22).

Resistance training (RT) has an important role in injury prevention and rehabilitation, as well as general well-being due to numerous beneficial effects on health and quality of life (23–25). However, nowadays there is not a solid based about RT structuration and recommendation for IOP control, in fact, studies about IOP evaluation in glaucoma population or those at risk of glaucoma barely exist. If we identified what type of RT is more dangerous could recommend which type of them to practice. It is interesting to know what effect causes RT about IOP, because many RT exercises are extrapolated in the real life, and this will help to know how IOP fluctuate during daily actions, like transport, holding o carry weight (shopping, baby, etc.). In this regard, Vera et al. (26) said in healthy young, that holding a load corresponding to 20% of body weight during 5 min causes as increment in IOP.

Traditional recommendation for glaucoma population or those at risk is saffron spice intake, a high-fibre diet, decreased coffee intake, sleeping with the head elevated and moderate aerobic exercise (27). Even greater moderate-to-vigorous physical activity and more time spent in no sedentary activity were associated with slower rates of visual field loss in a treated population of patients with glaucoma (28). However, Hecht & col (27) evidenced that this changes in dietary and lifestyle in glaucoma people during one month not appear to affect IOP, but may be is because is a short time to appear changes; however may improve illness perception. Besides from visual impairment, there are improvements in mental health issues in patients with glaucoma (that include anxiety and depression)(18), which is important.

The objective of the present systematic review was to evaluate the acute effects of different resistance training protocols on IOP values recorded during and after RT. The findings of this systematic review are expected to contribute to the development of RT protocols that enable at the same time to increase muscle strength and minimise the increments in IOP during training.

METHODOLOGY

A systematic review of available literature was conducted in agreement with the guideline for preferred reporting items for systematic reviews and meta-analyses (PRISMA statement)(29).

Pubmed, Scopus, BMC, Science Direct, and Cochrane Databases were searched from inception until December 2021 to identify all relevant published articles. The keywords used for this research were "Intraocular Pressure" AND "Strength" (first research), "Intraocular Pressure" AND "Strength Exercises" (second research), and finally "Intraocular Pressure" AND "Resistance training" (thirst research). This syntax was used for each database and applied to the title, abstract, and keyword search fields. In the secondary search, the reference lists of all included publications were screened and the studies that cited the included studies were examined through the Google Scholar database. The complete search strategies are presented in figure 1.

The literature search yielded 7143 results. Titles and abstracts of articles identified by the electronic database searches were extracted and duplicates were removed, this yielded 1867 duplicates, after the first screening we had 5276 results. The first eligibility criteria were that title and abstract included physical exercise, physical activity or exercise and intraocular pressure measure, and this results excluded 5247, so only rest 29 articles eligible. After, we selected articles that spoken about strength or resistance training and intraocular pressure measure. We eligible only articles that included intervention with all components explained, that includes: volume (Set, repetitions, and duration), intensity (RM, RPE, RIR or similar), frequency, rest, and training organization. This finally screening yielded 13 results. Now in the secondary search, the reference lists of all included publications were screened and the studies that cited the included studies were examined through the Google Scholar database, and this secondary search yielded 8 more articles. Therefore, we have analysed 21 articles.

Eligibility criteria for this systematic review were articles that (1) included strength or resistance training or exercise, and (2) the pre and after IOP measure; and (3) that included full text articles published in English or Spanish version in (4) subjects that did not present any kind of eye disease.

From the studies that met the inclusion criteria, the following data were extracted into an Excel spreadsheet: (1) study identification information; (2) study design; (3) sample size; (4) participants' characteristics, including age, body mass, sex, strength levels, and training experience; (5) resistance training prescription details; and (6) means and standard deviations for relevant outcome IOP measures. If insufficient data were reported, the authors of those studies were contacted by-email, and this data were included if author provided the requested data. The Web Plot Digitizer software (Version 4.5; TX, USA) was used for the extraction of data from figures when the authors of the original studies did not report the data. Data extraction was completed independently by two authors (JCF and AGR) using a pilot-tested form on five randomly selected studies which was then modified accordingly. Coding files were cross-checked between the authors, and any observed differences were resolved via discussion and agreement.

RESULTS

The results in boolean search were in the first search: Pubmed (281 results); Scopus (482 results), BMC (366 results); Science Direct (5922 results) and Cochrane (0 results). In the second search: Pubmed (2 results); Scopus (5 results); BMC (1 result); Science Direct (6 results) and Cochrane (0 results). In the third search we found in Pubmed (15 results); Scopus (25 results) BMC (4 results); Science Direct (23 results) and Cochrane (0 results). The literature search yielded 7143 results. In addition, in the secondary search, we found 8 more articles. The literature search is presented in figure 1.

The results of the different studies included in the systematic review are presented in detail in Tables 1, 2 and 3. Table 2 shows 13 studies that evaluated dynamic strength and table 3 shows 10 studies that evaluated isometric strength. Two studies evaluated both types of strength (dynamic and isometric). In 13 studies IOP was evaluated during and after training, 7 studies IOP was only evaluated after training, and only one study evaluated during training. In one of these studies the IOP was evaluated during and after training no reported date before exercise.

In 10 studies the exercise protocol included only multi-joint exercises, and in 5 studies only single-joint exercises. In 5 studies included both, single- and multi-joint exercises, and evaluated them separately. And 1 study consisted of a circuit exercise protocol that included single- and multi-joint exercises, and evaluated IOP during and after protocol.

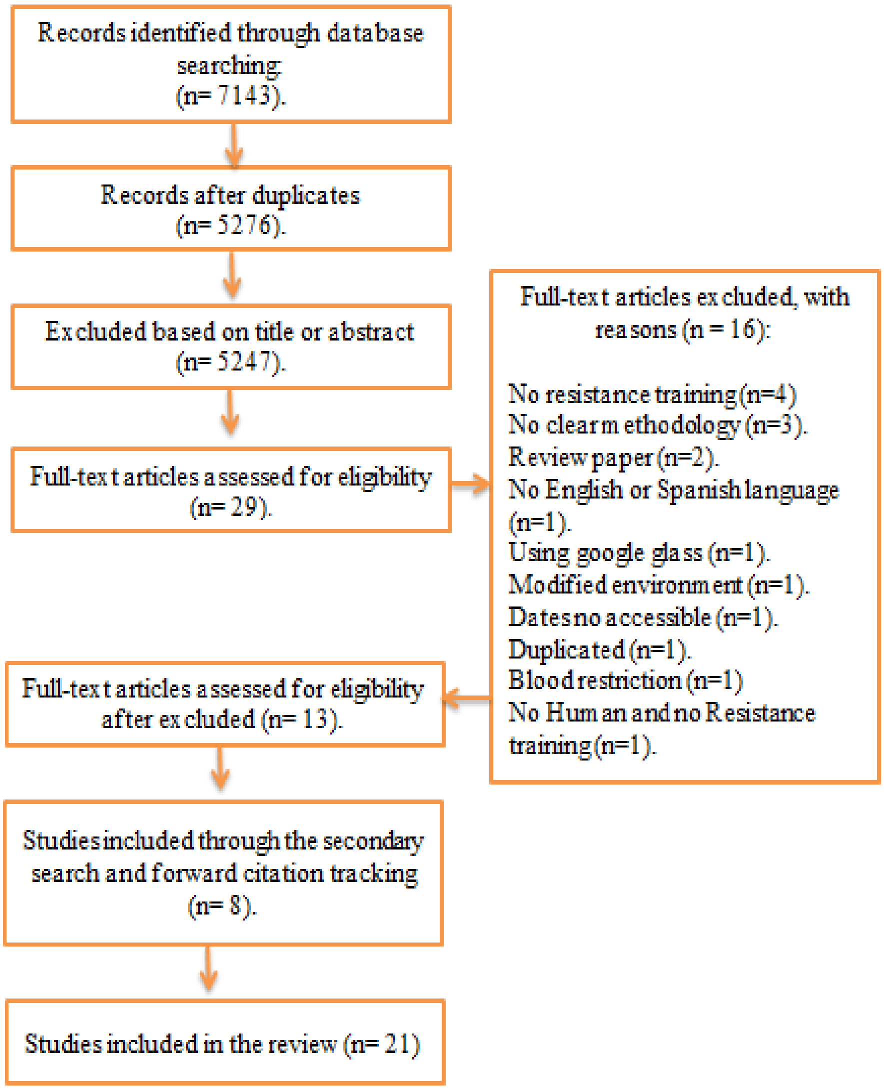

Figure 1. Literature search flow chart. n= number of studies

Only one study used a control condition, where IOP was measure in rest, the same measure that in moderate and high load. All studies are within-group except one, that evaluated other conditions like aerobic training and we did not include it in this review.

3 Studies included exercises with valsalva breathing; all of them evaluated the same exercise with valsalva and normal breathing. In the rest of studies (unless otherwise stated) the exercise was realised with normal breathing.

In many articles IOP was measured with volunteers sitting and focusing on a distant object with the contralateral eye (at time intervals identical to those of the exercise sessions) but in a resting state (30–46). In some articles IOP was measured in supine position (47–49) ,and one in standing position (50). In all studies (unless otherwise stated) the IOP was measured in the right eye.

Table 1. Summary of the studies included in this review.

Study	Participants' characteristics	Study design	IOP assessment	IOP (mean + standard deviation) (mmHg)		
				Before exercise	During exercise	After exercise
Avunduk et al.1999. (30)	n= 67 Patients referred to the physiotherapy unit with various musculoskeletal system diseases. Patients were randomly divided into two groups. **Group A** consisted of 31 patients, 16 female and 15 male, with an age range of 24–40 (33.2 ± 4.1), **Group B** contained 32 patients, 16 female and 16 male, with an age range of 23–40 (, 33.5 ± 4.3).	**Between--groups** Group A and B patients were given isokinetic and isometric exercise programs, respectively. Application of **Isokinetic** Exercise Full extension of the knee, conducted in a knee movement of 0–90°. Every patient repeated the movements with right and left legs 4 times at a low speed of 60 mm/s, and 20 times at a high speed of 180 mm/s with 20 s of resting time between the two speed settings. Patients were instructed to exert full effort during the exercise. Application of **Isometric** The same posture as explained in isokinetic exercise was used. Patients were instructed to exert full effort 20 times for 5 s for extensor muscles at 60° extension, and for flexor muscles at 30° flexion. Exertion of maximum effort, and preservation of MT during isometric and isokinetic exercises were monitored on the machine's display. Patients were verbally encouraged to keep up MT during the exercises.	Shiøtz tonometer was used just before and 10 min following exercise. IOP was measured 10 min after the completion of exercise. Cybex 6000 dynamometer was used.	*Group A.* 17.1 ± 2.0 *Group B.* 16.9 ± 2.1	*NR*	*Group A.* 10.1 ± 3.5 *Group B.* 13.7 ± 3.7

Bakke et al. 2009. (31)	n= 9 (3 women) Healthy subjects. Age: 23.6± 0.7 years BMI: 22.5±0.6 kg/m² Height: 175±2.6 cm. Weight: 68±3.4 kg	**Within--groups** A custom-made handgrip unit was used, and a digital display gave the test subjects continuous information, making it possible to maintain the intended force. MVC was determined approximately 10 minutes before the experimental protocol by asking the test subjects to apply maximum force around the handgrip transducer for 3 seconds. The experimental protocol was as follows: After a rest period of 30 seconds, a 2-minute period followed in which the subjects exerted 40% of maximum voluntary force, before a final rest period of 30 seconds the subjects were supine during the experimental protocol. During test subjects were instructed to relax all the muscles not primarily involved in contraction, to avoid recruitment of accessory muscle mass and an increase in venous pressure.	The IOP was continuously acquired by an improved Schiøtz electronic tonometer (dynamic tonometer; Nycotron, Oslo, Norway) before, during and after exercise. A custom-made handgrip unit was used to measure and display the force exerted by the test subjects when squeezing the grip with the right hand.	15.1 ± 1.4	18.7 ± 1.8	15.6 ± 1.5
Vera et al. 2019. (32).	n= 26 (13 women). Physically active (students Faculty of Sport Sciences).	**Within--groups** Participants were instructed how to execute the isometric squat exercise correctly. The within participants factors were the load (low, medium, high) and the point of measure (before exercise,	A rebound tonometer (Icare, TiolatOy, Inc). During the 1-minute isometric exercise, the examiner acquired IOP values in a continuous fashion. Baseline IOP was measured before each exercise, and a recovery measurement was	*Low Load:* 16.2 ± 0.7 *Medium-Load:* 15.7 ± 0.5 *High-Load:* 16.3 ± 0.5	*Low Load*: IOP1: 18.7 ± 0.7 IOP2: 19.0 ± 0.8 IOP3: 19.4 ± 0.8 IOP4: 20.0 ± 0.7 IOP5: 20.0 ± 0.6 IOP6: 20.3 ± 0.7 IOP7: 20.4 ± 0.7 IOP8: 20.5 ± 0.8	*Low Load:* 15.5 ± 0.7 *Medium-Load:* 15.2 ± 0.6 *High-Load:* 15.7 ± 0.9

	Males. Age: 23.4 ± 2.8 years. Female: Age: 22.1 ± 2.5 years. None of them was an active athlete. All participants had 2 or more years of experience in strength training.	during exercise [points: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10], and recovery), and the sex (men and women) was the between-participants factor. A maximum of 3 attempts were needed to determine the heaviest load. After this, participants rested for 10 minutes before the beginning of the first experimental condition. Participants randomly performed the isometric squat exercise against 3 different loads that were separated by 10 minutes. The external load for the medium and maximum loading conditions was applied by means of the barbell of a Smith machine (Technogym) positioned across the top of the shoulders and upper back. A rest period of 10 minutes was imposed between successive sets.	obtained 10 seconds after the exercise.		IOP9: 20.8 ± 0.7 IOP10: 21.1 ± 0.8 *Medium-Load:* IOP1: 19.7 ± 0.9 IOP2: 20.8 ± 0.8 IOP3: 21.1 ± 0.8 IOP4: 20.7 ± 0.8 IOP5: 21.6 ± 0.7 IOP6: 22.1 ± 0.7 IOP7: 21.6 ± 0.8 IOP8: 22.4 ± 0.7 IOP9: 23.1 ± 0.7 IOP10: 23.1 ± 0.7 *High-Load:* IOP1: 19.7 ± 0.9 IOP2: 21.1 ± 0.8 IOP3: 22.1 ± 0.9 IOP4: 22.7 ± 0.6 IOP5: 23.4 ± 0.7 IOP6: 23.6 ± 0.6 IOP7: 24.0 ± 0.7 IOP8: 24.3 ± 0.7 IOP9: 24.1 ± 0.6 IOP10: 25.1 ± 0.7	
Vera et al. 2020. (33)	n=17 Physically active healthy men and had a minimum of 2years of resistance training.	**Within--groups** The first session was used to determine the 1RM in the bench press. The second consisted in four resistance training sets of bench press to muscular failure against different	Rebound tonometer (Icare TA01, TiolatOy, Inc, Helsinki, Finland). The IOP was measured in eight occasions: before and immediately after the execution of each of the four sets of repetitions to failure.	*IOP 65% RM:* 14.9±2.1 *IOP 75% RM:* 14.5±2.0 *IOP 85% RM:* 14.4 ±1.8	*NR*	*IOP 65% RM*: 14.9±1.9 *IOP 75% RM*: 15.4±2.3 *IOP 85% RM*: 15.8±2.5 *IOP 95% RM*: 17.1±2.6

	Age = 23.1 ± 3.1 years, Weigh = 75.9 ± 6.4 kg; Height=178.4 ± 8.6cm; bench press 1RM=77.1±9. 9 kg.	relative loads (65% RM, vs. 75% RM vs. 85% RM vs. 95% RM). Ten-minute breaks were given between the execution of bench press with the different loads, and participants performed the different training sets in a randomized order. Participants were instructed to perform the concentric phase of all repetitions at the maximum intended velocity.		*IOP 95% RM:* 14.1±2.2		
Vera et al. 2018. (34)	n=25 (12 women). Women: Age = 21.4 ± 2.7 years, Weigh= 55.7 ± 4.9 kg; 13 Men: Age = 23.6 ± 3.7 years, Weigh = 77.8 ± 5.9 kg. Healthy and physically active.	**Within-group** Aaccumulated repetitions (10 repetitions against the 10RM load) in four different exercises: squat (SQ), military press (MP), (PR), biceps curl (BC), and calf raise (CR) . Two sessions separated by at least 48 hours. The first session, the 10RM in the four exercises was determined, without fatigue. In the second session, participants randomly performed each exercise. They performed one set of 10 repetitions against the 10RM load with the four tested exercises, and a resting period of 10 min was given between exercises.	IOP with rebound tonometry (Icare, TiolatOy, INC. Helsinki, Finland). Six rapidly consecutive measurements. , In the second session, IOP was measured before exercise, after each of the 10 repetitions, and after 1 min of recovery from the last repetition (a total of 12 IOP measurements were taken in each exercise).	*IOP* baseline were between, 15.1 y 15.7	*SQ***:** IOP 1: 16.2 ± 0,5 IOP 2: 16.9 ± 0.6 IOP 3: 17.1 ± 0.6 IOP 4: 17.3 ± 0.6 IOP 5: 18.2 ± 0.7 IOP 6: 18.5 ± 0.7 IOP 7: 18.9 ± 0.6 IOP 8: 19.4 ± 0.6 IOP 9: 19.7 ± 0.6 IOP 10: 19.9 ± 0.6 *MP* IOP 1: 15.6 ± 0,6 IOP 2: 16.0 ± 0.5 IOP 3: 16.8 ± 0.7 IOP 4: 16.9 ± 0.6 IOP 5: 17.2 ± 0.5 IOP 6: 17.2 ± 0.6 IOP 7: 17.5 ± 0.6 IOP 8: 17.8 ± 0.6 IOP 9: 17.8 ± 0.5	*SQ:* 15.5 ± 0.5 *MP:* 16.0 ± 0.5 *BC:* 15.6 ± 0.5 *CR***:** 15.4 ± 0.5

					IOP 10: 17.9 ± 0.5 *BC* IOP 1: 15.7 ± 0.6 IOP 2: 16.00 ± 0.6 IOP 3: 16.5 ± 0.6 IOP 4: 16.9 ± 0.5 IOP 5: 17.6 ± 0.7 IOP 6: 17.7 ± 0.7 IOP 7: 17.9 ± 0.7 IOP 8: 18.3 ± 0.7 IOP 9: 18.3 ± 0.7 IOP 10: 18.5 ± 0.7. *CR* IOP 1: 15.9 ± 0,6 IOP 2: 16.3 ± 0.6 IOP 3: 16.7 ± 0.8 IOP 4: 16.2 ± 0.8 IOP 5: 16.5 ± 0.7 IOP 6: 16.2 ± 0.8 IOP 7: 16.6 ± 0.8 IOP 8: 16.7 ± 0.8 IOP 9: 17.1 ± 0.9 IOP 10: 17.3 ± 0.9	
Vera et al. 2018. (35)	n=40 Military personnel males. Age: 44 ± 8 years Inclusion	**Within--groups** **Jump Squat Balistic (JSB).** Incremental loading test at four different intensities in the countermovement jump exercise performed in a Smith machine against external loads corresponding to 20%, 40%, 60%, and 80% of their body mass. Participants performed	Rebound tonometer (Icare TAO1, Tiolat Oy, INC. Helsinki, Finland) was used to assess IOP just before and after each repetition in a randomly selected eye, using the same eye for all the subsequent IOP measures. A linear velovity transducer (T-	*LF JSB*: - 50% RM: 14.1 ± 1.3 - 60% RM: 14.1 ± 1.1 - 65% RM: 14.2 ± 1.09 - 75% RM: 14.3 ± 1.2	*NR*	*LF JSB:* - 50% RM: 14.1 ± 0.8 - 60% RM: 15.5 ± 1.0 - 65% RM: 16.3 ± 1.0 - 75% RM: 16.5 ± 0.8

	criteria: (1) be free of any ocular disease, (2) baseline IOP below 21 mmHg, and (3) be able to jump with an external load corresponding to 80% of their body mass	two repetitions with each load, and they were instructed to jump as high as possible. **Bench press Balistic (BPB).** An incremental loading test at four different intensities of the ballistic bench press exercise was also performed in a Smith machine. The lightest load was set at 20 kg for all participants, and it was progressively increased by 2.5, 5, or 10 kg based on the maximum velocity of the bar recorded by a linear velocity transducer. The heaviest load of the test was associated with a maximum velocity of ~1.40 m·s−1. The four loads corresponded to ~30%1-RM, ~40%1-RM, ~50%1-RM, and ~60% 1-RM. Participants performed two repetitions with each load using the standard "touch-and-go". Participants were instructed to throw the barbell as high as possible. In both cases, the rest period was 1 min between trials with the same load and 5 min between different loads. The jump squat and ballistic bench press tests were performed in a randomized order separated by 15 min.	Force System; ergotech, Murcia, Spain) attached to the barbell of the Smith machine was used to record its mean propulsive velocity. 1-RM was estimated from the individual load-velocity.	*LF BPB:* - 30% RM: 14.9 ± 1.4 - 40% RM: 14.8 ± 1.4 - 50% RM: 14.9 ± 1.2 - 60% RM: 15.0 ± 1.3 - 1RM: 14.8 ± 1.1 *HF JSB*: - 50% RM: 16.1 ± 1.8 - 60% RM: 16.0 ± 1.5 - 65% RM: 15.9 ± 1.5 - 75% RM: 15.9 ± 1.4 *HF BPB*: - 30% RM: 15.4 ± 2.2 - 40% RM: 15.3 ± 1.9 - 50% RM: 15.3 ± 1.9 - 60% RM: 15.3 ± 1.9 - 1RM: 15.3 ±		*LF BPB:* - 30% RM: 15.3 ± 1.2 - 40% RM: 16.2 ± 0.8 - 50% RM: 16.9 ± 0.9 - 60% RM: 17.7 ± 1.2 - 1RM: 18.4 ± 1.3 *HF JSB:* - 50% RM: 15.6 ± 1.3 - 60% RM: 16.3 ± 1.1 - 65% RM: 16.5 ± 1.2 - 75% RM: 16.9 ± 1.2 *HF BPB*: - 30% RM: 15.5 ± 1.7 - 40% RM: 16.5 ± 1.3 - 50% RM: 16.9 ± 1.4 - 60% RM: 16.8 ± 1.2 - 1RM: 17.1 ± 1.1.

		Participants were divided in **two groups (low fit – LF- and high fit – HF-)** based on their relative to body mass 1-RM value obtained in each specific test. However, when the IOP responses were compared between the jump squat and ballistic bench press exercises, the averaged 1-RM value of both tests was used to classify the participants in the low-fit and high-fit groups.		1.8.		
Vera et al. 2020.(36)	n=19 (7 women). Collegiate students. Age = 19.2 ± 1.3 years, Height = 172.2 ± 5.9 cm, Weigh = 66.6 ± 10.7 kg. All participants had at least 1 year of resistance training experience	**Within--groups** Four sets (2 exercise type × 2 exercise phase) of 10 repetitions leading to muscular failure separated by 10 min. The exercises were back squat (BS) and biceps curl (BC). The 10-RM load during the back squat and biceps curl exercises was determined in the first testing session. The second visit comprised the main experimental session, in which participants randomly performed 4 sets.	Portable rebound tonometry (Icare Tonometer, TiolatOy, INC. Helsinki, Finland) at baseline, after each of the 10 repetitions, and after 1 min of recovery. The only difference between the two sets of the same exercise was that in one set the IOP measurement was collected after finishing the concentric (C) phase and in another set after finishing the eccentric (E) phase.	*BS*: C: 16.3 ± NR E: 16.5 ± NR *CB:* C: 15.8 ± NR E: 15.6 ± NR	*BS:* C1: 17.2 ± NR C2: 18.3 ± NR C3: 18.9 ± NR C4: 19.2 ± NR C5: 19.7 ± NR C6: 20.0 ± NR C7: 20.5 ± NR C8: 20.9 ± NR C9: 21.1 ± NR C10: 21.3 ± NR E1: 19.8 ± NR E2: 22.5 ± NR E3: 24.7 ± NR E4: 25.6 ± NR E5: 26.9 ± NR E6: 27.8 ± NR E7: 28.9 ± NR E8: 30.1 ± NR E9: 30.5 ± NR E10: 31.2 ± NR *CB*:	*BS*: C : 15.7 ± NR E : 16.9 ± NR *CB:* C : 16.4 ± NR E : 15.5 ± NR

					C1 : 16.9 ± NR C2: 18.9 ± NR C3: 19.7 ± NR C4: 20.7 ± NR C5: 22.0 ± NR C6: 22.1 ± NR C7: 22.8 ± NR C8: 23.2 ± NR C9: 24.5 ± NR C10: 25.0 ± NR E1: 16.2 ± NR E2: 17.5 ± NR E3: 18,5 ± NR E4: 19.00 ± NR E5: 19.3 ± NR E6: 19.8 ± NR E7: 20.8 ± NR E8: 21.2 ± NR E9: 21.4 ± NR E10: 21.6 ± NR	
Vera et al. 2020. (37)	n= 20 (12 women) Physically active young adults. Age = 22.4 ± 2.1 years. All participants had at least one year of resistance training experience.	**Within--groups** A cross-sectional study was performed to assess the impact of the breathing pattern adopted during isometric training on IOP. The first session was used to determine the heaviest load that each participant could hold for 1 minute during the back squat (BS) and biceps curl (BC) exercises. The second session was the main experimental session and consisted of 6 sets (2 exercises × 3 breathing	Portable rebound tonometer (ICare, Tiolat Oy, Inc. Helsinki, Finland). IOP was measured just before each training set, during the 1-min isometric effort (semi-continuous IOP assessment: 14 measurements), immediately after exercise cessation, and after 1-min of passive recovery in the second session.	*BS:* *BS CB:* 15.7 ± 0.4 *BS 10 sec:* 15.7 ± 03 *BS 25 sec:* 16.1 ± 0.3 *BC.* *BC CB::* 16.2 ± 0.5 *BC 10-sec:* 15.9 ±	*BS CB:* Constant: IOP1: 17.7 ± 0.4 IOP2: 18.4 ± 0.4 IOP3: 19.7 ± 0.5 IOP4: 19.4 ± 0.5 IOP5: 20.5 ± 0.4 IOP6: 20.9 ± 0.5 IOP7: 21.0 ± 0.5 IOP8: 21.4 ± 0.6 IOP9: 21.9 ± 0.6 IOP10: 21.8 ± 0.5 IOP11: 21.9 ± 0.6 IOP12: 22.4 ± 0.6	*BS:* *Constant After (CA):* 21.4 ± 0.7 *Constant Recuperation* (CR): 17.9 ± 0.6 *10-sec-Valsava After (10-sec-A):* 20.4 ± 0.6 *10-sec-Valsava Recuperation (10 sec-R):* 16.3± 0.4 *25-sec-Valsalva After (25*

		patterns) of 1-min isometric effort performed in a randomized order. The isometric back squat exercise was performed at a 90º knee angle with a free-weight barbell over the participants' shoulders. The standing EZ-bar isometric biceps curl exercise was also performed at a 90º elbow angle. 80% of load measured in first session was applied on the main experimental session (session 2) to ensure that all participants could complete 1-min isometric effort without reaching muscular failure (23.3 ± 3.4 kg for the back squat and 13.3 ± 3.0 kg for the biceps curl). Two consecutive sets were separated by 10 min of passive recovery. A metronome was used to guide the participants during the 3 breathing patterns used in this study: - Constant breathing (CB): Participants completed a total of 10 cycles consisting of 3 seconds of inhalation followed by 3 seconds of exhalation. - 10-sec Valsalva (10-sec): Participants completed a total of 3 cycles consisting of 10 seconds of the Valsalva maneuver (i.e., holding the breath) followed by 10 seconds of		0.5 *BC 25-sec*: 16.2 ± 0.5	IOP13: 22.9 ± 0.6 IOP14: 22.8 ± 0.5 *BS 10 sec:* IOP1: 17.2 ± 0.4 IOP2: 18.3 ± 0.6 IOP3: 18.3 ± 0.6 IOP4: 18.5 ± 0.6 IOP5: 20.2 ± 0.7 IOP6: 21.0 ± 0.6 IOP7: 20.8 ± 0.7 IOP8: 21.3 ± 0.8 IOP9: 21.9 ± 0.8 IOP10: 22.5 ± 0.8 IOP11: 21.6 ± 0.7 IOP12: 22.3 ± 0.8 IOP13: 23.2 ± 0.9 IOP14: 22.6 ± 0.7 *BS 25 sec:* IOP1: 18.4 ± 0.4 IOP2: 19.9 ± 0.5 IOP3: 20.8 ± 0.5 IOP4: 21.8 ± 0.5 IOP5: 22.6 ± 0.4 IOP6: 22.9 ± 0.6 IOP7: 22.6 ± 0.7 IOP8: 22.7 ± 0.6 IOP9: 22.7 ± 0.6 IOP10: 23.7 ± 0.7 IOP11: 23.7 ± 0.7 IOP12: 25.0 ± 0.57 IOP13: 24.5 ± 0.7 IOP14: 24.2 ± 0.6	*sec-A):* 21.4 ± 0.7 *25-sec-Valsalva Recuperation (25 sec-R):* 16.3 ± 0.5 *BC:* *CA*: 20.4 ± 0.5 *CR:* 16.3 ± 0.6 *10-sec-A*: 19.1 ± 0.7 *10-sec-R*: 16.7 ± 0.6 *25-sec-A*: 20.8 ± 0.8 *25-sec-R:* 17.0 ± 0.5

		normal breathing (i.e., inhaling and exhaling). - 25-sec Valsalva (25-sec): Participants completed a total of 2 cycles consisting of 25 seconds of the Valsalva maneuver (i.e., holding the breath) followed by 5 seconds of normal breathing (i.e., inhaling and exhaling).			*BC CB:* IOP1: 17.7 ± 0.5 IOP2: 18.2 ± 0.5 IOP3: 18.6 ± 0.6 IOP4: 19.5 ± 0.8 IOP5: 19.8 ± 0.7 IOP6: 19.8 ± 0.8 IOP7: 19.9 ± 0.6 IOP8: 20.5 ± 0.8 IOP9: 20.7 ± 0.6 IOP10: 20.7 ± 0.6 IOP11: 20.8 ± 0.7 IOP12: 20.8 ± 0.6 IOP13: 21.0 ± 0.7 IOP14: 21.2 ± 0.7 *BC 10 sec:* IOP1: 16.8 ± 0.5 IOP2: 17.6 ± 0.5 IOP3: 17.6 ± 0.6 IOP4: 18.4 ± 0.7 IOP5: 19.0 ± 0.7 IOP6: 19.6 ± 0.6 IOP7: 19.1 ± 0.7 IOP8: 20.4 ± 0.9 IOP9: 21.3 ± 0.8 IOP10: 21.0 ± 0.7 IOP11: 19.8 ± 0.8 IOP12: 21.1 ± 0.8 IOP13: 21.8 ± 0.5 IOP14: 21.2 ± 0.6 *BC 25 sec:* IOP1: 18.2 ± 0.6 IOP2: 19.3 ± 0.7	

					IOP3: 20.1 ± 0.7 IOP4: 20.8 ± 0.6 IOP5: 21.6 ± 0.5 IOP6: 21.6 ± 0.5 IOP7: 21.8 ± 0.5 IOP8: 21.7 ± 0.5 IOP9: 22.5 ± 0.8 IOP10: 23.0 ± 0.7 IOP11: 23.6 ± 0.8 IOP12: 24.2 ± 0.7 IOP13: 24.6 ± 0.6 IOP14: 23.6 ± 0.6	
Vieira, et al. 2006.(38)	n= 30. Healthy males at the Catholic University of Brasılia health club. Age: 18 through 40 years. Regular exercise practitioners.	**Within--groups** A bench press set was used to perform the exercise. An 80% of 1 maximum repetition was standardized for each subject. The 1 maximum repetition values was determined from 1 week to 1 day before the start of the IOP measurements. Two exercise modes were tested. In mode I (MI), the subjects performed 4 repetitions, exhaling when lifting the weight and inhaling when lowering it. At the last repetition, however, subjects were instructed not to exhale but to keep holding the breath and to hold the bar elevated long enough for the examiner to obtain 1 or 2 reliable measurements (around 8 seconds) in the right eye. In mode II (MII), subjects were	An electronic tonometer (Tono-pen XL; Medtronic Solan, Jacksonville, Fla). At least 4 measurements were obtained in the right eye in each subject before and during exercise, as well as before, during, and after exercise in the left eye, and the averages were computed. Both eyes of each subject were enrolled so that right and left eyes were chosen to evaluate modes I and II, respectively. The IOP was checked again in the left eye 1 minute after subjects finished the exercise.	*MI:* 18.6 ± 4.2 *MII:* 18.8 ± 4.6	*MI:* 23.0 ± 5.6 *MII:* 21.0 ± 5.1	*MI* & *MII:* 17.5 ± 3.6

		asked not to hold the breath at the last repetition but to continue to exhale while lifting the bar for the IOP measurements in the left eye. A 1-hour rest period was interposed between exercise modes I and II				
Conte et Scarpi. 2013. (39)	n = 19 (6 women). Age = 22 ± 3 years. Boxing athletes with resistance training experience.	**Within-group** **Moderate load (ML)** - 60% RM, 15 rep, 3 set, 30 second rest between sets, controlled lifting velocity. **Heavy load (HL)**. - 80% RM, 8 rep, 3 set, 90 second rest between sets, controlled lifting velocity. **Control (C).** - The same IOP measures but in rest all time. The exercises in both programs were: 1)bench press; 2) incline bench press; 3) pulldown; 4) upright row; 5) deltoid development; 6) shoulder fly; 7) standing barbell curl; 8) pushdown; 9) reverse curl; 10) 45° leg press; 11) leg curl 12) and seated calf raise.	Perkins Tonometer (Clement Clarke H/S). Six time points: i) before exercise; ii) exercise 1 (E1): during the workout (or immediately to repeated exercise , and immediately after finishing the bench press exercise (5 minutes after the start of the workout); iii) exercise 2 (E2): immediately after finishing the standing barbell curl exercise (35 minutes after the start of the workout); iv) exercise 3 (E3): immediately after finishing the 45º leg press exercise (50 minutes after the start of the workout); v) recovery 1 (R1): three minutes after finishing the workout; and vi) recovery 2 (R2): six minutes after finishing the workout.	*ML*: 11,6 + 2,2 *HL*: 11,8 + 2,2 *C*: 11,7 + 2,5	*ML E1*: 9,0 + 2,3 *ML E2*: 9,2 + 1,9 *ML E3*: 9,9 + 2,7 HL *E1*: 10,5 + 1,7 *HL E2*: 10,4 + 2,0 *HL E3*: 11,5 + 1,9 *C E1*:11,5 + 2,1 C *E2*: 11,2 + 2,3 C *E3*: 11,4 + 2,7	ML R1: 10,6 + 2,3 ML R2: 11,9 + 3,0 HL R1: 12,4 + 2,4 HL R2: 13,1 + 1,7 *C R1*: 11,8 + 2,3 C *R2*: 11,6 + 2,4
Chromiak et al. 2003.(40)	n= 30 (15 women). Healthy active. Male:	**Within--groups** Subjects visited in 3 separate occasions with a minimum of 48 hours between testing sessions.	Tonometry with a Tono-Pen XL (Medtronics/ Solan, Jacksonville, FL). Before experimental the initial	*LP***:** 13.8 ± 1.9 *CP***:** 14.7 ± 2.2	*LP***:** *Set 1*: 12.7 ± 2.8 *Set 2*: 11.8 ± 2.5 *Set 3*: 11.9 ± 2.5	*LP***:** 12.0 ± 2.4 *CP***:** 13.6 ± 2.1

	Age 22,5 ± 1.7 years. Height 181 ± 4.4 cm. Weight 81.6 ± 16.5kg. Female: Age 20.9 ± 0.9 years. Height: 164.3 ± 6.0 cm. Weight: 66.7 ± 14.6 kg.	On the first day of testing, 1RM strength for the seated leg press (LP) and chest press (CP) exercises were determined on Cybex VR equipment For the following testing sessions, subjects performed 3 sets of 10 repetitions of either the leg press (LP) or chest press (CP) exercise using a resistance of ;70% of 1RM in random order.	IOP was measured. IOP was measured in men and women prior to and immediately following the first, second, and third set of resistance exercise as well as 5 minutes after the exercise was established (after the third set).		*CP*: *Set 1*: 14.4 ± 2.2 *Set 2*: 13.8 ± 2.4 *Set 3*: 13.0 ± 1.6	
Huang et al Rosenfield. 2015. (41)	n= 20 (16 women). Healthy subjects. Age: between 22 and 28 years (mean age=24 years). In a second study, IOP (isotonic exercise trial): 14 healthy subjects between 23 and 28 years of age (age=24 years)	**Between--groups** For the isotonic exercise trial, subjects maintained an unsupported static squat position with knees flexed to a 90° angle for a continuous 2 minute period while watching television at 3 meters.	Handheld Tonopen tonometer (Reichert Technologies, Depew, NY). IOP was measured before and after 1 minute of isotonic exercise (i.e., while the subject was still in the squatting position)	*Pre-Squats*: 17.4 ± 0.8	*NR*	*Post-Squats*: 16.6 ± 0.9

	participated. Each subjects participated in 3 trials, namely: aerobic exercise, isotonic exercise, and a control condition. The trial order was randomized, and each trial was separated by a 10 minute rest period.					
Pérez-Castilla et al. 2021. (42)	n= 176 (74 women) Sports science students, physically active. Age 20.5 ± 2.4 years.	**Within-group** Each group of men and women was subdivided in two groups: - Low-strength (Men Low Strength – MLS- and Women Low Strength – WLS-) - High-strength (Men High Strength – MHS- and Women High Strength – WHS-). A single session. . Thereafter, participants performed the maximal isometric handgrip	Handgrip strength was measured using a TKK dynamometer (TKK 5101 Grip-D; Takey, Tokyo, Japan). Portable rebound tonometer (Icare® TA01i, TiolatOy, INC., Helsinki, Finland). Six rapidly consecutive measurements. IOP was recorded before the handgrip test (baseline measurement), during the test (intra-effort measurement), and 5 seconds after completing each test (post-effort measurement).	*Men Baseline* 17.1 ± 2.0 *Women Baseline* 16.9 ± 1.7	*Dominant Hand:* *MLS*: 3.9 ± 2.7 *WLS*: 3.3 ± 2.0 *MHS*: 4.3 ± 3.1 *WHS*: 2.9 ± 2.0 *No Dominant Hand:* *MLS*: 3.1 ± 2.4*,† (-2, 10) *WLS*: 2.9 ± 1.8 (0, 7) *MHS*: 4.3 ± 3.1 (-2, 12)	*Dominant Hand:* *MLS*: 0.1 ± 2.7 *WLS*: 0.5 ± 2.0 *MHS*: 0.6 ± 2.4 *WHS*: 0.9 ± 1.5 *No Dominant Hand:* *MLS:* 0. 4 ± 2.3 *WLS*: 0.1 ± 1.7 (-3, 4) *MHS*: 0.7 ± 1.7 (-2, 4) *WHS*: 0.5 ± 1.7 (-4, 5)

		strength test twice with each hand. Participants were instructed to produce maximal force from the beginning of the test which lasted approximately 5 s. Hands were alternated to minimise fatigue. All participants started with their dominant hand. One-minute of rest was given between each attempt and no verbal encouragements were provided.			*WHS*: 2.9 ± 2.0 (-1, 10)	
Rüfer et al. 2014. (43)	n = 21 (10 women). Age = 26 ± 3 years Physically active.	**Within-group** Four conditions in random order separated by 30 min: **LC20:** 20 repetitions of leg curl at 65% of Pmax. **LC10:** 10 Repetitions of leg curl at 75% of Pmax. **BM20:** 20 repetitions of butterfly machine at 65% of Pmax **BM10:** 10 repetitions of butterfly machine at 75% of Pmax.	Portable rebound tonometer (ICare, Espoo, Finland). Mean IOP of both eyes recorded before exercise, immediately after exercise (A0), and 10-min after exercise (A10).	*LC20*: 17.0 ± NR *LC 10*: 16.8 ± NR *BM20*: 16.4 ± NR *BM10*: 16.3 ± NR	*NR*	*LC20 A0*: 17.2±NR *LC20 A10*: 17.1±NR *LC10 A0*: 17.2 ± NR *LC10 A10*: 16.7 ± NR *BM20 A0*: 17.2 ± NR *BM20 A10*: 16.3 ± NR *BM10 A0:* 16.9 ±NR *BM20 A10*: 16.6 ± NR
Soares, et al. 2015 (44).	n= 20 (10 women). Healthy. Exclusion criteria were: i) media opacity; ii) volume change of ocular bulb or absence of	**Within--groups** The volunteers underwent two interventions separated by an interval of 72 hours, both with the same volume and intensity in the leg-press exercise, , a time interval between series of 60 seconds and moderate speed, according to the following positions: P1) leg-press performed in a sitting position and P2) leg-press in	Perkins tonometer, in three moments: M1) immediately before the exercise, M2) immediately after the third set and M3) three minutes after the completion of the third set; in both eyes.	*P1 M1:* Rigth Eye: 12.9 ± 1.9 Left Eye: 12.2 ± 1.8 *P2 M1:* Rigth Eye: 12.4 ± 2.3 Left Eye: 11.8 ± 1.4	*NR*	*P1 M2***:** Rigth Eye: 9.3 ± 2.0 Left Eye: 9.4 ± 2.0 *P2 M2* Rigth Eye: 9.6 ± 1.2 Left Eye: 8.8 ± 1.2 *P1 M3:* Rigth Eye: 9.3 ± 2.4 Left Eye: 9.0 ± 2.5 *P2 M3:*

	ocular bulb iii) age below 20 or over 40 years old, and iv) time practicing resistance training below 30 days.	the supine position. 3 set 15 repetitions with 60% MR in both. To determine the training loads, the prediction test initially performed was the leg-press exercise, through applying submaximal loads until exhaustion.				Rigth Eye: 9.2 ± 1.9 Left Eye: 8.4 ±1.8
Vaghef et al. 2021. (45)	n=24 (9 women). Healthy. Age. 22.7±2.7 years. Inclusion criterial: 1) at least 2 years of experience in resistance exercises training,2) that included at least two sessions per week,3) free of any musculoskeletal or cardiovascular limitations 4) familiarity with a leg press machine.	**Withing--groups** The participants are then asked to perform three types of lifts of (a) one repetition at 95% of maximum weight (1RM), (b) six repetitions at 75% of maximum weight (6RM) and (c) isometric hold (ISO) of 10 s against weight that is much heavier than maximum weight that could be lifted by the participant (ie, immovable) (ISO)	IOP was measured preexercise, during and immediately following the exercise using an iCare TA01i rebound tonometer.	*1 RM*: - 13.7±3.0 *6 RM:* - 12.2±2.6 *ISO:* - 12.2±2.7	*1 RM* : - 40.7±14.3 *6 RM* : - 35.9±13.8 *ISO* : - 40.9±20.1	*1 RM*: - 13.1 ± 2.7 *6 RM*: - 12.8 ± 1.9 *ISO*: - 13.04 ± 2.4

Vera et al. 2017. (46).	n= 17. Physically active male military officers to Spanish Army. Age: 46±4.77 years. All participants had a recent verification of good health and free medication.	**Within--groups** Jump Squat (JS) and Ballistic Press exercise were used, and incremental loading test at four different intensities in both exercise. Countermovement jump exercise was performed in a Smith Machine, and the loads used were 20, 40, 60 and 80% of body weight. Participants performed two repetitions as quickly as possible with each load. In the Ballistic Bench was performed in a Smith Machine. Initial loads were a set at 20 kg for all participants. This load was progressively increased by 2,5 ; 5 or 10kg based on the maximum velocity of the bar recorded by a linear velocity transducer (T-Force System). Participants performed two repetitions with each load using the standard "touch and go". In both exercise, rested for 1 min between trial with the same load and 5 min between different loads.	Portable rebound tonometer (ICare, Tiolat Oy, Inc. Helsimki, Finland) in a randomily selected eye, using de same eye for all subsequent IOP measures. After warm up, IOP was measured and they began and after the second repetitions of each incremental load in a standing position (2-5seg) with the exception of bench press 1-RM where just one repetition was carried out whit the corresponding load. After the first incremental test, participants were asked to rest for 10 min, and then we followed the same protocol for the second test.	*JS***:** 50% RM: 14.3 ± 2.5 60% RM: 14.5 ± 2.2 65% RM: 14.4 ± 1.9 75% RM: 14.4 ± 1.6 ***BP*****:** 30% RM: 14.2 ± 2.7 40% RM: 14.2 ± 2.5 50% RM: 14.4 ± 2.5 60% RM: 14.4 ± 2.4 1RM. 14.4 ± 2.2	*NR*	*JS:* 50% RM: 14.2 ± 3.1 60% RM: 15.2 ± 2.7 65% RM: 15.9 ± 2.5 75% RM: 17.9 ± 2.8 *BP:* 30% RM: 14.8 ± 3.0 40% RM: 15.5 ± 2.3 50% RM: 16.8 ± 1.9 60% RM: 18.2 ± 1.8 1RM: 19.8 ± 2.9
Zhang et al. 2012. (47)	n= 4 (1 women). Healthy Age: Between 25–36 years.	**within--groups** Each subject was imaged in multiple sessions (1–3) on different days. Multiple trials (2–4) were acquired within each session. A break of 10	IOP measurements were made using a Tono-Pen XL (Reichert Inc., Depew, NY) on a separate day from the MRI study under the identical rest-exercise paradigm in the supine position.	11 ±3	11 ±3	*NR*

		minutes was given between trials to allow complete rest before the next trial. Subjects were instructed to squeeze a stress ball as hard as possible while maintaining similar strength over 1 minute. Moreover, to avoid hypo- or hyperventilation, subjects were instructed to inhale only (or exhale only) at the end of each data acquisition block during the entire fMRI trial.	Measurements were made during rest and in the middle of the handgrip task.			
Makarov et Voronkov. 2018.(48)	n=19 Young powerlifters men. Age from 18 to 30 years (the average 21.8). Healthy subjects.	**Within-group** **Bench press exercise.** **First Series.** During 5 min, the subject was lying motionless breathing steadily. Then, the subject jerked the weight four times (the first exercise) during 15–20 s. In the first series, the exercises were done . Inhaled before the jerk, exhaled during it and inhaled again while placing the weight down.. Then, four-time jerks were repeated (the second exercise); **Second series.** The subject was suggested to make a deep breath in during the jerk then to hold breath for 3–5 s with a barbell stiffarmed, and to exhale after placing it down (similar to Valsalva). Afterwards, the four-time jerks were repeated again (the second exercise),	IOP was measured by pneumotonometer before the exercises. By the end rest time before exercise, a triple measurement of IOP was made. By the end the first exercise period (in first and second series), a triple measurement of IOP was made spending around 2–4 min. After the last jerk in the second exercise (in first and second series), the IOP was measured.	**Initial IOP (all group):** 11.3 ± 3.6 **IOP after 5 min** in supine position before weightlifting: 10.6 ± 3.0	**All Group**: *first series* : 13.6 ± 2.7 *Second series*: 18.2 ± 5.1 **Group 1 .** *Firs Series***.** 21.8 ± 5.5 *Second Series.* 22.4 ± 5.9 **Group 2:** *First Series:* o 17.2 ± 5.5 *Second Series.* 17.0 ± 4.7	**All Group**: 12.5 ± 3.1 **Group 1.** 14.3 ± 2.8 **Group 2:** 11.7 ± 1.8

		and the IOP measurement as in the first series.. There are 3 analyses groups, all subjects (all group), 11 young men admittedly unskilled in powerlifting (group 1), and 8 athletes who had practiced weightlifting for at least a year (group 2).				
Banner, et al. 2015. (49).	30 healthy male subjects. aged between 18-27 years	**withing--groups** Subjects in supine position resting and the subjects were made to sit and instructed to sustain the handgrip with dominant hand at 20% of the predetermined MVC (Maximum voluntary contraction) till exhaustion. When subjects were not able to hold the exertion, they were instructed to inform. MVC was determined before each experiment as the highest value recorded in three trials. After one hour of rest same procedure was repeated for 40% of predetermined MVC	Handgrip Dynamometer (HGD) was used for isometric exercise (Inco Labs, Ambala, India). IOP with Schiotz tonometer. IOP was recorded before, immediately (M1), 5 minutes (M2) and 10 minutes (M3) after exercise respectively. IOP was measured in supine position. IOP was recorded first in the right eye and then in the left eye.	17.4 ± 1.8	*NR*	*20% MVC:* M1: 13.9 ± 1.9 M2: 15.5 ± 2.3 M3: 17.1 ± 2.0 *40% MVC:* M1: 12.7 ± 2.4 M2: 14.3 ± 2.4 M3: 17.2 ± 2.6
Vera et al. 2019. (50)	n= 20 (10 women) Physically active young adults Age: 23,8 ± 3.1 years	**Within--groups** Three conditions in random order separated, low (LI) medium (MI) and hight intensity (HI); to correspond 0%, 25%, and 50% of the maximum isometric strength, in two different exercise: mid-thigh clean pull (MTCP) and	A portable rebound tonometer (Icare, TiolatOy, INC. Helsinki, Finland). During the 1-minute isometric exercise as well as during the 1-minute recovery period, IOP was values in a continuous fashion. Due to (i) the	*NR*	*MTCP LI:* IOP1: 17.2 + NR IOP2: 17.7 + NR IOP3: 17.0 + NR IOP4: 17.2 + NR IOP5: 17.9 + NR IOP6: 17.9 + NR IOP7: 17.7 + NR IOP8: 17.9 + NR	*MTCP LI:* IOP1: 17.6 + NR IOP2: 16.9 + NR IOP3: 16.6 + NR IOP4: 16.4 + NR IOP5: 16.3 + NR IOP6: 16.1 + NR IOP7: 16.0 + NR IOP8: 16.2 + NR

	Weight: 68.4 ± 7.2 kg Height: 171.5 ± 8 cm. All participants had at least two years of recreational experience with resistance training.	squat protocol (SQ), respectively. Participants were instructed to pull or push the bar "as fast and as hard as possible" in both exercise. A rest period of 5 min was given between isometric protocols. The order of each protocol was randomized between participants. The first session was used for anthropometrical measures as well as to determine the maximum isometric strength. The second session consisted of an isometric squat and mid-thigh clean pull protocol against three relative intensities Only one trial was performed for each loading condition (a total of six series) and a rest period of 10 min was imposed between successive trials. Afterwards, participants had to achieve the required exertion and maintain constant tension during a 1-min period.	tonometer's inability to acquire IOP measurements at exact time intervals, (ii) the lack of exact timestamps for the measurements and (iii) the manual logging of the values, we describe a process to overcome these technical restrictions and obtain a set of equally distributed values at regular intervals with exact timestamps. A computer screen placed in front of the participants and at eye level allowed them to receive visual feedback of the forcetime trace using the force platform software (BioWare v. 5.3.0.7, Kistler, Switzerland), while an experienced optometrist simultaneously measured the IOP. When the isometric effort ended, participants adopted a standing position without producing any exertion and IOP was measured during the immediate subsequent 1-min recovery period.		IOP9: 18.2 + NR IOP10: 17.9 + NR IOP11: 18.4 + NR IOP12: 18.1 + NR IOP13:18.0 + NR IOP14: 18.0 + NR IOP15: 17.9 + NR *MTCP MI :* IOP1: 17.9 + NR IOP2: 18.1 + NR IOP3: 18.6 + NR IOP4: 18.8 + NR IOP5: 19.8 + NR IOP6: 19.8 + NR IOP7: 20.1 + NR IOP8: 20.2 + NR IOP9: 20.3 + NR IOP10: 20.6 + NR IOP11: 20.4 + NR IOP12: 20.5 + NR IOP13: 20.7 + NR IOP14: 21.2 + NR IOP15: 20.8 + NR *MTCP HI:* IOP1: 20.3 + NR IOP2: 20.9 + NR IOP3: 21.0 + NR IOP4: 21.6 + NR IOP5: 21.6 + NR IOP6: 22.0 + NR IOP7: 22.4 + NR IOP8: 21.8 + NR IOP9: 22.2 + NR	IOP9: 16.2 + NR IOP10: 16.3 + NR IOP11: 16.2 + NR IOP12: 16.3 + NR IOP13: 16.2 + NR IOP14: 16.1 + NR IOP15: 16.36 + NR *MTCP MI :* IOP1: 18.3 + NR IOP2: 16.9 + NR IOP3: 16.3 + NR IOP4: 16.7 + NR IOP5: 16.4 + NR IOP6: 16.2 + NR IOP7: 16.4 + NR IOP8: 16.6 + NR IOP9: 16.8 + NR IOP10: 16.4 + NR IOP11: 16.6 + NR IOP12: 16.2 + NR IOP13: 16.1 + NR IOP14: 15.9 + NR IOP15: 16.0 + NR *MTCP HI* IOP1: 19.0 + NR IOP2: 16.0 + NR IOP3: 15.9 + NR IOP4: 15.9 + NR IOP5: 16.1 + NR IOP6: 16.3 + NR IOP7: 15.6 + NR IOP8: 16.0 + NR IOP9: 16.8 + NR

					IOP10: 22.9 + NR IOP11: 23.0 + NR IOP12: 23.3 + NR IOP13: 23.3 + NR IOP14: 23.1 + NR IOP15: 23.6 + NR *SQ LI:* IOP1: 17.8 + NR IOP2: 17.8 + NR IOP3: 18.5 + NR IOP4: 18.7 + NR IOP5: 18.7 + NR IOP6: 18.9 + NR IOP7: 19.0 + NR IOP8: 19.2 + NR IOP9: 19.8 + NR IOP10: 19.9 + NR IOP11: 20.3 + NR IOP12: 20.6 + NR IOP13: 20.6 + NR IOP14: 20.3 + NR IOP15: 19.9 + NR *SQ MI:* IOP1: 19.00 + NR IOP2: 19.4 + NR IOP3: 21.1 + NR IOP4: 22.4 + NR IOP5: 21.4 + NR IOP6: 21.6 + NR IOP7: 22.1 + NR IOP8: 22.7 + NR IOP9: 22.5 + NR	IOP10: 16.4 + NR IOP11: 16.6 + NR IOP12: 16.5 + NR IOP13: 16.4 + NR IOP14: 16.3 + NR IOP15: 16.6 + NR *SQ LI:* IOP1: 17.3 + NR IOP2: 15.5 + NR IOP3: 14.6 + NR IOP4: 15.1 + NR IOP5: 15.4 + NR IOP6: 16.1 + NR IOP7: 15.6 + NR IOP8: 15.9 + NR IOP9: 15.8 + NR IOP10: 15.9 + NR IOP11: 15.6 + NR IOP12: 15.7 + NR IOP13: 15.5 + NR IOP14: 15.7 + NR IOP15: 15.7 + NR *SQ MI:* IOP1: 17.4 + NR IOP2: 14.4 + NR IOP3: 15.0 + NR IOP4: 15.1 + NR IOP5: 15.4 + NR IOP6: 15.4 + NR IOP7: 14.9 + NR IOP8: 15.6 + NR IOP9: 15.8 + NR

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NR= *Not reported.* C = they made the same measurements as in the experimental situations but with the subjects always at rest.

Table 2. Effect of Dynamic Strength Training.

Study	Subject	Protocol / exercise	IOP effect
Avunduk, et al. 1999. (30)	N= 31 various musculoskeletal diseases.	DT (Leg-curl, 1 set 4 rep, at a low speed & 20 times at a high speed, 20 sec rest between two speed).	↓*
Vera et al. 2020. (33).	N= 17 physical active men.	DT (Bench press 1 set to failure at 65% RM) DT (Bench press 1 set to failure at 75, 85 & 95% RM)	↔* ↑*
Vera et al. 2018. (34)	N= 25 physical active.	DT (Squat 1 set of 10 rep 10 RM,) DT (Militar press 1 set of 10 rep 10 RM,) DT (Bíceps Curl 1 set of 10 rep 10 RM,) DT (Calf Raise 1 set of 10 rep 10 RM)	↑** ↔* ↑** ↑* ↑** ↔* ↑** ↔*
Vera et al. 2018. (35)	N= 40 military personnel males.	DT (Jump Squat balisctic 1 set 2 rep in 50 % RM) Low fit. DT (Jump Squat balisctic 1 set 2 rep in 60, 65 & 75 % RM) Low fit. DT (Jump Squat balisctic 1 set 2 rep in 50 % RM) High fit. DT (Jump Squat balisctic 1 set 2 rep in 60 % RM) High fit DT (Jump Squat balisctic 1 set 2 rep in 65 & 75 % RM) High fit. DT (Bench press Balistic 1 set 2 rep in 30 RM) Low Fit. DT (Bench press Balistic 1 set 2 rep in 40, 50, 60 % & 1RM) Low fit. DT (Bench press Balistic 1 set 2 rep in 30% RM) High fit. DT (Bench press Balistic 1 set 2 rep in 40, 50, 60 % & 1RM) High fit.	↔* ↑* ↓* ↔* ↑* ↔* ↑* ↔* ↑*
Vera et al.2020 (36).	N= 19 Physical active.	DT (Back Squat , 1 set of 10 rep, to failure, in concentric phase) DT (Biceps Curl, 1 set of 10 rep, to failure, concentric phase) DT (Back Squat , 1 set of 10 rep, to failure, eccentric phase) DT (Biceps Curl, 1 set of 10 rep, to failure, eccentric phase)	↑** ↓* ↑** ↑* ↑** ↔* ↑** ↔*
Vieira et al. 2006.(38)	N = 30 physical active male.	DT (Bench press, 1 set 4 rep at 80% RM, normal breath) DT (Bench Press, 1 set 4 rep at 80% RM, *Valsalva*)	↑** ↓* ↑** ↓*
Conte et Scarpi. 2013. (39)	N= 19 boxing training	DT (Different exercise at 3 set 15 rep 60% RM, 30 sec rest DT (Different exercise at 3 set 15 rep 80% RM 90 sec rest)	↓** ↓** ↔[6*] ↓** ↑**↑[6*]
Chromiak, et al. 2003. (40)	N = 30 recreational active.	DT (seated leg press 3 set 10 rep, 70% RM). DT (chest press 3 set 10 rep, 70% RM).	↓**↓*↓[5*] ↓**↓*↓[5*]
Rüfer et al. 2014 (43).	N= 21 physical active.	DT (Leg-curl, 60%, 20 Rep, P. Max). DT (Leg-Curl, 75%, 10 rep, P.Max) DT (Butterfly, 65%, 20 reps, P. Max). DT (Butterfly, 75%, 10 rep, P.Max)	↔* ↔[10*] ↔* ↔[10*] ↑* ↔[10*] ↑* ↔[10*]
Soares, et al.2015 (44).	N= 20 Healthy.	DT (leg-press sitting, 3 set 15 repetitions with 60% MR) DT (leg-press supine, 3 set 15 repetitions with 60% MR)	↓*↓ ** ↓*↓ **

Vaghef et al. 2021. (45)	N = 27 physical active.	DT (lifts 1 set 1 Rep, 95% RM) DT (Lift 1 set 6 Rep, 75% RM)	↑** ↓* ↑** ↑*
Vera et al. 2017. (46)	N = 17 physically active male military.	DT (Jump Squat ,1 set 2 rep, máx velocity at 50% RM) DT (Jump Squat ,1 set 2 rep, máx velocity at 60% ,65% & 75 % RM) DT (Ballistic Press, 1 set 2 rep, máx velocity at 30%, 40%, at 50%, 60%, & 1RM)	↔* ↑* ↑*
Makarov et Voronkov. 2018. (48)	N= 19 powerlifters (with more o less experience).	DT (Bench press 1 set 4 rep in 20 sec without *Valsalva*) DT (Bench press 1 set 4 rep in 20 sec with *Valsalva*)	↑** ↑* ↑** ↑*

** *IOP during exercise*. * *IOP immediately after exercise*. * *IOP after 1 min rest.* ** *IOP after 3 min rest* . 5* *IOP after 5 min rest*. 6* *IOP after 6 mi rest.* 10* *IOP after 10 min rest*. MVC = *Max Voluntary Contraction*. MT = *Max tension*.

Table 3. Effect of Isometric Training.

Study	Subject	Protocol / exercise	IOP effect
Avunduk et al.1999(30).	N= 32 various musculoskeletal diseases.	ISO (leg-curl 60º ISO, 20 rep, 5 sec ISO in MT)	↓*
Bakke et al.2009 (31).	N = 9 Healthy	ISO (Handgrip 40% MCV)	↑** ↑*
Vera et al. 2019 (32).	N= 26 Physical active.	ISO (Squat at Low Load, 1 min ISO). ISO (Squat at Medium Load, 1 min ISO). ISO (Squat at Low, High Load, 1 min ISO).	↑** ↓* ↑** ↓* ↑** ↓*
Vera et al. 2020 (37).	N= 20 Physical active	ISO (Back Squat 2 set, 80% máx ISO Strength , 1 min ISO, at normal breathing) ISO (Back Squat 2 set, 80% máx ISO Strength , 1 min ISO, at 10 sec Valsalva) ISO (Back Squat 2 set, 80% máx ISO Strength , 1 min ISO, at 25 sec Valsalva) ISO (Bíceps Curl 2 set, 80% máx ISO Strength , 1 min ISO, at normal breathing) ISO (Bíceps Curl 2 set, 80% máx ISO Strength , 1 min ISO, at 10 sec Valsalva) ISO (Bíceps Curl 2 set, 80% máx ISO Strength , 1 min ISO, at 25 sec Valsalva)	↑ ** ↑* ↑* ↑ ** ↑* ↔* ↑ ** ↑* ↔* ↑ ↑** ↑* ↑* ↑ ↑** ↑* ↑* ↑ ↑** ↑* ↔*
Huang et Rosenfield .2015 (41)	N= 14 healthy.	ISO (Squat ISO, 2 min)	↓*
Pérez-Castilla et al. 2021 (42).	N= 176 Physical active.	ISO (Handgrip, 2 rep, MVC in dominant hand in subject with Low Strength) ISO (Handgrip, 2 rep, MVC in dominant hand in subject with High Strength) ISO (Handgrip, 2 rep, MVC in no dominant hand in subject with Low Strength) ISO (Handgrip, 2 rep, MVC in no dominant hand in subject with High Strength)	↑** ↔* ↑** ↑* ↑** ↔* ↑** ↑*
Vaghef et al.2021 (45).	N = 27 physical active.	ISO (Lift de maximum weight).	↑** ↑*
Zhang et al. 2012 (47).	N= 4 healthy.	ISO (squeeze a stress ball, 1 min ISO, MVC).	↔**
Banner et al.2015 (49).		ISO (Handgrip 20% MVC to exhaustion). ISO (Handgrip 40% MVC to exhaustion).	↓* ↓5* ↔ 10* ↓* ↓5* ↔ 10*
Vera et al. 2019 (50).	N = 20 physical active.	ISO (Squat, 0, 25-50 & 100% Máx Isometric Strength). ISO (Clean pull, 0, 25-50 & 100% Máx Isometric Strength).	.↑** ↓* ↑**↓* No data baseline

*** IOP during exercise*. ** IOP immediately after exercise*. * *IOP after 1 min rest*. ** *IOP after 3 min rest*. 5* *IOP after 5 min rest*. 6* *IOP after 6 mi rest*. 10* *IOP after 10 min rest*. MVC = *Max Voluntary Contraction*. MT = *Max tension*

DISCUSSION

Our results are similar to a recently meta-analysis (51), where they observed that isometric exercise may cause increase IOP after exercise; however they no included additional load and they searched only isometric resistance exercise for lower limbs. Our observations were similar but we include isometric exercise for upper and lower body. However, in contrast Risner et al (17) said that both dynamic and isometric exercise could lower IOP, although there were conflicting data suggesting that IOP increased or remained unchanged in certain isometric exercise.

In this review, we have found that valsalva breathing increases more IOP values during and after exercise. There are few studies that evaluated this, but the majority of them show the same, according to Vera et al (52), that analysed different types of breathing and concluded that normal breathing is better than both valsalva and modified breathing. So, maybe will be interesting consider the fitness level or performance people, because in our analysis it seems that people with higher fitness levels or more experience have less IOP values during and after training. Besides they recovered faster their normal IOP. This is according to different studies (48,53,54)

Despite that analysed IOP elevation o reduction after exercise, Kim & Caprioli (55) “recommend the consideration of IOP "modulation" rather than just IOP "reduction" when glaucoma patients are treated, so may be is important analysed fluctuation in long time of the day”, as occur with Arterial Tension . Acute effects of resistance training or exercise in PIO are knows, but it necessary investigate chronic effects, like said Aleman (19), in fact in a combination of regular exercise (aerobic and strength training) shown chronic effect with significant reduction in IOP (20). This is important because IOP can be affect for many factors, as Covid Pandemic, when IOP increase if glaucoma people use FFP2 / N95 mask (56) volume and intensity of training, between people, time to measure IOP, and other factors as lifestyle.

CONCLUSION.

No clear results exist about the acute effects of strength training on IOP values; however we could say that IOP was elevated after isometric exercise and during exercise, but is not really clear after exercise. While there is a controversial about dynamic strength training.

Besides, it seems to be that exercise that included lower body, the acute IOP values could be reduced, but not will happen the same when exercise included upper body. It is also important that if the measure is not immediately after exercise (spent time more than 1 min) this IOP will be decreased or not altered in both type of training. During exercise IOP will be increased to greater time or greater number of repetitions in both type of training. As well the IOP will be greater the more intensity and volume the exercise has.

The quality of the studies is low and heterogeneous, all studies analysed except one of them do not have a control group. Nevertheless, it is important to note that impact that induce RT in IOP depends of different factors as intensity, type of exercise, fitness level and sex (32,34,39,57,58). In fact, it is interesting to know more about the relationship of IOP with Blood Pressure (BP), because diferents studies (31,59,60) show this relation, and may is other influencer factor. If this correlation will be really certain, will be interesting continue the investigations that had shown beneficial in BP and check it out in IOP values. Thus, is important to know what values are dangerous and allow increases IOP no dangerous, because maybe as happens with BP, exercise could be benefits in IOP and control IOP during daily. So, the IOP will be used as physiological indicator of physical exertion (59), because an maximal incremental physical exertion leads to a significant increase in IOP and BP, returning these indices completely to the initial levels after 5 minutes of active recovery.

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