Sportis

Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad

Scientific Technical Journal of School Sport, Physical Education and Psychomotricity

**Published by:** Campus Educa Sportis. **Collaborator:** University of A Coruña A Coruña. Spain

**E-mail**: v.arufe@udc.es **Web**: www.sportisjournal.com

ISSN-e 2386-8333



Original article. Acute effect of blood flow restriction on muscle response measured with tensiomyography. Vol. 11, n. º 4; p. 1-22, October 2025. https://doi.org/10.17979/sportis.2025.11.4.11661

# Acute effect of blood flow restriction on muscle response measured with tensiomyography

# Efecto Agudo de la restricción del flujo sanguíneo sobre la respuesta muscular medida con tensiomiografía

Jesús López-Bedoya [1]; Alicia Salas-Morillas [2]; Leopoldo Ariza-Vargas [3]; Mercedes Vernetta-Santana [1]

1. Department of Physical and Sports Education, Faculty of Physical Activity and Sports Sciences, Granada (Spain).

2.. Faculty of Health and Sports, University Alfonso X el Sabio, Málaga (Spain). Department of Physical and Sports Education, University International of la Rioja (Spain). Research Group 'IMCS, Grupo de Investigación Multidisciplinar en Ciencias de la Salud, University of Alfonso X el Sabio.

3. Departament of Didactics of Artistic and Corporal Expression, Faculty of Education Sciences, University of Córdoba.

*Correspondence Author: Alicia Salas alicia.salas@unir.net

**Editorial schedule:** *Article received 23/01/2025 Accepted: 20/06/2025 Published: 01/01/2025*

https://doi.org/10.17979/sportis.2025.11.4.11661

**To cite this article use the following reference:**

López-Bedoya, J.; Salas-Morillas, A.; Ariza-Vargas, L.; Vernetta-Santana, M. (2025). Acute effect of blood flow restriction on muscle response measured with tensiomyography. Sportis Sci J, 11 (4), 1-22 https://doi.org/10.17979/sportis.2025.11.4.11661

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




**Author contribution:**

J.L.B.: Conceptualization of the research, design and layout of the methodology, and data collection.

A.S.M.: Data collection, data analysis, methodology layout, manuscript writing, corresponding author.

L.A.V.: Data analysis and interpretation of results.

M.V.S.: Manuscript writing, methodology review and layout, data collection, and data analysis.

**Funding:** No funding was received for this study.

**Conflict of interest:** The authors declare no conflicts of interest.

**Ethical aspects:** All procedures performed in this study adhered to relevant ethical standards. Ethical principles were respected throughout the research, ensuring the integrity and protection of participants and data.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




**Abstract**
The aim was to compare the acute effect of a session with and without blood flow restriction on bicep brachii muscle response by Tensiomyography and perception of effort. Fourteen male and female university students participated (age 22.48± 1.41 years). The training consisted of 4 sets (30, 15, 15 and 15 repetitions) of the Biceps Curl exercise at 30% of 1RM, with a 30-s rest between sets. The speed of execution was 2s:2s, the load being determined with a pre-training measurement of 1RM and remaining unchanged throughout the period. Exercise was performed without and with without blood flow restriction with occlusive pressure set at 140% of the subject's systolic pressure measured in mm Hg. Compression was maintained throughout the session. Contraction time (Tc), muscle activation time (Td), contraction maintenance time (Ts), relaxation time (Tr) and muscle belly deformation (Dm) were assessed by Tensiomyography before and immediately after the session. No significant differences were found between the two interventions in any of the variables (Td, Tc, Ts, Tr and Dm) except Td $p < 0.01$. The perception of effort showed statistically significant differences $p < .001$, being higher in the session with blood flow restriction. It is concluded that a session with and without blood flow restriction of Biceps Curl did not generate significant variations in muscle response, with the exception of Td which was lower with the intervention without blood flow restriction, being the perception of effort higher with blood flow restriction.
**Keywords:** Kaatsu, vascular blood flow restriction, adults, tensiomyography.

**Resumen**
El objetivo fue comparar el efecto agudo de una sesión con y sin restricción del flujo sanguíneo en la respuesta muscular del bicep braquial mediante Tensiomiografía y la percepción del esfuerzo. Participaron 14 estudiantes universitarios de ambos sexos (edad 22,48± 1,41 años). El entrenamiento consistió en 4 series (30, 15, 15 y 15 repeticiones) del ejercicio *Curl Biceps* al 30% de 1RM, con un descanso de 30-s entre series. La velocidad de ejecución fue de 2s:2s determinándose la carga con una medición previa al entrenamiento de 1RM y manteniéndose sin cambios durante todo el período. El ejercicio se realizó sin y con restricción del flujo sanguíneo con presión oclusiva fijada al 140% de la presión sistólica del sujeto medida en mm Hg. La compresión se mantuvo durante toda la sesión. Se evaluaron tiempo de contracción (*Tc*), tiempo de activación muscular (*Td*), tiempo de mantenimiento de la contracción (*Ts*), tiempo de relajación (*Tr)* y la deformación del vientre muscular (*Dm*) mediante Tensiomiografía antes e inmediatamente después de la sesión. No se encontró diferencias significativas entre las dos intervenciones en ninguna de las variables (*Td, Tc, Ts, Tr y Dm*) excepto el *Td* $p < 0,01$. La percepción del esfuerzo mostró diferencias estadísticamente significativas $p < ,001$, siendo superior en la sesión con restricción del flujo sanguíneo. Se concluye que una sesión con y sin restricción del flujo sanguíneo de *Curl Bíceps* no generó variaciones significativas en la respuesta muscular, a excepción del *Td* que fue menor con la intervención sin restricción del flujo sanguíneo, siendo la percepción del esfuerzo mayor con restricción del flujo sanguíneo.
**Palabras Clave**: Kaatsu, restricción vascular del flujo sanguíneo, adultos, tensiomiografía.

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




## Introduction

*Blood flow restriction training* (BFRT) or Kaatsu training is characterized by the application of external compression on the most proximal part of the limbs, using pneumatic cuffs that totally or partially restrict the blood flow of the complete arterial occlusion (Laurentino et al., 2016). It appears that its use with low-intensity resistance exercise (20-30% of one repetition maximum (1RM) produces muscle adaptations similar to those observed with high-intensity resistance exercise, allowing a positive effect on various manifestations of strength (Grønfeldt et al., 2020; Ramis et al., 2020).

Scientific evidence shows improvements in muscle hypertrophy, and increased muscle work capacity (Figueroa & Vicil, 2011; Loenneke & Pujol 2009; Slysz et al., 2016; Yasuda et al., 2006).

The mechanism by which external compression enhances the effect of low-load resistance training is not well established but appears to be related to increased muscle activity associated with reduced blood flow (Figueroa & Vicil, 2011; Takarada et al., 2002). However, several studies have suggested that altered metabolite levels may be the basis for the improvement observed with external compression (Madarame et al., 2010; Reeves et al., 2006).

Other studies have shown that resistance training at a low intensity of 20% of 1RM max can cause effective increases in muscle size and strength when combined with moderate blood flow restriction (Figueroa & Vicil, 2011; Weatherholt et al., 2013; Yasuda et al., 2012). This type of BFRT has been found to evoke enhanced endocrine responses, one of the main ones being an increase in growth hormone (GH) which is assumed to play a role in muscle hypertrophy, (Pearson et al., 2015; Reeves, et al. 2006; Tanimoto et al., 2005). Takarada et al. (2002), showed that low-intensity occlusive exercise for the lower extremities caused a greater increase in plasma GH concentration than normal exercise of the same intensity and volume. Other authors speak of an increase in the number of fast fibres recruited to compensate for the localised hypoxic situation by increasing lactic anaerobic metabolism to cope with ATP resynthesis (Loenneke et al., 2010; Reina-Ramos et al., 2014). The increase in recruitment of type II muscle fibres increases mechanical stress and metabolite accumulation, thus increasing GH levels which induces muscle growth both directly and indirectly (Reina-Ramos et al., 2014).

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




On the other hand, among the different possibilities for assessing the muscular response to training in different muscle groups, Tensiomyography (TMG) is a non-invasive, reliable and easily reproducible tool (Rodríguez-Matoso et al 2012). This technique measures, by means of surface recording, the movement caused by the muscle belly during an artificially provoked isometric contraction.In recent years it has been presented as a useful and accurate method to perform an analysis of the mechanical characteristics and contractile capacity of any of the superficial muscles by measuring the radial displacement of the muscle in response to a standardised electrical stimulus of 1 millisecond (Pus et al., 2023). Several studies have been carried out by various authors using TMG (Rodríguez-Ruiz et al., 2014; Rojas-Barrionuevo et al., 2017; Rojas-Barrionuevo et al., 2016).The consequences of acute BFRT-based training on muscle response measured by TMG are not known.

On the other hand, perceived exertion is defined as the subjective intensity of effort, stress, discomfort or degree of fatigue felt during exercise (Robertson et al., 2003). Borg's (1982) scale, also known as *Rating of Perceived Effort* (REP) or *Rating of Perceived Effort* (RPE), is a subjective rating instrument for estimating intensity.

The aim of the study was to determine and compare the acute effect of strength training with and without blood flow restriction on biceps brachii (BB) muscle response, using and perception of exertion in young adults.

## Material And Method

### *Participants*

14 healthy young people of both sexes, 5 women and 9 men between 21 and 25 years (age 22.48± 1.41 years; body mass = 66.72±9.42 kg; height = 170.41±8.12 cm), all Spanish students of Physical Activity and Sport Sciences participated voluntarily in the study after signing their informed consent. None of them were currently undergoing any type of programmed physical training, nor did they suffer from injuries to the muscles of the upper limbs, or any other muscular or joint ailment that would prevent them from carrying out the intervention or assessment test. The study was conducted at an altitude of 738 m above sea level . The study is included in the Helsinki Declaration on research ethics and Spanish regulations applicable to clinical research on human beings (Royal Decree 561/1993 on clinical trials).

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




### *Design and Variables*

A quasi-experimental repeated measures pretest-posttest research design was used to achieve the proposed objective where each participant performed each experimental intervention (with and without blood flow restriction) separately with a minimum of one week as shown in Figure 1.

The independent variables were the two intervention conditions with resistance at 30% of 1 RM in *Biceps Curl* (with Kaatsu and without Kaatsu). As dependent variables, the following values provided by the TMG and selected as relevant for our research were evaluated: radial displacement of the muscle belly (*Dm*); contraction time (*Tc*); activation, latency or reactivity time (*Td*); contraction maintenance time (*Ts*) and relaxation time (*Tr*), as well as the perception of pain.

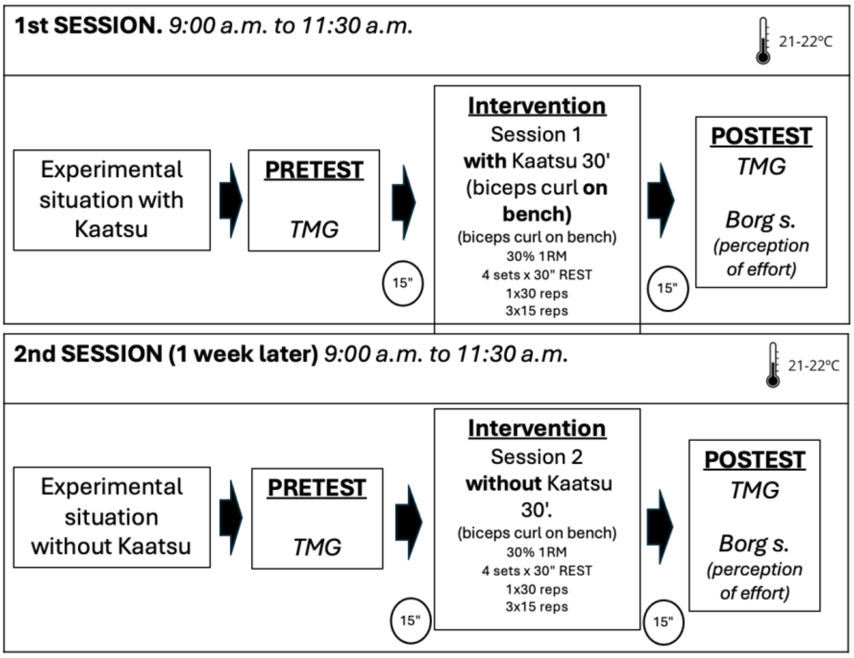


Figure 1. Experimental design

### *Instruments*

The KAATSU Master was used. Touch screen device. ® KAATSU GLOBAL, INC. 4 sets of different sizes of KAATSU Air Bands were used during the intervention. A TMG-

Sportis Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




S1 precision sensor tesiomyograph (Furlan & Co., Ltd.) was used to determine the assessment of muscle response. ®

***Assessment** Procedure*

The TMG assessment was performed using electrical stimulation with a *TMG-S1* precision sensor (*Furlan & Co., Ltd.*), placed perpendicularly on the muscle belly. Measurement points were marked with a dermatological pencil (Tous-Fajardo et al., 2010) (Figure 2).

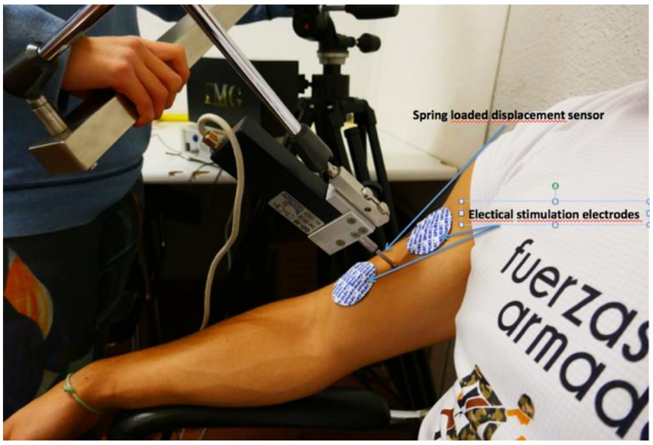


Figure 2. Placement of the sensor and electrodes for biceps brachii (BB) measurements.

The measurement point for the BB muscle was determined anatomically as the point of maximum displacement of the muscle belly, detected by palpation during a voluntary elbow extension of the subject (Simunic, 2003). To elicit the contraction, a bipolar electric shock of variable intensity of one millisecond duration was applied by means of two adhesive electrodes placed at the proximal and distal ends of the BB muscle, at the point of greatest muscle diameter, perpendicular to its surface and 4 cm apart from the midpoint. In our study, each measurement was performed at a constant intensity of 100mA (Rodriguez-Ruiz, et al., 2014), with an initial plunger pressure of $1.5x10^2$ N/mm$^2$ (Ditroilo et al., 2013). Two consecutive measurements were carried out at an interval of 10 s to avoid fatigue and post-tetanic activation (Benítez et al., 2013).

The parameters evaluated were *Dm* evaluates muscle *stiffness*, *Tc* is obtained by determining the time elapsed between 10% and 90% of the maximum radial deformation, *Td* represents the time it takes for the analysed muscle to reach 10% of its maximum radial deformation, *Ts*, determined by the time elapsed between 10% and 90% of the

Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Sportis Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity




maximum radial deformation, Tc represents the time it takes for the analysed muscle to reach 10% of its maximum radial deformation, *Ts*, determined by the time that elapses until the deformation values return to values of 50% of the maximum deformation, during the relaxation phase, and *Tr, the* time that, during the relaxation phase, the muscle goes from a deformation equivalent to 90% of maximum deformation to 50% of Dm (Rodríguez-Matoso, et al., 2012).

Likewise, the perception of effort was assessed immediately after the intervention through the Borg Scale (Williams, 2017).

***Training Protocol***

In session 1, after the pre-test TMG assessment, each subject was fitted with an elastic belt around the upper proximal portion of each arm during the Kaatsu test only. They were tested at a pressure of 40 base SKU (standard Kaatsu units) corresponding to the initial tightness of the KAATSU airbands when first manually placed on the limbs. Prior to the KAATSU training session, the subjects, seated in a chair, were subjected to a complete non-motion cycle consisting of 8 cycles of 20 seconds of pressure on, followed by 5 seconds of pressure off. This process was repeated automatically and in an ascending fashion until a final restraining pressure of 140% of an individual's resting systolic blood pressure was reached. During the Kaatsu session, participants performed the *Biceps Curl* exercise with the dominant arm only (Figure 3).

The training consisted of performing four sets: one set of 30 repetitions, plus three sets of 15 repetitions; two-second concentric and two-second eccentric execution rate of the *Curl Biceps* exercise*;* with a 30-s rest period between sets and a restriction duration of around 15 minutes (Slysz et al., 2016). The loads of the session were determined according to the previous measurement of a %1RM, using a load at 30% of 1RM located within the recommended literature between 20-40% (Villalba, 2022), remaining unchanged throughout the session and the compression of the cuffs were continuous (Freitas et al., 2020; Slysz et al., 2016).

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




Figure 3. Execution of the Biceps Curl training.

The exercise was performed with BFR set at 140% of the subject's systolic pressure measured in mm Hg. Compression was maintained throughout the session, including rest periods, with the strap pressure being released immediately after completion of the workout.

The protocol lasted approximately 30min, all participants were assessed by the same specialist after the protocol.

The protocol without BFR had the same 30min duration and sequence as the occlusion session, with a week's rest in between, to ensure that fatigue did not influence the data obtained. Similarly, subjects without kaatsu were assessed for the parameters indicated with TMG before and immediately after the intervention protocol and the assessment did not exceed 5 minutes for each of them.

Participants were always scheduled in the same time range (from 9.00 to 11:30 a.m.) but on different days and the ambient temperature of the gym room was controlled between 21-22º C. Between the pre-test, intervention and post-test phases there were intervals of 15 seconds. To estimate the ratio of perceived exertion, participants were asked at the end of the session to score from 1 to 10 based on the Borg scale, with 1 (minimal exertion) to 10 (extreme exertion) (Williams, 2017).

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Open Access Creative Commons



***Statistical analysis***

Firstly, the reliability of the two measurements taken, associated with each of the dependent variables (*Td, Tc, Ts, Tr and Dm*), was assessed using the Intraclass Correlation Coefficient (ICC), through a mixed effects model. The following conventional values were considered for interpretation: ICC < 0.40 (Poor), 0.40 ≤ ICC ≤ 059 (Sufficient), 0.60 ≤ ICC ≤ 0.74 (Good) and 0.75 ≤ ICC ≤ 1 (Excellent).

The normality of the distributions was tested using the Shapiro-Wilk statistic. Comparison of means between pre- and post-treatment conditions in each experimental situation, as well as between the variations produced (gains or losses) between experimental situations was performed using Student's t-statistic for paired samples. A significance level of $p < 0.05$ was estimated. The effect size was calculated using Cohen's *d* statistic for related samples. The statistical package used was SPSS-v25 (SPSS Inc., Chicago, IL, USA).

**Results**

***Inter-rater reliability analysis was performed for each of the dependent variables.***

Table 1 shows the Intraclass Correlation Index obtained from the two measurements performed for each dependent variable, according to the different experimental situations.

Table 1. Intraclass Correlation Index obtained from the two measurements made for each dependent variable, in each experimental situation.

| Treatment | Measurement | | Td | Tc | Ts | Tr | Dm |
|---|---|---|---|---|---|---|---|
| Without Kaatsu | Pre | ICC | .824 | .899 | .967 | .931 | .906 |
| | | *P* | .000 | .000 | .000 | .000 | .000 |
| | Post | ICC | .963 | .965 | .919 | .826 | .981 |
| | | *P* | .000 | .000 | .000 | .000 | .000 |
| With Kaatsu | Pre | ICC | .839 | .991 | .919 | .952 | .985 |
| | | *P* | .000 | .000 | .000 | .000 | .000 |
| | Post | ICC | .663 | .944 | .925 | .945 | .922 |
| | | *P* | .001 | .000 | .000 | .000 | .000 |

*Td* = response or activation time; *Tc* = contraction time, Dm = maximum radial displacement of the muscle belly*; Ts* = contraction maintenance time (50% of *Dm* to 50% of *Dm*); Tr = relaxation time (50% of *Dm* to 10% of *Dm).*

As there was an excellent concordance index between the two measurements, it was decided to consider the first record made for each of the dependent variables (*Td, Tc, Ts, Tr and Dm*), with the Shapiro-Wilk statistic showing a normal behaviour of the different distributions.

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333



Original article. Acute effect of blood flow restriction on muscle response measured with tensiomyography. Vol. 11, n. º 4; p. 1-22, October 2025. https://doi.org/10.17979/sportis.2025.11.4.11661

***Gain produced between the Pre- and Post-test measurements in the dependent variables, according to the different experimental conditions.***

Statistically significant differences were only observed in the response or activation time (*Td*) between the pre- (M = 24.29, SD = 1.82) and post-treatment measurements (M = 22.79, SD = 1.92) when the Kaatsu was not applied, $t(12) = 3.657$, $p$ = ,003, $d = 1.01$, see tables 2 and 3.

Table 2. Descriptive analysis of the dependent variables Td, Tc, Ts, Tr and Dm. Data are shown as Mean (Standard deviation)

| Treatment | Measure | Td | Tc | Ts | Tr | Dm |
|---|---|---|---|---|---|---|
| Without Kaatsu | Pre (N=13) | 24.29(1.82)* | 27.35(4.16) | 92.35(26.79) | 53.17(20.75) | 12.13(4.32) |
| | Post (N = 13) | 22.79(1.92) | 27.54(4.99) | 101.02(29.67) | 57.24(19.98) | 13.01(3.86) |
| With Kaatsu | Pre (N = 13) | 24.34(1.46) | 32.92(9.95) | 107.75(27.44) | 59.89(28.52) | 11.81(3.62) |
| | Post (N = 13) | 24.20(1.73) | 29.08(4.59) | 114.43(28.31) | 54.74(18.12) | 10.37(4.71) |

(*) Statistically significant differences between pre- and post-treatment measures ($p < 0.01$).

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
OPEN ACCESS Creative Commons



Table 3. Student's t-statistic for paired samples, according to the pairs constituted by the pre- and post-test measures of the dependent variables *Td, Tc, Ts, Tr and Dm*, in each experimental situation.

| Treatment | Statistic | Td | Tc | Ts | Tr | Dm |
|---|---|---|---|---|---|---|
| Without Kaatsu | *t* (gl = 12) | 3.657 | -1.141 | -1.058 | -.554 | -.677 |
| | *P* | .003 | .891 | .311 | .590 | .511 |
| With Kaatsu | *t* (gl = 12) | .263 | 1.099 | -.545 | .572 | 1.376 |
| | *P* | .797 | .293 | .595 | .578 | .194 |

*Td* = response or activation time; *Tc* = contraction time, *Dm* = maximum radial displacement of the muscle belly; *Ts* = contraction maintenance time; *Tr* = relaxation time.

***Analysis of the variation (gain or loss) produced in both experimental situations.***

Table 4 shows the average values of the variations produced between the pre- and post-treatment measurements of the variables *Td, Tc, Ts, Tr and Dm*, depending on whether Kaatsu was applied or not.

The contrast statistic showed no statistically significant differences between the two situations for each of these variables. Therefore, it can be affirmed that the fact of using an BFR intervention during the *Biceps Curl* work does not generate significant variations (gains or losses) on these variables, in comparison with standard training.

Table 4. Descriptive analysis of the variation produced between the pre- and post-test measurements, in each dependent variable *Td, Tc, Ts, Tr and Dm*, according to the different experimental situations. Student's T test for paired samples.

| Treatment | Td (N = 13) | Tc (N = 13) | Ts (N = 13) | Tr (N = 13) | Dm (N = 13) |
|---|---|---|---|---|---|
| Without Kaatsu | -1.50(1.48) | .19(4.87) | 8.67(29.54) | 4.08(26.55) | .87(4.64) |
| With Kaatsu | -.1392(1.91) | -3.84(12.60) | 6.68(44.17) | -5.15(32.42) | -1.44(3.76) |
| s t | $t(12) = -1.941$ $p = .076$ | $t(12) = 1.189$ $p = .257$ | $t(12) = .118$ $p = .908$ | $t(12) = .652$ $p = .527$ | $t(12) = 1.279$ $p = .225$ |

*Td* = response or activation time; *Tc* = contraction time, *Dm* = maximum radial displacement of the muscle belly; *Ts* = contraction maintenance time; *Tr* = relaxation time.
Data are shown as Mean (Standard Deviation).

***Perception of effort measured in the two experimental situations.***

The Student's t-statistic shows the presence of statistically significant differences in the mean values of the perception of effort (recorded through the Borg Scale) in both

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




experimental situations $t(12) = -10.521$, $p < ,001$, $d = -2.92$; being higher when the Kaatsu procedure is applied (M = 8.46, SD = 1.3) than when it is not applied (M = 2.92, SD = 1.8) (See Figure 4).

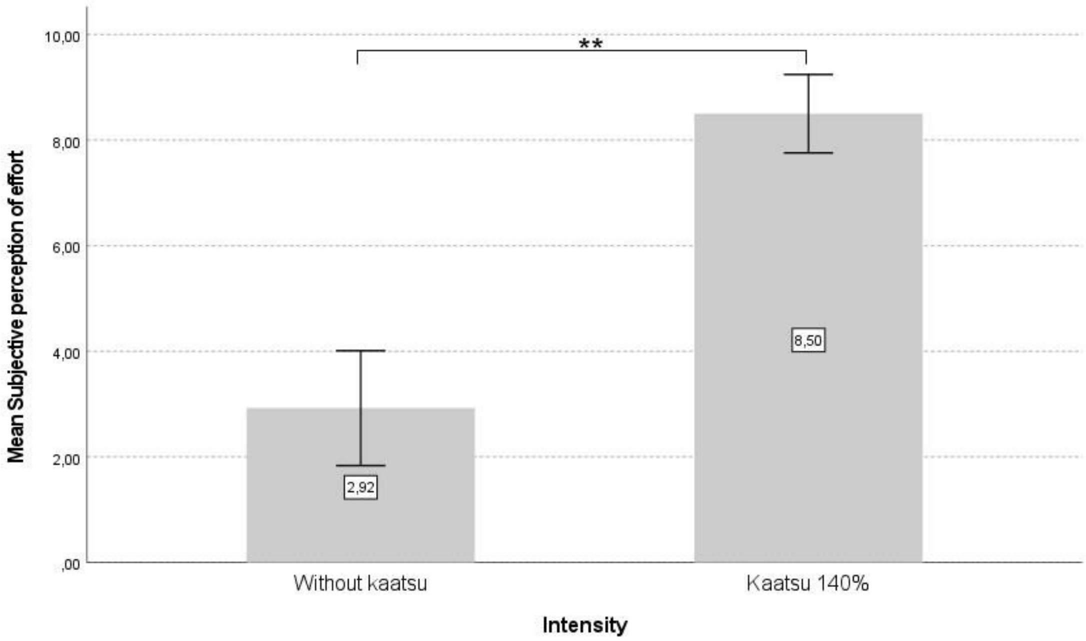


Figure 4. Mean values of Subjective perception of effort according to intervention (with and without kaatsu). Error bars. 95% CI. ** p < .001.

## Discussion

This study aimed to compare the acute effect of a strength session with and without blood flow restriction on biceps brachii muscle response by TMG and perception of exertion in young adults. The main findings show that there are no differences in the gains or losses of all the analysed variables of muscle mechanics in the BB during the *Biceps Curl* exercise with and without BFR, except for the response or activation time which was lower without BFR, being higher the perceived exertion in the intervention with BFR.

Analysing the TMG data for all the variables studied in our study, the changes observed are slight in *Tc*, *Tr*, *Ts* and *Dm*, and only the response or activation time (*Td* $p < 0.01$) decreases significantly in the session without BFR between the pretest and posttest. This is surprising as this decrease in *Td* in the session without BFR may indicate fatigue effect in the muscle group, but not in the session with BFR.

Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




This is cautiously confirmed in the *Dm* of the BB muscle belly, as it has increased slightly in the session without BFR, a sign of potentiation tending to fatigue (Rojas-Barrionuevo et al., 2017) and has decreased with BFR, although without significant difference in both cases. According to Krizaj et al. (2008) low values indicate high muscle tone and excess stiffness in the muscle structures, while higher values indicate a lack of muscle tone or a high degree of fatigue. Lower *Dm* values in the Kaatsu session could be interpreted cautiously as increased muscle tone or muscle stiffness. However, the increase in *Dm* in the session without BFR from 12.13 to 13.01 would point to fatigue (Krizaj et al., 2008).
As for the *Ts* or contraction duration data, although they increase in the two interventions without significant differences, which could indicate muscle fatigue in both cases, however, the increase is slightly greater in the training without BFR (from 92.35 to 101.02ms), compared to the BFR (from 107.75 to 114.4ms).
Different acute studies have found that low-intensity training and BFR promote similar increases in muscle thickness when compared to high-intensity training (Yasuda et al., 2012; Picón, 2018).
In the study by Yasuda et al. (2012), immediately after elbow flexor exercise, muscle thickness increased acutely ($p<0.01$) with concentric - BFR and eccentric - BFR contraction, but was greater with concentric - BFR (11.7%) ($p<0.01$) than with eccentric - BFR (3.9%).
Similarly, Matthew et al. (2018), assessed acute muscle responses for the upper body (with the elbow flexion exercise performed to failure) comparing different BFR pressures (0, 10, 20, 20, 30 50 and 90%) using a load of 30% of 1RM, finding an increase in muscle thickness for all conditions with no significant differences between them.
Although the adaptations obtained in muscle mass with low intensity strength training and BFR seem to be evident, the acute effects still raise some doubts and research on this subject continues to grow (Picón, 2018).
The result of our study suggests, on the one hand, that the exercise intensity used for the BB arm muscle was not sufficient to induce changes in the musculature, as well as, a single session is insufficient to generate variations in the contractile capacity of the BB muscle in the variables assessed through TMS in both sessions (with and without BFR).

However, several studies assessing muscle response, but using electromyography

Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Sportis. Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity




(EMG), have found an increase in muscle activity during BFR exercise (Takarada et al. 2002; Yasuda et al., 2006). These data are confirmed by Yasuda et al. (2008), who found an increase in muscle activity for the BB in a *biceps curl* exercise. It was found that the optimal compression to obtain the highest values is modified, the EMG was between 147 and 160 mm Hg. The authors indicate that low intensity muscle contractions in the BB performed with an external compression of 147 mmHg appear to alter muscle flow, leading to increased muscle activation without decreases in the work done during the contraction period.

Similarly, in the review by Dankel et al. (2016) who specifically analysed the effect of BFR on the upper limb, they observed that muscle mass gains in the biceps and triceps were greater compared to training without BFR at low loads and similar to high intensity training.

Likewise, Arenas-Sánchez et al. (2023) confirmed that low-load muscular strength training with BFR in the upper extremities can improve muscular power in the bench press exercise in young adults, in this case 12 sessions were carried out.

De Freitas et al. (2017), state that skeletal muscle adjusts according to the contractile activity to which it is subjected and such responses are specific to the type of training performed.

Overall, therefore, our data do not corroborate studies indicating that training at a low intensity such as 20% or 30% of 1RM can cause effective increases in muscle size and strength when combined with moderate blood flow restriction (Arenas-Sánchez et al., 2023; Dankel et al., 2016; Figueroa & Vicil, 2011). However, the few existing works in the literature references that evaluated acute muscle responses for the upper body make it difficult to link a discussion around our results. In addition, it can be added that most of the studies found that have compared the use or non-use of BFR in the same way as ours have been in the field of sport with the purpose of assessing its ergogenic effect in competition or the possibility of optimising recovery time (Williams et al., 2018).

Regarding perceived exertion, the mean values recorded through the Borg Scale showed statistically significant differences $t(12) = -10.521$, $p < ,001$, $d = -2.92$, being higher in the session with Kaatsu. Similarly the rating of perceived exertion was higher with BFR at low load (30% of 1 RM) in the study by (Loenneke et al., 2010). Also in Loenneke et

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Sportis Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity




al. (2011), perceptual responses to exertion were altered with BFR, data concurring with Hollander et al. (2010) who showed that partial BFR with a low load (30% 1RM) altered changes in perceived exertion, similar to higher intensity exercise (70% 1RM). However, it disagrees with Wernbom et al. (2006), who found no difference between vascular occlusion training and regular low-intensity exercise for perception of exertion, probable consequence of the lack of occlusive training sessions.

In our case, the perception of effort was greater in the Kaatsu session, corroborating the acute work of Husmann et al. (2018), who found an increase in fatigue immediately following Kaatsu exercise with an average age similar to ours (25 years old). The authors suggest the strong impact of this BFR on neuromuscular functioning, albeit with a short duration, as fatigue decreased considerably within two minutes of the cessation of occlusion. However, it can be said that a greater perception of effort in this case is not associated with significant changes in the muscular response of the variables evaluated in this study by the TMG, except for the muscle activation time, which was greater.

The main limitations of this study were the small sample size, which makes it difficult to generalise the results obtained. Therefore, it would be interesting to increase the sample size in both male and female participants in order to establish the existence of possible gender differences. Another major limitation was the scarcity of previous studies on the measurement of the acute effects of training with and without Kaatsu with TMG.

Despite the above, among the strengths of the study, it is possible to highlight the high reliability of the TMG assessment instrument in all the variables analysed in this study, with an excellent concordance index between the two measures analysed. Caution should be exercised when extrapolating the results, as they were obtained using a specific protocol of only one session with a single arm exercise. Future lines of research could focus on the application of a longitudinal intervention lasting several weeks in order to establish the possible chronic effects of Kaatsu on muscle response in the *Biceps Curl* exercise

## Conclusion

The findings of this study indicate that a single biceps curl session performed at 30% of 1RM, both with and without BFR, did not lead to significant differences in the gains or

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333





losses of the mechanical muscle variables analyzed in the biceps brachii. The only exception was the response or activation time, which was shorter in the session without BFR. Additionally, the perceived exertion was notably higher in the BFR condition.

From a scientific perspective, this study contributes valuable knowledge by exploring the acute neuromuscular responses under low-load resistance exercise with and without BFR, a method increasingly used in both athletic and clinical populations. The use of TMG as an evaluation tool adds further depth to the analysis, as it provides objective, non-invasive insights into muscle contractile properties such as delay time, contraction time, and muscle displacement. These metrics are highly sensitive to fatigue, neural activation, and muscle stiffness, making TMG a powerful technique for assessing muscular function beyond traditional strength measurements.

The incorporation of TMG enhances the scientific value of this research by offering a more precise understanding of how muscle responds mechanically to different training modalities. It allows practitioners and researchers to detect subtle neuromuscular adaptations or impairments that may not be visible through conventional assessments. As such, the results support a more critical view of the efficacy of BFR in acute settings, especially when the goal is to optimize muscle performance without unnecessarily increasing perceived effort. This has practical implications for designing tailored interventions in sports training, injury prevention, and rehabilitation, particularly for populations where high-load training is contraindicated.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




## References

Arenas-Sánchez, G., Mamani-Tapia, B., Inostroza-Téllez, E., Peiret-Villacura, L., Farias-Valenzuela, C., Orellana-Montini, J., & Espinoza-Salinas, A. (2023). Effect of vascular occlusion training on muscle power in the bench press exercise in trained adults. *SPORT TK-EuroAmerican Journal of Sport Science*, *12*, 9. doi:10.6018/sportk.598341

Benítez, A., Fernández, K., Montero, J. M. & Romacho, J.A. (2013). Reliability of tensiomyography (tmg) as a muscle assessment tool. *International Journal of Medicine and Physical Activity and Sport Sciences. 13(52),* 647-656.

Dankel, S. J., Jessee, M. B., Abe, T. & Loenneke, J. P. (2016) The Effects of Blood Flow Restriction on Upper-Body Musculature Located Distal and Proximal to Applied Pressure. *Sports Med*, 46: 23-33. doi: 10.1007/s40279-015-0407-7

De Freitas, M. C., Neto, J., Zanchi, N., Lira, F. S., & Rossi, F. (2017). Role of metabolic stress for enhancing muscle adaptations: Practical applications. *Worl Journal of Methodology*, *7*(2), 46-54. doi: 10.5662/wjm.v7.i2.46

Ditroilo, M., Smith, J., Fairweather, M. & Hunter, A. (2013). Long-term stability of tensiomyography measured under different muscle conditions. *Journal of Electromyography and Kinesiology,* *23*, 558-563. doi: 10.1016/j.jelekin.2013.01.014

Figueroa, A., & Vicil, F. (2011). Post-exercise aortic hemodynamic responses to low-intensity resistance exercise with and without vascular occlusion. *Scandinavian Journal of Medicine & Science in Sports*, *21*(3), 431-436. doi: 10.1111/j.1600-0838.2009.01061.x

Grønfeldt, B. M., Nielsen, J., Mieritz, R. M., Lund, H., & Aagaard, P. (2020). Effect of blood-flow restricted vs heavy-load strength training on muscle strength: Systemtic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports, 30*(5), 837-848. doi: 10.1111/sms.13632

Hollander, D. B., Reeves, G. V., Clavier, J. D., Francois, M. R., Thomas, C. & Kraemer, R. (2010). Partial occlusion during resistance exercise alters effort sense and pain. *J Strength Cond Res, 24,* 235-243. doi: 10.1519/JSC.0b013e3181c7badf

Husmann, F., Mittlmeier, T., Bruhn, S., Zschorlich, V. & Behrens, M. (2018). Impact of

Blood Flow Restriction Exercise on Muscle Fatigue Development and Recovery. *Medicine and Science in Sports and Exercise, 50*. 436-446 p.doi: 10.1249/MSS.0000000000001475

Krizaj, D., Simunic, B. & Zagar, T. (2008). Short-term repeatability of parameters extracted from radial displacement of muscle belly. *Journal of Electromyography and Kinesiology*, *18*, 645-651. doi: 10.1016/j.jelekin.2007.01.008

Laurentino, G. C., Loenneke, J. P., Teixeira, E. L., Nakajima, E., Iared, W., & Tricoli, V. (2016). The effect of cuff width on muscle adaptations after blood flow restriction training. *Medicine and Science in Sports and Exercise*, *48*(5), 920-925. doi: 10.1249/MSS.0000000000000833

Loenneke, J. P., Balapur, A., Thrower, A. D., Barnes, J. T., & Pujol, T. J. (2011). The perceptual responses to occluded exercise. *International Journal Sports Medicine, 32*, 181-184. doi: 10.1055/s-0030-1268472

Loenneke, J. P., Kearney, M. L., Thrower, A. D., Collins, S., & Pujol, T. J. (2010). The acute response of practical occlusion in the knee extensors. *Journal of Strength and Conditioning Research, 24*, 2831-2834.doi: 10.1519/JSC.0b013e3181f0ac3a

Loenneke, J. P. & Pujol, T. J. (2009). The use of occlusion training to produce muscle hypertrophy. *Journal of Strength and Conditioning Research. 31*, 77-84.doi:10.1519/SSC.0b013e3181a5a352

Freitas, E. D., Miller, R. S., Heishman, A. D., Ferreira-Junior, J. B., Araújo, J. P., & Bemben, M. G. (2020). Acute physiological responses to resistance exercise with continuous versus intermittent blood flow re- striction: A randomized controlled trial. *Frontiers in Physiology, 11*. doi: 10.3389/fphys.2020.00132

Madarame H., Kurano M., Takano H., Iida H., Sato Y., Ohshima H. & Nakajima T. (2010). Effects of low-intensity resistance exercise with blood flow restriction on coagulation system in healthy subjects. *Clinical Physiology and Functiona Imaging 30*, 210-213. doi: 10.1111/j.1475-097X.2010.00927.x

Matthew, M. B., Mattocks, K. T., Buckner, S. L., Mouser, J. G., Counts, B. R., Dankel, S. J., ... Loenneke, J. P. (2018). The acute muscular responses to blood-flow restricted exercise with very low relative pressure. *Clinical Physiology and Functional Imaging, 38*(2), 304-311.doi: 10.1111/cpf.12416

Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333



Picón, M. (2018). *Acute effects of training with blood flow restriction on tendon, cardiovascular response and muscle response*. University of Alicante. Doctoral thesis.

Pearson, S. J. & Hussain, S. R. (2015) A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. Journal of *Sports Medicine*, *2,* 187-200.doi: 10.1007/s40279-014-0264-9

Pus, K., Paravlic, A. H. & Šimunič, B. (2023) The use of tensiomyography in older adults: a systematic review. *Frontier of Physiology*. *14*, 1-11. doi: 10.3389/fphys.2023.1213993

Reeves, G. V., Kraemer, R. R., Hollander, D. B. & Fry, A. C. (2006). Comparison of hormone responses following light resistance exercise with partial vascular occlusion and moderately difficult resistance exercise without occlusion. *Journal of Applied Physiology 101*, 1616-22.doi: 10.1152/japplphysiol.00440.2006

Reina-Ramos, C. & Domínguez, R. (2014) Blood flow restriction training and muscle hypertrophy. *Revista Internacional de Ciencias del Deporte, 10,* 366-382.doi:10.5232/ricyde2014.03806

Ramis, T. R., De Lemos Muller, C. H., Boeno, F. P., Teixeira, B. O. S., Rech, A., Pompermayer, M. G., Da Silva Medeiros, N., Reischak-Oliveira, A., Pinto, R. S., & Ribeiro, J. L. (2020). Effects of traditional and vascular restricted strength training program with equalized volume on isometric and dynamic strength, muscle thickness, electromyographic activity, and endothelial function adaptations in young adults. *Journal of Strength and Conditioning Research, 34*(3), 689-698. doi: 10.1519/JSC.0000000000002717

Robertson, R. J., Goss, F. L., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J., Frazee K, Dube J, Andreacci, J. (2003). Concurrent validation of the OMNI Perceived Exertion Scale For Resistance Exercise. *Medicine and Science sport and Excercise, 35* (2), 333-341. doi: 10.1249/01.MSS.0000048831.15016.2A.

Rodríguez-Matoso, D., García-Manso J.M., Sarmiento, S., de Saa, Y., Vaamonde, D., Rodríguez-Ruiz, D. & Da Silva-Grigoletto, M. E. (2012). Muscle response assessment as a monitoring tool in the field of physical activity, health and sport. *Revista Andaluza Medicina del Deporte*, *3(1),* 28-40.

Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




Rodríguez-Ruiz, D., Diez-Vega, I., Rodríguez-Matoso, D., Fernandez-del-Valle, M., Sagastume, R. & Molina, J.J. (2014). Analysis of the Response Speed of Musculature of the Knee in Professional Male and Female Volleyball Players. *BioMed Research International, 2014,* 239708, 8 doi: 10.1155/2014/239708.

Rojas-Barrionuevo, N. R., Vernetta, M., Alvariñas, M. & López-Bedoya, J. (2017). Acute effect of acrobatic jumps on different elastic platforms in the muscle response evaluated through tensiomyography. *Journal of Human Sport & Exercise*. *12* (3), 728-741. doi:10.14198/jhse.2017.123.17

Rojas-Barrionuevo, N. R, Vernetta, M. & López-Bedoya, J. (2016). Functional assessment of muscle response in lower limbs of tumbling gymnasts through tensiomyography. *Revista de la Facultad de Medicina, 64 (3),* 505-512. *doi: http://dx.doi.org/10.15446/revfacmed.v64n3.54004.*

Simunic, B. (2003). *Model of longitudinal constractions and transverse deformations in skeletal muscles*. Doctoral Thesis. Ljubljana.

Slysz, J. T., Stultz, J., & Burr, J. F. (2016). The efficacy of blood flow restricted exercise: A systematic review & meta-analysis. *Journal of Science and Medicine in Sport, 19*(8), 669-675. doi: 10.1016/j.jsams.2015.09.005

Takarada, Y., Sato, Y. & Ishii, N. (2002). Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. *European Journal of Applied Physiology*. *86*, 308-14. doi: 10.1007/s00421-001-0561-5

Tanimoto, M., Madarame, H. & Ishii, N. (2005). Muscle oxygenation and plasma growth hormone concentration during and after resistance exercise: comparison between KAATSU and other types of regimens. *International Journal of KAATSU Training Research 1,* 51-6. doi:10.3806/ijktr.1.51

Tous-Fajardo, J., Moras, G., Rodríquez-Jimenez, S., Usach, R., Doutres, D. M., Mar-Tous-Fajardo, J., Moras, G. & Marffiuletti, N. A. (2010). Inter-rater reliability of muscle contractile property measurements using non-invasive tensiomyography. *Journal of Electromyography and Kinesiology*, 20, 761-6.doi: 10.1016/j.jelekin.2010.02.008

Villalba, F. (2022). Blood flow restriction training. *Argentinian Journal of Respiratory & Physical Therapy*, *4*(1), 52-56. doi:10.58172/ajrpt.v4i1.215

Sportis Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333




Williams, N., Russell, M., Cook, C. J., & Kilduff L. P. (2018). The effect of lower limb occlusion on recovery following sprint exercise in academy rugby players. *Journal of Science and Medical Sport 21*(10), 1095-9. doi: 10.1016/j.jsams.2018.02.012

Williams, N. (2017). The Borg Rating of Perceived Exertion (RPE) scale. *Occupational Medicine*, *67*(5), 404-405. doi:10.1093/occmed/kqx063

Wernbom, M., Augustsson, J. & Thomee, R. (2006). Effects of vascular occlusion on muscular endurance in dynamic knee extension exercise at different submaximal loads. *The Journal Strength and Conditional Research*, *20,* 372-377.doi: 10.1519/R-16884.1

Yasuda, T., Abe, T., Kurano, M., Takano, H., Meguro, K., Brechue, W.F. & Nakajima, T. (2008). Effects of low-intensity muscle contractions with blood flow restriction on venous blood gas values. *Medicine and Science in Sports and Exercise, 40*, S350.doi: 10.1016/j.metabol.2010.01.016

Yasuda, T., Fujita, Y., Miyagi, Y., Kubota, Y., Sato, Y., Nakajima, M.G., Abe, T., (2006). Electromyographic responses of arm and chest muscle during bench press exercise with and without KAATSU. *Int. J. KAATSU Training Res, 2,* 15-18.doi:10.3806/ijktr.2.15

Yasuda, T., Loenneke, J. P., Thiebaud, R. S., & Abe, T. (2012). Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength. *PLoS One*, *31*(7), e52843. doi: 10.1371/journal.pone.0052843