Physiology International 110 (2023) 1, 64–73
DOI: 10.1556/2060.2023.00153

AKADÉMIAI KIADÓ

Cuff width does not affect discomfort ratings immediately following isometric handgrip exercise

ROBERT W. SPITZ[1], JUN SEOB SONG[1], YUJIRO YAMADA[1], VICKIE WONG[1], ZACHARY W. BELL[2], RYO KATAOKA[1] and JEREMY P. LOENNEKE[1]*

[1] Department of Health, Exercise Science, and Recreation Management, Kevser Ermin Applied Physiology Laboratory, The University of Mississippi, MS, USA

[2] Department of Kinesiology and Physical Education, Exercise Metabolism and Nutrition Research Laboratory, McGill University, Montreal, Quebec, Canada

Received: September 18, 2022 • Revised manuscript received: December 2, 2022 • Accepted: January 6, 2023
Published online: February 22, 2023

ABSTRACT

Previous work has found that wide cuffs produce greater discomfort with elbow flexion exercise than narrower cuffs. It is our hypothesis that this is due to the balling up of the biceps underneath the cuff that is more pronounced with a wider cuff. One method to test this is through an upper body exercise where there is no contraction of the biceps. *Purpose:* To investigate the effects of cuff width on discomfort following isometric handgrip exercise. *Methods:* One hundred participants completed this experiment. In a randomized order, the participants performed four sets of two-minute isometric handgrip contractions with thirty seconds of rest at thirty percent of their maximal voluntary contraction with a 5 and 12 cm cuff inflated to 40% of arterial occlusion pressure. Discomfort ratings (0–100) were given after the fourth set of exercise. Average force was recorded for all four sets. *Results:* There was no difference in discomfort ($BF_{10} = 0.158$) [median difference (95% credible interval) −0.997 (−3.360, 1.283) arbitrary units], or in average force ($BF_{10} = 0.132$) [median difference (95% credible interval) 0.08 (−0.199, 0.372) kilograms], between cuff conditions. There did not appear to be a greater preference for either cuff. Forty people preferred the narrow cuff ($BF_{10} = 0.325$), forty people preferred the wide cuff ($BF_{10} = 0.325$), and twenty people had no preference ($BF_{10} = 7.719$). *Conclusion:* Cuff width does not appear to influence discomfort or the average force produced. This provides support for our hypothesis that the shape of the muscle may interact with wider cuff sizes, leading to greater discomfort.

* Corresponding author. Department of Health, Exercise Science, and Recreation Management, Kevser Ermin Applied Physiology Laboratory, The University of Mississippi, P.O. Box 1848. University, MS 38677, USA. Tel.: +(662) 915-5567, fax: +(662) 915-5525. E-mail: jploenne@olemiss.edu

KEYWORDS

perceptual response, cuff width, blood flow restriction, preference

INTRODUCTION

Low load resistance training with blood flow restriction (the reduction of arterial inflow) has been shown to induce favorable muscle [1, 2] and vascular adaptations [3, 4]. One notable limitation of this style of training is the increased feelings of discomfort [5], which may prevent some individuals from choosing or continuing to perform blood flow restricted exercise [6, 7]. Several studies have investigated the applied pressure [7–9] and cuff width [10–12] which can both augment the discomfort associated with blood flow restriction training. While lower applied pressures typically result in lower feelings of discomfort [7–9], the effect of cuff width, has not been consistent in the literature. Previously, it has been reported that wider cuffs produce greater [10], lower [13, 14], or similar ratings of discomfort [12, 15] when compared to a narrow cuff.

These inconsistent results may be related to differences in cuff material [13, 14], or how the pressure was applied [10] (i.e., relative or absolute pressures). To account for this, our laboratory investigated the effects of cuff width (5 vs 12 cm) on discomfort at rest and immediately following elbow flexion exercise to failure (at 30 percent of the concentric one-repetition maximum), using cuffs made of the same material (nylon), which were inflated to the same relative pressure (40% arterial occlusion pressure) [11]. There were no differences in discomfort between cuff sizes at rest; however, following elbow flexion exercise the narrow cuff condition had lower ratings of discomfort despite performing a greater exercise volume. This suggested that something during the exercise bout other than the work performed contributed to the difference in discomfort ratings. During contraction the biceps muscle may change shape or “ball up” under the 12 cm cuff but not the 5 cm cuff.

This “balling up” of the biceps muscle may increase the intramuscular pressure, resulting in a greater reduction in blood flow in the 12 cm cuff condition relative to 5 cm cuff condition, causing greater blood flow restriction leading to greater discomfort [7–9]. To test this hypothesis, we investigated the effects of cuff width in the lower body using a bipennate muscle (quadriceps), which would not “ball up” under the cuff. Immediately following knee extension exercise, discomfort was not different between cuff width [12]. While this seemed to support our hypothesis, one limitation of the previous study is that the majority of the sample (77/96 participants) had to use an estimated pressure during the 5 cm condition. In the group where the pressure was quantified, there was anecdotal evidence for a difference in discomfort (BF_{10} = 2.087), but this was not observed when the applied pressure was estimated (BF_{10} = 0.179).

The purpose of this study was to investigate the effects of cuff width on discomfort immediately following isometric handgrip exercise. Isometric handgrip exercise serves as a suitable model because the active muscles (i.e., forearm muscles) will not be directly under the cuff. Additionally, using the upper body will ensure that all participants will be able to have their arterial occlusion pressure directly measured.

MATERIALS AND METHODS

Participants

One hundred participants were recruited to participate in this single visit experiment. Participants were excluded if they used tobacco regularly in the last six months, had an injury preventing exercise, or if they met two or more of the following risk factors for thromboembolism: (1) body mass index ≥30; (2) diagnosis of Crohn's Disease; (3) past fracture of hip, pelvis, or femur; (4) major surgery within last 6 months; (5) varicose veins; (6) family or personal history of deep vein thrombosis; or (7) family or personal history of pulmonary embolism [16]. This study was approved by the University's Institutional Review Board (protocol number 22–024). Prior to participation, all participants provided written informed consent. Participants also completed a physical activity readiness questionnaire to ensure they were able to exercise without needing physician's clearance. All participants abstained from alcohol consumption and exercise 24 h prior to their visit. Additionally, the participants were instructed to not eat two hours and to not consume caffeine 8 h before the visit. Both trained and untrained individuals were included in this study since they were being compared to themselves (within-subject data).

Experimental design

After arriving to the laboratory, the participant completed paper work, anthropometric measurements, and a strength assessment (isometric handgrip) on both arms in a randomized order. After 10 min of supine rest, arterial occlusion pressure was determined in the supine position in the arm, with either a 5 cm or 12 cm cuff. The participant completed 4 sets of 2-min contractions at 30% of the previously determined maximal voluntary contraction with the cuff inflated to 40% of the arterial occlusion pressure. Following the fourth set of exercise the participant gave their discomfort rating, then the cuff was deflated. The participant would then rest for 10 min and arterial occlusion pressure would be measured in the other arm with the other sized cuff. After completing the second exercise condition the participant would rate their discomfort, whilst being shown how they rated the previous condition. Showing the participants their previous discomfort rating allowed the participant to anchor the second rating of discomfort to the first rating. Lastly, the participant was asked which condition (exercise with a narrow cuff or a wide cuff) they would prefer to use more (i.e., cuff preference).

Height and body mass

Following the initial paperwork, the participant's height was measured with a stadiometer (Seca, Chino, USA) to the nearest 0.1 cm and their body mass was measured with a digital scale (Seca, Chino, USA) to the nearest 0.1 kg.

Maximal voluntary contraction

The participant laid in the supine position with one arm abducted to 90°. The participant squeezed a digital grip strength dynamometer (TKK 1268, Takei Scientific Instruments Co., Ltd., Niigata, Japan) for 5 s 3 times. After the third attempt the participant would repeat this same procedure using the other arm. One and a half minutes of rest were allowed between attempts. The load was recorded to the nearest 0.1 kg. The highest values were recorded and use to set the load for the exercise protocol. Visual feedback and verbal encouragement were provided to the participant.

Arterial occlusion pressure determination

In a randomized order, arterial occlusion pressure was measured in one arm with a 5 cm nylon cuff (Hokanson, Bellevue, WA) and with a 12 cm nylon cuff (Hokanson, Bellevue, WA) in the other arm. The cuff would be placed on the most proximal portion of the participants' arm. The participant then rested for ten minutes in the supine position before arterial occlusion pressure was determined. Arterial occlusion pressure was determined by placing a Doppler probe (MD6, Hokanson, Bellevue, WA) at the radial artery so that it emitted an auditory signal. The pressure was then increased by an E20 rapid cuff inflator (Hokanson, Bellevue, WA) until the auditory signal was no longer detected. The lowest pressure at which the auditory signal was no longer heard was determined to be the arterial occlusion pressure. After the participant performed the first experimental exercise condition, the other cuff (i.e., with the cuff not used in the first assessment) would be placed on the arm that did not exercise. Following another 10 min of rest, arterial occasion pressure was determined in the other arm. A single investigator measured approximately 90% of the sample with the other 10% being measured by two equally skilled technicians. However, all conditions within a single person were determined by a single investigator.

Exercise intervention

In a randomized and counter balanced order the participants completed four sets of two-minute isometric handgrip contractions with 30 s of rest at 30% of their predetermined maximal voluntary contraction [17]. The same handgrip dynamometer was used for both the maximal voluntary contraction testing and for the exercise intervention. A digital screen was placed over the participants head to allow for visual feedback of their force production. Force production was recorded every 15 s during the two-minute contractions. The average of these eight measurements was used to calculate average force for the set. The average force for the cuff condition was determined as the average of the four sets.

Discomfort scale

The instructions for the discomfort scale were read to the participant prior to each of the experimental exercise conditions. The participants were asked to "anchor" their second rating of discomfort to their first. The participants' first rating of discomfort was presented on a hand-held white board to ensure the participant could anchor their second rating of discomfort. As a way to standardize the instructions one investigator would read the following script: "The scale begins at 0 which is described as no perceivable discomfort. This can be likened to a perception of discomfort at a time where you feel no noticeable sensations relating to physical activity. The scale ends at 100 which is described as the maximal perceivable discomfort. This can be likened to a perception of discomfort at a time where you could not imagine the sensations relating to physical activity being any more intense" [18]. All participants confirmed that they understood the scale before beginning the exercise condition.

Condition preference

After completing the second exercise condition the participants were asked to read a sign that said; "Of the two conditions completed today which would you prefer to use more?" Participants could choose either the first, the second, or no difference [11, 12].

Statistics

All data was analyzed using JASP (Version 0.16.2, Netherlands) and in RStudio version 2022.2.2.485 (https://www.r-project.org/) using the Bayes Factor package (0.9.12-4.3). Bayesian paired samples *t*-tests were performed to assess differences in discomfort and in average force between cuff sizes. Uninformed priors of 0.707 (Cauchy distribution, centered on zero) were used for all paired samples *t*-tests [19]. To assess cuff preference, a Bayesian binomial test with a test value of 0.333 with uniformed priors for each parameter was used as a follow up test. Bayes factors (BF_{10}) were used to provide evidence for ($BF_{10} \leq 0.33$) or against the null ($BF_{10} \geq 0.33$). Briefly, A BF_{10} of "3" means that the observed data are 3 times more likely under the alternative than the null hypothesis. Likewise, a BF_{10} of 0.33 means that the observed data are 3 times more likely under the null than the alternative hypothesis. Data are presented as mean (SD) except for the posterior distribution which is represented as the median (95% credible interval).

RESULTS

Participants

One hundred participants completed this experiment [mean age = 22 (SD 3) years, height = 171.2 (SD 7.18) centimeters, body mass = 73.7 (SD 15.7) kilograms]. There were 50 males and 50 females completed in this study. Fourteen percent of the participants were left-handed.

Arterial occlusion pressure

The average arterial occlusion pressure was 157 (SD 22) mmHg for the 5 cm cuff and 121 (SD 11) mmHg for the 12 cm cuff. The average applied pressure was 61 (SD 10) mmHg for the 5 cm cuff and 48 (SD 4) mmHg for the 12 cm cuff.

Discomfort

There was no difference in discomfort between cuff conditions ($BF_{10} = 0.158$) [median difference δ (95% credible interval) -0.083 (-0.276, 0.110)]. The unstandardized mean discomfort ratings for each condition and the median difference in discomfort is shown in Fig. 1.

Preference

When the proportions were tested against a value of 0.333, there did not a appear to be greater a preference for either cuff. Forty people preferred the narrow cuff ($BF_{10} = 0.325$), forty people preferred the wide cuff ($BF_{10} = 0.325$), and twenty people had no preference ($BF_{10} = 7.719$). While the majority of participants had a preference for a specific condition, this did not differ between cuffs. The distribution is shown in Fig. 2.

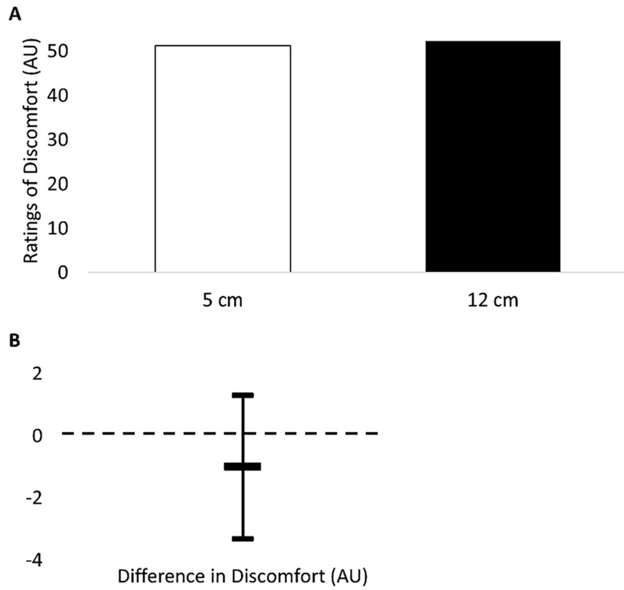

Fig. 1. The effect of cuff width on ratings of perceived discomfort
A: The average ratings of discomfort in the narrow (white) and wide (black) cuffs B: The median difference in discomfort ratings between cuff widths surrounded by the 95% credible interval.

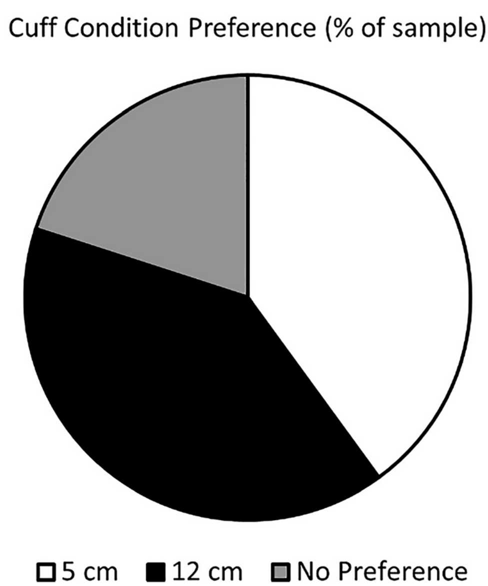

Fig. 2. Cuff preference for both conditions shown as a percent of the total sample preferring to exercise with the narrow cuff (white), the wide cuff (black), or no preference (grey)

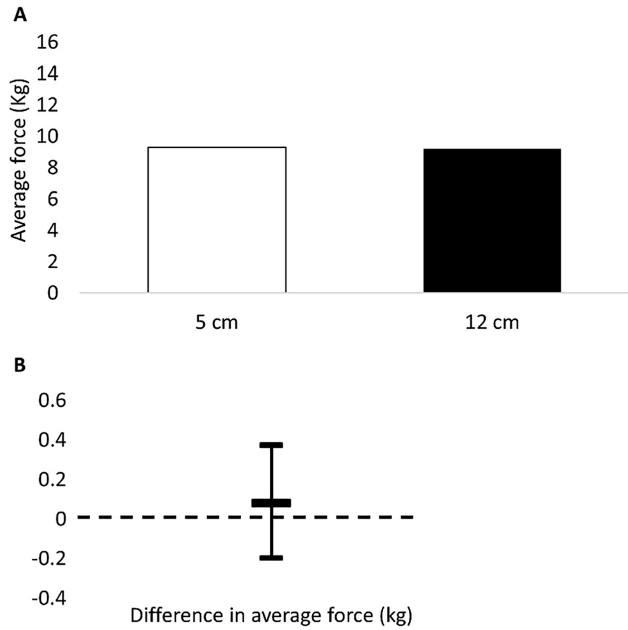

Fig. 3. The effect of cuff width on average force
A: The average force in the narrow (white) and wide (black) cuffs B: The median difference in average force between cuff widths surrounded by the 95% credible interval.

Force

There was no difference in average force between cuff conditions (BF_{10} = 0.132) [median difference δ (95% credible interval) 0.058 (−0.134, 0.251)]. The unstandardized mean force for each condition and the median difference in force is shown in Fig. 3.

DISCUSSION

In line with our hypothesis, when blood flow restriction was combined with an exercise that did not directly target a muscle under the cuff, there were no differences in discomfort. Additionally, the average force across sets was not different between a wide and narrow cuff. This provided suggestive evidence that the wider cuff was not producing greater reductions in blood flow than the narrower cuff.

Some degree of context is required in order to discuss the impact of cuff width on discomfort. Early work found that wider cuffs may produce greater feelings of discomfort than narrower cuffs [10]. However, a limitation of that study was that the applied pressure was not made relative to the cuff. In other words, both cuff conditions exercised at the same absolute pressure meaning that the wider cuff was reducing more blood flow [20]. To address this, we had individuals perform elbow flexion exercise in the upper body with a wide cuff or a narrow cuff inflated to the same relative pressure (40% of the pressure required to cut off blood flow with each respective cuff) [11]. It was thought that this would produce similar ratings of discomfort, however, that is not what we found. We found that wider cuffs produced greater feelings of discomfort, even though they did less overall work (repetitions to failure). Interestingly, we only found this effect of cuff width when combined with exercise. There was no impact of cuff width on discomfort when the cuffs were inflated in the absence of exercise. We hypothesized that the balling up of the biceps muscle underneath the wider cuff may reduce blood flow which would explain both greater discomfort and the reduction in total exercise volume [11]. We attempted to test this using the knee extension exercise because the pennate shape of the quadriceps muscles does not ball up underneath the cuff like the biceps brachii [12]. In line with that idea, there were no differences in discomfort between the two cuff widths. However, due to limitations of the equipment (maximum pressure of 300 mmHg), the applied pressure had to be estimated for the majority of participants in the 5 cm cuff condition. In other words, this study ended up having the same limitation as the Rossow et al. study [10].

The aforementioned work led us to the present study design where we used an exercise that involved musculature not directly under the blood flow restriction cuff. With this approach, we controlled for the balling up effect and the relative applied pressure (% arterial occlusion pressure). When this was done, we found no differences in discomfort or exercise volume between the two cuff widths. When the tissue underneath the cuff is not contracting [20], it is possible that the amount of blood flow restricted is similar between a 5 and 12 cm cuff when each are inflated to the same percentage of the arterial occlusion pressure. This suggested that the greater discomfort and lower number of repetitions we previously observed in the upper body with the wider cuff was due to the interaction between cuff width and the muscle underneath the cuff [11]. Taken together, we hypothesize that wider cuffs do not inherently cause more discomfort or decrease exercise volume; but rather it is the combination of the wider cuff interfering with the biceps muscle.

Although ratings of discomfort are important, it is also useful to know which cuff width the participants preferred to use. Previous studies [11, 12] have suggested there is a greater preference for narrow cuffs compared to wide cuffs. Interestingly this seemed to be independent of the discomfort rating. There is some evidence that exercise performance may be positively related to exercise enjoyment, which could affect preference [21]. The results of previous studies support this hypothesis, where the 5 cm conditions performed greater exercise volumes and were also preferred more by the participants [11, 12]. There were no differences in exercise volume in the present study between cuff widths. Further, although the majority of the sample had a preference there was not a greater preference for either cuff. The reason for this cuff preference is not known from the present study.

Our study is not without limitations. In the current investigation we used isometric exercise; however, previous studies used isotonic exercise [11, 12]. Nonetheless, because the active tissue was not in contact with the cuff, we feel that our results would be similar had we done isotonic forearm exercise. A second limitation is that we did not ask the participants why they had a particular preference. This makes it difficult to determine if exercise volume or discomfort was a factor.

In conclusion, when performing an exercise that removes the balling up effect, cuff width does not appear to influence discomfort or the total amount of work performed. This provides support for our hypothesis that the shape of the muscle may interact with wider cuff sizes, leading to greater discomfort in the elbow flexion exercise. Furthermore, there does not appear to be a greater preference for either cuff following isometric exercise. Our results suggest that wider cuffs do not inherently cause greater discomfort.

ACKNOWLEDGEMENTS

No sources of funding were used to assist in the preparation of this article. Authors declare that they have no conflicts of interest relevant to the content of this review.

REFERENCES

1. Jessee MB, Buckner SL, Mouser JG, Mattocks KT, Dankel SJ, Abe T, et al. Muscle adaptations to high-load training and very low-load training with and without blood flow restriction. Front Physiol 2018; 9: 1448. https://doi.org/10.3389/fphys.2018.01448.
2. Nielsen JL, Aagaard P, Bech RD, Nygaard T, Hvid LG, Wernbom M, et al. Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. J Physiol 2012; 590(17): 4351–61. https://doi.org/10.1113/jphysiol.2012.237008.
3. Hunt JE, Galea D, Tufft G, Bunce D, Ferguson RA. Time course of regional vascular adaptations to low load resistance training with blood flow restriction. J Appl Physiol (1985) 2013; 115(3): 403–11. https://doi.org/10.1152/japplphysiol.00040.2013.
4. Mouser JG, Mattocks KT, Buckner SL, Dankel SJ, Jessee MB, Bell ZW, et al. High-pressure blood flow restriction with very low load resistance training results in peripheral vascular adaptations similar to heavy resistance training. Physiol Meas 2019; 40(3): 035003. https://doi.org/10.1088/1361-6579/ab0d2a.
5. Spitz RW, Wong V, Bell ZW, Viana RB, Chatakondi RN, Abe T, et al. Blood flow restricted exercise and discomfort: a review. J Strength Cond Res 2022; 36(3): 871–9. https://doi.org/10.1519/JSC.0000000000003525.
6. Wernbom M, Augustsson J, Thomee R. Effects of vascular occlusion on muscular endurance in dynamic knee extension exercise at different submaximal loads. J Strength Cond Res 2006; 20(2): 372–7. https://doi.org/10.1519/R-16884.1.
7. Mattocks KT, Jessee MB, Counts BR, Buckner SL, Grant Mouser J, Dankel SJ, et al. The effects of upper body exercise across different levels of blood flow restriction on arterial occlusion pressure and perceptual responses. Physiol Behav 2017; 171: 181–6. https://doi.org/10.1016/j.physbeh.2017.01.015.
8. Loenneke JP, Kim D, Mouser JG, Allen KM, Thiebaud RS, Abe T, et al. Are there perceptual differences to varying levels of blood flow restriction? Physiol Behav 2016; 157: 277–80. https://doi.org/10.1016/j.physbeh.2016.02.022.
9. Soligon SD, Lixandrao ME, Biazon T, Angleri V, Roschel H, Libardi CA. Lower occlusion pressure during resistance exercise with blood-flow restriction promotes lower pain and perception of exercise compared to higher occlusion pressure when the total training volume is equalized. Physiol Int 2018; 105(3): 276–84. https://doi.org/10.1556/2060.105.2018.3.18.
10. Rossow LM, Fahs CA, Loenneke JP, Thiebaud RS, Sherk VD, Abe T, et al. Cardiovascular and perceptual responses to blood-flow-restricted resistance exercise with differing restrictive cuffs. Clin Physiol Funct Imag 2012; 32(5): 331–7. https://doi.org/10.1111/j.1475-097X.2012.01131.x.
11. Spitz RW, Chatakondi RN, Bell ZW, Wong V, Dankel SJ, Abe T, et al. The impact of cuff width and biological sex on cuff preference and the perceived discomfort to blood-flow-restricted arm exercise. Physiol Meas 2019; 40(5): 055001. https://doi.org/10.1088/1361-6579/ab1787.

12. Spitz RW, Chatakondi RN, Bell ZW, Wong V, Viana RB, Dankel SJ, et al. Blood flow restriction exercise: effects of sex, cuff width, and cuff pressure on perceived lower body discomfort. Percept Mot Skills 2021; 128(1): 353–74. https://doi.org/10.1177/0031512520948295.
13. Dankel SJ, Buckner SL, Counts BR, Jessee MB, Mouser JG, Mattocks KT, et al. The acute muscular response to two distinct blood flow restriction protocols. Physiol Int 2017; 104(1): 64–76. https://doi.org/10.1556/2060.104.2017.1.1.
14. Buckner SL, Dankel SJ, Counts BR, Jessee MB, Mouser JG, Mattocks KT, et al. Influence of cuff material on blood flow restriction stimulus in the upper body. J Physiol Sci 2017; 67(1): 207–15. https://doi.org/10.1007/s12576-016-0457-0.
15. Laurentino GC, Loenneke JP, Teixeira EL, Nakajima E, Iared W, Tricoli V. The effect of cuff width on muscle adaptations after blood flow restriction training. Med Sci Sports Exerc 2016; 48(5): 920–5. https://doi.org/10.1249/MSS.0000000000000833.
16. Motykie GD, Zebala LP, Caprini JA, Lee CE, Arcelus JI, Reyna J, et al. A guide to venous thromboembolism risk factor assessment. J Thromb Thrombolysis 2000; 9(3): 253–62. https://doi.org/10.1023/a:1018770712660.
17. Song JS, Yamada Y, Wong V, Bell ZW, Spitz RW, Abe T, et al. Hypoalgesia following isometric handgrip exercise with and without blood flow restriction is not mediated by discomfort nor changes in systolic blood pressure. J Sports Sci 2022; 40(5): 518–26. https://doi.org/10.1080/02640414.2021.2003569.
18. Steele J, Fisher J, McKinnon S, McKinnon P. Differentiation between perceived effort and discomfort during resistance training in older adults: reliability of trainee ratings of effort and discomfort, and reliability and validity of trainer ratings of trainee effort. J Trainology 2016; 6(1): 1–8. https://doi.org/10.17338/trainology.6.1_1.
19. Wagenmakers EJ, Love J, Marsman M, Jamil T, Ly A, Verhagen J, et al. Bayesian inference for psychology. Part II: example applications with JASP. Psychon Bull Rev 2018; 25(1): 58–76. https://doi.org/10.3758/s13423-017-1323-7.
20. Mouser JG, Dankel SJ, Jessee MB, Mattocks KT, Buckner SL, Counts BR, et al. A tale of three cuffs: the hemodynamics of blood flow restriction. Eur J Appl Physiol 2017; 117(7): 1493–9. https://doi.org/10.1007/s00421-017-3644-7.
21. Box AG, North JR, Whitney AJ, Newton EP, Feito Y, Petruzzello SJ. Preference and tolerance for high-intensity exercise performance and enjoyment. Int J Sport Exerc Psychol 2022: 1–11. https://doi.org/10.1080/1612197X.2022.2057568.