

Activation of triceps Surae during exercises on leg press, Smith and seated calf raise machines

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Abstract

Background: Triceps surae muscle activation and subsequently mechanical stimuli might be affected by the manipulation and combination of resistance training variables such as load, change the position of the feet, rest between sets and exercise selection. **Purpose.** The aim of the present study was to determine the activity of the soleus (SOL), medial (MG) and lateral (LG) gastrocnemius muscles during exercises performed with different equipment and foot positions. **Materials and methods.** Fifteen males physically independent adults aged ≥ 18 years participated these cross-sectional study. electromyographic activity of the SOL, MG and LG muscles was collected during the heel-raise movement, considering 50% of the load used in 10 maximum repetitions (MR) on the leg press, Smith and seated calf raise equipment (the loads used were specific to each equipment). For each device, three readings of five repetitions. **Results.** Two-way analysis of variance revealed a significant difference in the activity of the SOL, MG and LG muscles among the types of equipment ($F = 11.55$, $P < 0.001$; $\eta_p^2 = 0.20$). However, foot position exerted no influence on muscle activation ($F = 0.21$, $P = 0.97$; $\eta_p^2 = 0.005$). **Conclusions.** the heel raises exercises performed with 50% MR on the Smith machine led to a significantly greater increase in the activity of the MG and LG muscles in comparison to the leg press and seated calf raise equipment. The activity of the SOL, MG and LG muscles was not influenced by the position of the feet during the exercises performed on the three different types of equipment.

Key words: Gastrocnemius, Soleus, Resistance training, Electromyography.

Introduction

The triceps surae (TS) muscles are formed by the soleus (SOL), medial (MG) and lateral (LG) gastrocnemius muscles and receive considerable attention by practitioners of different sport modalities, such as running (Masumoto et al., 2018; Morley and Traum, 2018), jumping (Fatouros et al., 2000), bodybuilders (Marcori et al., 2017) and resistance training practitioners (Rosenberger et al., 2017). Plantar flexion exercises are the most widely used to increase the size, strength and power of these muscles (Kawakami et al., 2000; Mikkola et al., 2007).

However, it is important to consider that mechanical stimuli and subsequently muscle activation might be affected by the manipulation and combination of resistance training variables such as exercise selection (Gentil et al., 2017), load (Jenkins et al., 2015) and rest between sets (Miranda et al., 2018). In addition, the anatomic position and function of each muscle that makes up the TS are important factors to consider during the training of these muscles (Kawakami et al., 1998).

The insertion of the MG and LG muscles is in the femoral condyles and these muscles have the function of both knee flexion and plantar flexion of the ankle. The insertion of the SOL is in the posterior face of the tibia and head of the fibula and this muscle only contributes to plantar flexion of the ankle (Elias et al., 2003). Moreover, functional magnetic resonance imaging has revealed that the individual TS muscles play different functional roles during contraction (Kinugasa et al., 2005). These morpho-functional differences justify the need to use different trainings strategies for this muscle group, such as plantar flexion with the knee in complete extension (Marcori et al., 2017; Signorile et al., 2002) or near 180° to 90° of flexion (Kinugasa et al., 2005; Signorile et al., 2002).

Changing the position of the feet during TS training has also been demonstrated to be an important factor. Studies suggest that the activity of the gastrocnemius muscles is influenced by changes in foot position (Marcori et al., 2017; Riemann et al., 2011) and a smaller or larger angle of the knee (Tamaki et al., 1997). In tests conducted with body weight, extended knees, in the upright position and with maximum range of motion for the ankle joint, significant differences have been described for the activity of the gastrocnemius when the tests are performed with different foot positions: forward, inward and outward (Marcori et al., 2017). However, the load used during the tests in these studies were close to body weight, which does not reflect the demands of training when higher loads are normally used. Moreover, another study found no influence of foot position on the activity of the TS muscles during tests with five repetitions during heel raise exercises using the maximal load that enabled 10 repetitions (Pereira et al., 2017).

The results of the studies cited may be an indication that this muscle group produces different activations when exposed to different loads. Moreover, it is possible that the same effect may be found when TS training is performed with different types of equipment, such as a leg press machine (Pereira et al., 2017), Smith machine (Nilsen et al., 2015) and seated calf raise machine (Debenham et al., 2017; Echtes et al., 2018). Such knowledge can assist in the periodization strategies for the training of these muscles, as many professionals have used different types of equipment and foot positions in their training approach (Marcori et al., 2017; Pereira et al., 2017; Riemann et al., 2011). Therefore, an investigation on the electromyographic activity (EMG) of the TS muscles observed in different exercises and with the manipulation of the foot position, can contribute to a better understanding of these observations. In addition, it is important to highlight that strengthening the TS muscles might have important applications in rehabilitation of people with stroke (Park et al., 2020), to management of Achilles tendinopathy (Malliaras, 2022), to decrease the risk of falls in community-dwelling older adults [Maritz et al., 2016].

In the present study, we test the hypothesis that the activity of the TS muscles differs when exercises are performed on the leg press, Smith and seated calf raise machines and that the position of the feet exerts an influence on the activity of these muscles in different ways among these types of equipment. Thus, the aim of the present study was to analyze the electromyographic (EMG) activity of the SOL, MG and LG muscles on different machines (leg press, Smith and seated calf raise) with different foot positions (forward, inward and outward).

Methods

Participants

This cross-sectional study was conducted at the Center for Research in Movement Analysis (NAPAM) of Nove de Julho University (Uninove) in São Paulo, Brazil and was approved by the Local Ethics and Research Committee (certificate number: 2.100.780) and all participants were informed about the procedures of the study and signed the Informed Consent Term.

A convenience sample of 15 young men (age: 26.8 ± 5 years; weight 77.6 ± 10.8 Kg; height: 172.6 ± 6.3 cm) were recruited from the local community through verbal invitations. All were physical active, as determined by the Short Form International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003), trained the lower limbs two or more times per week for at least the previous six months (Haskell et al., 2007) and had no musculoskeletal disorders of the lower limbs or cognitive impairment.

Electromyography

The EMG signals of the SOL, MG and LG muscles were recorded using a 16-channel acquisition system (bandpass filter: 20 to 500 Hz; amplifier gain of 1000 times; common rejection mode ratio < 120 dB) (EMG System Ltda ®), with a sampling frequency of 2000 Hz and digitalized using analog-digital (A/D) conversion plates with 16-bit resolution. Muscle activity was detected using disposable, self-adhesive, differential, bipolar, Ag/AgCl surface electrodes measuring 1 cm in diameter (MediTrace, Kendall Healthcare), with a center-to-center inter-electrode distance of 2 cm. Surface electrodes were positioned according SENIAM recommendations (Hermens et al., 2000).

Procedures

The sequence of experimental events is summarized in Figure 1. Two tests were conducted in two previously scheduled sessions. The first session involved the collection of the anthropometric data (weight and height) and the administration of the IPAQ. Individuals who met the inclusion criteria performed the 10-maximum repetition (MR) test for each machine (leg press, Smith and seated calf raise) to establish the load to be used during the data collection. For the tests, the feet were in the neutral position and a five-minute rest period was given between collections to enable recovery (Anderson and Kearney, 1982; Dankel et al., 2017). The order of the equipment was randomized using opaque envelopes.

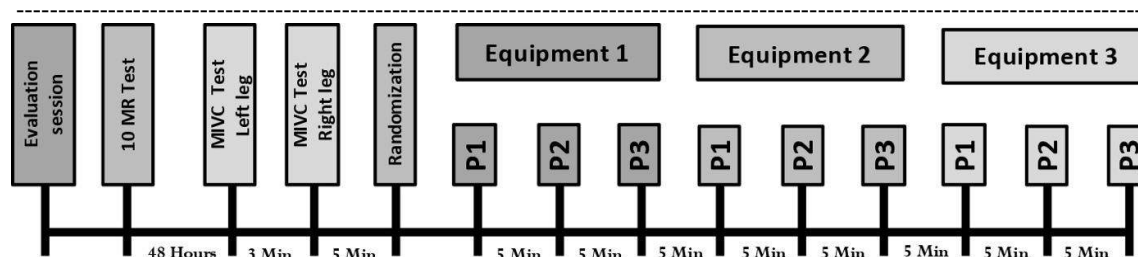


Figure.1 Flow sequence diagram of data recording. MR: maximum repetition. MIVC: maximum isometric voluntary contraction. P1, P2, P3: foot positions. MIVC (3 times), Left leg, Right leg.

The second session was scheduled after a 72-hour interval, during which the participants were instructed to practice physical exercises. The tests started with a warm-up exercise performed on a treadmill for 10 min at 1.5 m/s. After a two-minute rest interval, the participants were placed in a ventral decubitus position on an examining table with the lower limbs bare. The skin was cleaned with 70% alcohol and disposable electrodes were attached for the collection of the EMG signals (Figure 2-A). Each individual initially performed three maximal isometric voluntary contractions (MIVC) of the TS muscles. On this test, a 5-cm strap was positioned in the region of the metatarsals and attached to the base of the examining table (Figure 2-B). Once duly positioned, the participants were instructed to perform plantar flexion of the feet with maximum force for five seconds. This procedure was performed three times on each leg with a three-minute rest period between repetitions.

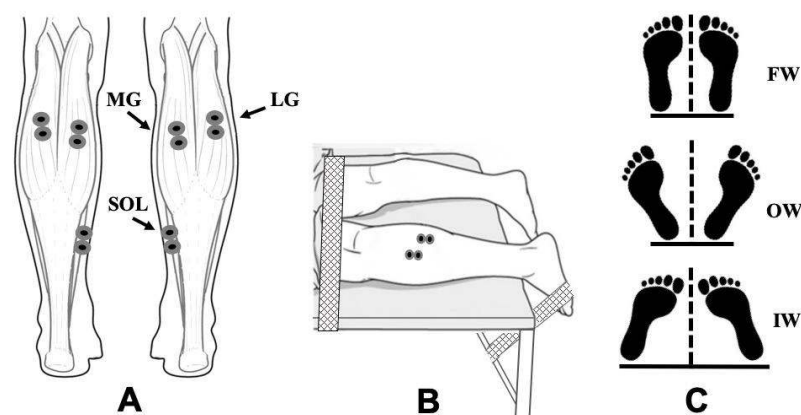


Figure 2. A: Positions of surface electrodes in the soleus (SOL), medial (MG) and lateral (LG) gastrocnemius muscles to collect the electromyographic signal. B: Maximal isometric voluntary contractions test position. C: Representation of the foot positions. The schematic illustration depicts the three configurations of the foot position used in the experimental design: forward (FW), outward (OW) and inward (IW).

The experimental tests began after a five-minute rest period following the last MIVC reading. The order of the equipment and positioning of the feet were randomized using opaque envelopes containing cards with letters to determine the equipment (A: leg press; B: Smith machine; C: seated calf raise) and numbers indicating the position of the feet during the reading (1: forward; 2: outward; 3: inward).

The tests were performed with 50% of the load used in the 10 RM test (50% RM) for each machine (the loads used were specific to each equipment).

The pace of the plantar flexion/extension movements during the trials was determined by a metronome adjusted to 40 beats per minute. Each participant performed three sets of exercises with five plantar flexions in the different foot positions: forward (0°), outward (45°) and inward (45°) (Figure 3-C). A five-minute rest period was given between trials.

In the three-foot positions used on the leg press machine, it was necessary to flex the knees up to 20° to enable greater comfort and avoid excessive load on the joint. On the seated calf raise machine, the kneed remained flexed at 90° in all positions. On the Smith machine, the knees remained extended at 0° in the forward foot positions, but flexion up to 20° was needed in the inward and outward positions. The semi-flexion of the knees was used so that the movements could be performed with greater efficiency and comfort, thereby reducing the possibility of injury.

Data processing

The EMG signals were analyzed offline using specific routines in the Matlab program (version R2016b; The MathWorks Inc., Natick, MA, USA). The amplitude of EMG signal was defined as the root mean square (RMS) of the signal calculated for each test. The RMS under each condition was normalized by the highest MIVC value ($\mu V/\mu V \times 100\%$ MIVC) and expressed as the percentage of MIVC. The mean normalized RMS obtained on the three tests was used to compare the influence of foot position on the activity of each muscle (SOL, MG and LG) on each machine (leg press, Smith and seated calf raise).

Statistical analysis

The statistical procedures were performed with the aid of SPSS version 20.0 (SPSS Inc.). The Shapiro-Wilk test demonstrated that the data were normally distributed. Mean, standard deviation values were calculated for the EMG data. Two-way analysis of variance (ANOVA) was used to analyze the influence of equipment (Leg press vs. Smith vs. Seated calf raise) and foot position (forward vs. inward vs. outward) on the muscle activity. The post hoc Bonferroni test used to verify differences in muscle activity between equipment and foot positions. Partial eta squared (η^2) was used to calculate the effect size (Lakens, 2013). The interpretation was based on the values established by Cohen (1998): small effect (less than: $\eta^2 = 0.01$), moderate effect (approximately: $\eta^2 = 0.06$) and large effect (greater than: $\eta^2 = 0.14$). For all analyses, a value of $p < 0.05$ was considered indicative of statistical significance.

Results

Figure 3 displays the mean and standard deviation values of the amplitude of the EMG signals of SOL, MG and LG muscle activity recorded during the use of the leg press, Smith and seated calf raise machines with the different foot positions (forward, inward and outward).

No significant interaction (foot position vs. group) was identified ($F = 0.02$, $P = 0.97$; $\eta^2 = 0.001$; ANOVA test) for SOL, MG or LG muscle activity. However, the type of equipment used for the exercise exerted a significant influence on the activity of these muscles ($F = 11.55$, $P < 0.001$; $\eta^2 = 0.20$; ANOVA). EMG activity of the MG and LG muscles recorded on Smith machine was significantly higher in comparison to activity recorded on the seated calf raise machine (post hoc test). Activity of the MG muscle was also significantly higher on the Smith machine compared to activity on the leg press machine.

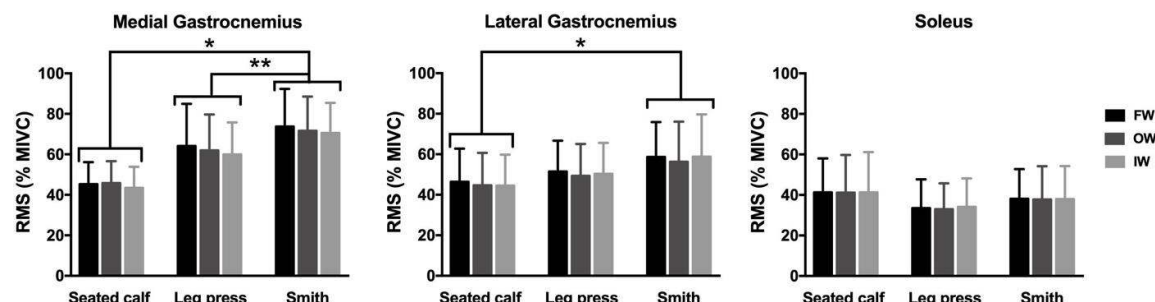


Figure 3. Mean and standard deviation of normalized amplitude (RMS) of EMG signal (% MIVC: maximum isometric voluntary contraction) of the soleus, medial and lateral gastrocnemius muscles recorded on three different types of equipment (leg press, Smith and seated calf raise machines) with three different foot positions: forward (FW), outward (OW) and inward (IW). * Significant difference among types of equipment (ANOVA Bonferroni *post hoc* test).

Discussion

The present study confirmed the hypothesis that activity of the TS muscles differs when exercises are performed on different machines (leg press, Smith and seated calf raise). In contrast, the positioning of the feet (forward, inward or outward) exerted no influence on the activity of these muscles.

The literature offers divergent data on the activity of the TS muscles with different foot positions. In texts involving plantar flexion exercises with the knees extended in the upright position that only used body weight as the load, the position of the feet exerted a significant difference on the activity of the TS muscles independently of the concentric and eccentric phase of the contraction (Marcori et al., 2017; Riemann et al., 2011).

In other studies, however, no significant change in the EMG signal of the LG and MG was found with different positioning of the feet during a plantar flexion exercise on the leg press equipment (Pereira et al., 2017) or on tests performed with and without body weight support (Cibulka et al., 2017).

A possible explanation for these divergent results may reside in differences among the experimental protocols. Indeed, it has been demonstrated that an increase in load during the contraction of the LG and MG diminishes the EMG activity in both muscles, suggesting different recruitment patterns (Fiebert et al., 2000). These data suggest that possible differences in the activation patterns of the LG and MG muscles are directly related to the amount of load imposed on the muscle during contraction.

This may be important information to the rehabilitation following the injury of these muscles, which often depend on concentrating the exercise on a specific TS muscle and with load limitation during the treatment process. However, when the objective is muscle hypertrophy, the findings of the present investigation and previous studies indicate that exercises performed with the feet in the forward position on the equipment used in this study promote a similar level of muscle activity between the LG and MG (Cibulka et al., 2017; Fiebert et al., 2000; Pereira et al., 2017).

Foot position exerted no significant influence on the activity of the SOL muscle when using the leg press, Smith and seated calf raise machines. This result is in agreement with data from a previous study involving the Smith machine (Pereira et al., 2017).

In the comparison of the different types of equipment, EMG activity of the MG and LG muscles recorded on the Smith machine was significantly higher in comparison to activity recorded on the seated calf raise machine and activity of the MG muscle was also significantly higher on the Smith machine compared to activity on the leg press machine. In contrast, no significant difference among the three types of equipment was found with regard to the activity of the SOL muscle.

Although the prediction of muscle strength based on EMG signals is limited (Disselhorst-Klug et al., 2009; Vigotsky et al., 2017), the increase in the amplitude of these signals may reflect a greater load on the muscles analyzed. Thus, the present results indicate that exercises for the TS performed on the Smith machine may be more efficient in terms of muscle hypertrophy compared to exercises performed on the leg press and seated calf raise equipment. However, this observation should be interpreted with caution. Although the increase in the amplitude of the EMG signal adequately represents an increase in muscle strength, other factors, such as muscle length, type of contraction (isometric or isotonic) and contraction velocity, also exert an influence on the results (Vigotsky et al., 2017).

The present results suggest that during strength training of the TS when using the Smith, leg press and seated calf raise machines, the feet should be positioned to provide maximum comfort and safety, as different foot positions exert no significant influence on the activity of these muscles. Although the present findings do not enable us to state that the significant increase in activity of the LG and MG muscles found during the exercise on the Smith machine can necessarily be translated into an increase in strength, this effect can be considered an objective way to select exercises for the gastrocnemius muscles.

Conclusions

This study showed that the heel raises exercises performed considering 50% of the load used in 10 maximum repetitions on the Smith machine lead to a significant increase in the activity of the lateral and medial gastrocnemius muscles when compared to exercises performed on the leg press and seated calf raise equipment. In contrast, no difference in activity of the soleus muscle was found among the exercises performed on the three different types of training equipment (Smith, leg press and seated calf raise machines).

The activity of the triceps surae muscles was not influenced by changes in foot position (forward, inward and outward) during the exercises performed on these three types of equipment. In practice, these results indicate that the Smith machine is best recommended to promote activation of the lateral and medial gastrocnemius muscles in relation to the exercises performed on leg press and seated calf raise machines. Considering that the position of the feet does not influence the activity of the plantar flexor muscles, the feet should be positioned to provide maximum comfort and safety during exercise.

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Supporting agencies

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Disclosure statement

No potential conflict of interest was reported by the authors

References

- Anderson, T., & Kearney, J.T. (1982). Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Research Quarterly for Exercise and Sport*, 53:1, 1-7.
- Cibulka, M., Wenthe, A., Boyle, Z., Callier, D., Schwerdt, A., Jarman, D., & Strube, M.J. (2017). Variation in medial and lateral gastrocnemius muscle activity with foot position. *International Journal Sports Physical Therapy*, 12, 233–241.
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*, 2 edition. ed. Routledge, Hillsdale, N.J.
- Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, 35, 1381–1395.
- Dankel, S.J., Counts, B.R., Barnett, B.E., Buckner, S.L., Abe, T., & Loenneke, J.P. (2017). Muscle adaptations following 21 consecutive days of strength test familiarization compared with traditional training. *Muscle and Nerve*, 56, 307–314.
- Debenham, J.R., Gibson, W.I., Travers, M.J., Campbell, A.C., & Allison, G.T. (2017). Modulation of stretch-shortening-cycle behavior with eccentric loading of triceps surae: a possible therapeutic mechanism. *Journal Sports and Rehabilitation*, 26, 151–158.
- Disselhorst-Klug, C., Schmitz-Rode, T., & Rau, G. (2009). Surface electromyography and muscle force: limits in sEMG-force relationship and new approaches for applications. *Clinical Biomechanics*, 24, 225–235.
- Ebben, W.P. (2009). Hamstring activation during lower body resistance training exercises. *International Journal Sports Physiology and Performance*, 4, 84–96.
- Eches, E.H.P., Ribeiro, A.S., Gerage, A.M., Tomeleri, C.M., Souza, M.F., Nascimento, M.A., Cavalcante, E.F., Schiavoni, D., Christofaro, D.G.D., Gurjão, A.L.D., Mayhew, J.L., Cyrino, E.S., Eches, E.H.P., Ribeiro, A.S., Gerage, A.M., Tomeleri, C.M., Souza, M.F., Nascimento, M.A., Cavalcante, E.F., Schiavoni, D., Christofaro, D.G.D., Gurjão, A.L.D., Mayhew, J.L., & Cyrino, E.S. (2018). Twenty minutes of post-exercise hypotension are enough to predict chronic blood pressure reduction induced by resistance training in older women. *Motriz*, 24(1), e1018142
- Elias, J.J., Faust, A.F., Chu, Y.-H., Chao, E.Y., & Cosgarea, A.J. (2003). The soleus muscle acts as an agonist for the anterior cruciate ligament. An in vitro experimental study. *American Journal Sports and Medicine*, 31, 241–246.
- Fatourous, I.G., Jamurtas, A.Z., Leontsini, D., Taxildaris, K., Aggelousis, N., Kostopoulos, N., & Buckenmeyer, P. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. *Journal Strengthening and Conditioning Research*, 14, 470.
- Fiebert, I.M., Spielholz, N.I., Applegate, B., Crabtree, F.G., Martin, L.A., Katherine L., & Parker, I. (2000). A comparison of iEMG activity between the medial and lateral heads of the gastrocnemius muscle during partial weight bearing plantarflexion contractions at varying loads. *Isokinetic and Exercise Science*, 8, 65–72.
- Gentil, P.; Fisher, J.; & Steele, J. A. (2017). Review of the acute effects and long-term adaptations of single- and multi-joint exercises during resistance training. *Sports and Medicine*, 47, 843–855.
- Haskell, W.L., Lee, I.-M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D., & Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, 39, 1423–1434.
- Hermens, H.J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *J. Electromyogr. Kinesiol. Off. International Society of Electrophysiology and Kinesiology*, 10, 361–374.
- Jenkins, N.D.M.; Housh, T.J.; Bergstrom, H.C.; Cochrane, K.C.; Hill, E.C.; Smith, C.M.; Johnson, G.O.; Schmidt, R.J.; & Cramer, J.T. (2015). Muscle activation during three sets to failure at 80 vs. 30% 1RM resistance exercise. *European Journal Applied Physiology*, 115, 2335–2347
- Kawakami, Y., Amemiya, K., Kanehisa, H., Ikegawa, S., & Fukunaga, T. (2000). Fatigue responses of human triceps surae muscles during repetitive maximal isometric contractions. *Journal Applied Physiology*, 1985(88), 1969–1975.
- Kawakami, Y., Ichinose, Y., & Fukunaga, T. (1998). Architectural and functional features of human triceps surae muscles during contraction. *Journal Applied Physiology*, 1985 85, 398–404.
- Kinugasa, R., Kawakami, Y., & Fukunaga, T. (2005). Muscle activation and its distribution within human triceps surae muscles. *Journal Applied Physiology*, 1985 (99), 1149–1156.
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers Psychology*, 26,4:863
- Malliaras, P. (2022). Physiotherapy management of Achilles tendinopathy. *Journal of Physiotherapy*, 68(4):221-23.

- Marcori, A.J., Moura, T.B.M.A., & Okazaki, V.H.A. (2017). Gastrocnemius muscle activation during plantar flexion with different feet positioning in physically active young men. *Isokinetics and Exercise Science*, 25, 121–125.
- Maritz, C.A., & Silbernagel, K.G. (2016). A Prospective Cohort Study on the Effect of a Balance Training Program, Including Calf Muscle Strengthening, in Community-Dwelling Older Adults. *Journal Geriatric Physical Therapy*, 39(3):125-31.
- Masumoto, K., Joerger, J., & Mercer, J.A. (2018). Influence of stride frequency manipulation on muscle activity during running with body weight support. *Gait and Posture*, 61, 473–478.
- Mikkola, J., Rusko, H., Nummela, A., Pollari, T., & Häkkinen, K. (2007). Concurrent Endurance and Explosive Type Strength Training Improves Neuromuscular and Anaerobic Characteristics in Young Distance Runners. *International Journal of Sports Medicine*, 28, 602–611.
- Miranda, H.; Maia, M.; de Oliveira, C.G.; Farias, D.; da Silva, J.B.; Lima, V.P.; Willardson, J.M.; & Paz, G.A.(2018). Myoelectric indices of fatigue adopting different rest intervals during leg press sets. *Journal Bodywork and Movement Therapy*, 22, 178–183
- Morley, J.J., & Traum, E., (2018). The effects of dorso-lumbar motion restriction on EMG activity of selected muscles during running. *Journal Bodywork and Movement Therapy Journal Bodywork and Movement Therapy*, 22, 166–177.
- Nilsen, T.S., Raastad, T., Skovlund, E., Courneya, K.S., Langberg, C.W., Lilleby, W., Fosså, S.D., & Thorsen, L. (2015). Effects of strength training on body composition, physical functioning, and quality of life in prostate cancer patients during androgen deprivation therapy. *Acta Oncologica*, 54, 1805–1813.
- Park, Hye-Kang & Yu, Ki-Gon & Shin, Jang-Hoon & Lee, & Wan-Hee. (2020). Correlation among triceps surae muscle structure, balance, and gait in persons with stroke. *Physical Therapy Rehabilitation Science*, 9, 155-164.
- Pereira, R., Azevedo, J., Politti, F., Paunksnis, M., Evangelista, A., Teixeira, C., Serra, A., Alonso, A., Pitta, R., Figueira junior, A., Reis, V., & Bocalini, D. (2017). Does feet position alter triceps surae EMG record during heel-raise exercises in leg press machine? *Manual Therapy, Posturology and Rehabilitation Journal*, 15:529.
- Riemann, B.L., Limbaugh, G.K., Eitner, J.D., & LeFavi, R.G. (2011). Medial and lateral gastrocnemius activation differences during heel-raise exercise with three different foot positions. *Journal Strength Conditioning Research*, 25, 634–639.
- Rosenberger, A., Beijer, Å., Johannes, B., Schoenau, E., Mester, J., Rittweger, J., & Zange, J., (2017). Changes in muscle cross-sectional area, muscle force, and jump performance during 6 weeks of progressive whole-body vibration combined with progressive, high intensity resistance training. *Journal Musculoskeletal and Neuronal Interactions*, 17, 38–49.
- Signorile, J.F., Applegate, B., Duque, M., Cole, N., & Zink, A. (2002). Selective recruitment of the triceps surae muscles with changes in knee angle. *Journal Strength Conditioning Research*, 16, 433–439.
- Tamaki, H., Kitada, K., Akamine, T., Sakou, T., & Kurata, H. (1997). Electromyogram patterns during plantarflexions at various angular velocities and knee angles in human triceps surae muscles. *European Journal Applied Physiology*, 75, 1–6.
- Vigotsky, A.D., Halperin, I., Lehman, G.J., Trajano, G.S., & Vieira, T.M. (2017). Interpreting Signal Amplitudes in Surface Electromyography Studies in Sport and Rehabilitation Sciences. *Frontier Physiology*, 8, 985.