

Effect of attentional focus on squats on lactate production and rating of perceived exertion in trained men Efecto del foco atencional en la sentadilla sobre la producción de lactato y la percepción del esfuerzo percibido en hombres entrenados

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Abstract. Purpose: The aim of this study was to investigate the effect of internal focus (IF) and external focus (EF) on lactate production and the perception of perceived exertion in the squat in strength trained-men. Methods: Thirteen men with experience in strength training (age = 22.61 ± 1.19 years; height = 180 ± 6.55 cm; body mass = 79.38 ± 5.57 kg; BMI = 24.56 ± 2.11 kg·m⁻²; Squat = 129 ± 20 kg) performed two sessions, separated by one week, comprising 3 sets of 10 repetitions of the back squat with one minute of rest between sets. During the IF protocol participants were instructed to focus on tightening the quads during all repetitions, while participants in the EF were instructed to focus on lifting the barbell. Blood lactate samples were collected before and at immediately after each of the 3 sets, as well as 15 minutes after the last set. Additionally, the rating of perceived exertion (RPE) was evaluated using the OMNI-RES scale immediately after the completion of each session. Results: Significant increases were found in the IF protocol at the end of each of the 3 sets, with significant effect sizes (1^a set, P= .000, d= 2.66; 2^a set, P= .000; d= 3.14; 3^a set, P= .000, d= 3.50), as in the EF protocol (1^a set, P= .001, d= 2.24; 2^a set, P= .000, d= 3.35; 3^a set, P= .000; d= 3.67). However, there were no significant inter-group differences between pre and any set (1^a set, P=0.951, d=0.03; 2^a set, P=0.239, d=0.47; 3^a set, P=0.435, d=0.31, respectively). Additionally, the perceptions on the RPE scale were higher in the IF (P= 0.032; d= 0.47). Conclusions: Findings suggest that the application of IF may indirectly contribute to muscle hypertrophy in multi-joint lower limb exercises, due to the increase in RPE values and the existing correlation with lactate production.

Keywords: Mind-muscle, muscle hypertrophy, internal focus, mind-muscle connection, resistance training

Resumen. Objetivo: El objetivo de este estudio fue investigar el efecto del foco interno (FI) y del foco externo (FE) sobre la producción de lactato y la percepción del esfuerzo percibido en la sentadilla en hombres entrenados en fuerza. Métodos: Trece hombres con experiencia en el entrenamiento de fuerza (edad = 22,61 ± 1,19 años; altura = 180 ± 6,55 cm; masa corporal = 79,38 ± 5,57 kg; IMC = 24,56 ± 2,11 kg·m⁻²; sentadilla = 129 ± 20 kg) realizaron dos sesiones, separadas por una semana, que comprendían 3 series de 10 repeticiones de la sentadilla con un minuto de descanso entre series. Durante el protocolo de FI, los participantes fueron instruidos para concentrarse en tensar los cuádriceps durante todas las repeticiones, mientras que los participantes en el EF fueron instruidos para concentrarse en levantar la barra. Se tomaron muestras de lactato en sangre antes e inmediatamente después de cada una de las 3 series, así como 15 minutos después de la última serie. Además, se evaluó la calificación del esfuerzo percibido (RPE) utilizando la escala OMNI-RES inmediatamente después de la finalización de cada sesión. Resultados: Se encontraron aumentos significativos en el protocolo IF al final de cada una de las 3 series, con tamaños de efecto significativos (1^a serie, P= .000, d= 2,66; 2^a serie, P= .000; d= 3,14; 3^a serie, P= .000, d= 3,50), al igual que en el protocolo FE (1^a serie, P= .001, d= 2,24; 2^a serie, P= .000, d= 3,35; 3^a serie, P= .000; d= 3,67). Sin embargo, no hubo diferencias intergrupales significativas entre el pre y cualquier set (1^a set, P=0,951, d=0,03; 2^a set, P=0,239, d=0,47; 3^a set, P=0,435, d=0,31, respectivamente). Además, las percepciones en la escala RPE fueron mayores en la IF (P= 0,032; d= 0,47). Conclusiones: Los hallazgos sugieren que la aplicación de la IF puede contribuir indirectamente a la hipertrofia muscular en ejercicios multiarticulares de miembros inferiores, debido al aumento de los valores de RPE y a la correlación existente con la producción de lactato.

Palabras clave: Mente-músculo, hipertrofia muscular, foco interno, conexión mente-músculo, entrenamiento de resistencia.

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Introduction

The proper manipulation of exercise program variables and the knowledge of their underlying scientific bases, are key for optimizing the results from resistance training interventions (Morton, Colenso-Semple, & Phillips, 2019). Cadence, rest intervals, intensity, volume or frequency are variables that have been evaluated in isolation, even grouping several of them in different protocols (Vargas et al., 2019). Attentional focus is another relevant program variable to take into account when seeking to maximize muscular adap-

tations (Morton et al., 2019). There are two basic categories of attentional focus: internal focus (IF) and external focus (EF). An IF centers on the mind-muscle connection, with the objective of isolating the target muscle as much as possible from other working muscles (e.g. synergists and antagonists). Alternatively, an EF directs attention to external elements (e.g. floor, bar, wheels...) (Wulf, Hoss, & Prinz, 1998), which favors increases in strength and task performance (Halperin, Chapman, Martin, & Abbiss, 2017; Wulf, 2013). Studies show that an IF elicits a greater electromyographic activation in the target muscle compared to an EF

(Calatayud et al., 2016; Snyder & Fry, 2012; Snyder & Leech, 2009). Moreover, an IF has been shown to promote superior increases in muscle thickness of the biceps brachii when compared to an EF over an 8-week resistance training intervention, although no hypertrophic differences were observed between conditions for the quadriceps (Schoenfeld et al., 2018).

Exercise-induced metabolic stress has been proposed as a contributing stimulus for muscle hypertrophy (Schoenfeld, 2013). In particular, blood lactate [bLa-] is considered a potential hypertrophic signaling metabolite (Ozaki, Loenneke, Buckner, & Abe, 2016; Schoenfeld, 2013). Recently, it has been hypothesized that [bLa-] per se does not promote muscle hypertrophy, although it is indirectly related due to the induction of fatigue, the recruitment of motor units and the muscle activation that is generated. (Dankel et al., 2017).

Rating of Perceived Exertion (RPE) scales are often used for the determination of exercise intensity because they are an accurate measure of physiological indicators affecting exercise. Their use is valid and reliable across different populations and different exercise modalities (Halperin & Emanuel, 2019; Blázquez, García et al., 2021). However, these scales can be altered by different situations that may occur during training (Halperin & Emanuel), such as the different internal and/or external foci used, and the relationship between RPE and the use of internal or external foci during exercise is unknown.

On the other hand, a greater perceived exertion (RPE) would increase [bLa-] (Aniceto et al., 2015; Kraemer, Noble, Clark, & Culver, 1987; Vargas-Molina, Martin-Rivera, et al., 2020). However, is unknowing if the application of IF or EF could indirectly favor muscle hypertrophy by improving these parameters.

The purpose of this study was to investigate the effect of IF and EF on [bLa-] and RPE in the squat (SQ) exercise in strength-trained participants. Based on the previous relationships found, between [bLa-] and muscle activation (Candotti et al., 2008; Snarr, Howell, & Sheppard, 2018), as well as IF and muscle activation (Calatayud et al., 2016) we hypothesized that employing an IF would promote a greater increase in both [bLa-] and RPE than when employing an EF.

Materials and methods

Participants

Thirteen men (age = 22.61 ± 1.19 years; height = 180 ± 6.55 cm; body mass = 79.38 ± 5.57 kg; BMI = 24.56 ± 2.11 kg·m⁻²; Squat = 129.20 ± 20.66 kg) with over two years of continuous strength training experience volunteered to participate in this study. The exclusion criteria were: a) be outside the age range of 18 to 30 years; b) have less than two years of experience with high-intensity strength training

c) had used doping agents (e.g. androgenic anabolic steroids) in the previous two years; d) currently taking any kind of sport supplement (e.g. whey protein, creatine); e) had suffered a traumatic injury at neuromuscular or musculoskeletal level on the lower limb (e.g. knee or hip) in the previous six months or had surgery on their knee or hip joint. Participants were instructed not to consume stimulant-containing beverages (e.g., caffeine) 3-4 hours prior to the assessments, and not to perform lower limb exercise in the 72 hours prior to each laboratory visit. Additionally, they were instructed to get a minimum of 8 hours of sleep before the testing sessions.

Prior to participation, participants filled out a PAR-Q questionnaire; no participant answered affirmatively to the established questions. Participants were informed about the experimental procedures and the possible risks and signed informed consent. The study adhered to the ethical guidelines of the World Medical Association Declaration of Helsinki (WMA, 2013). The research protocol was reviewed and approved by the Ethics Committee of the of the EADE-University of Wales Trinity Saint David (Málaga, Spain) Committee's reference number: (EADECAFYD2021-1).

Measures

Procedures

The participants made three visits to the laboratory. In the first session, we obtained anthropometric measurements from participants and familiarized them with the concepts of IF and EF, as well as the use of the rating perceived exertion scale (RPE), OMNI-RES (Robertson et al., 2003). After familiarization, we obtained estimates of participants' 1RM in the back squat (BS). During the second and third sessions the respective IF and FE protocols were carried out in a randomized fashion, with sessions separated by a one-week recovery interval.

Familiarization session and 1RM testing

In the first session, body mass was assessed by a digital scale (Tanita, model BC-601, Tokyo, Japan) and height via a stadiometer (SECA, model 217, Hamburg, Germany). Additionally, participants completed the PAR-Q questionnaire and were informed about how to employ an IF and EF, with verbal instruction provided to facilitate learning of both approaches

The warm-up in both the familiarization session and the experimental sessions followed the guidelines employed in our previous research (Vargas-Molina, Petro, et al., 2020). A pre-test warm-up of 7-10 minutes of light cardiovascular exercise (set at a RPE 5-6) was performed. One set of 12 to 15 repetitions was then performed with 40% of the 1RM estimated by the participants. Load increases of approximately 10% of the 1MR were performed until a mean pro-

pulsive velocity (MPV) of 0.5 ms was achieved using a linear position transducer (SmartCoach Power Encoder SPE-35, SmartCoach Europe AB, Stockholm, Sweden) followed by increments of 5 to 10 kg until 1RM were reached, based on (Gonzalez-Badillo & Sanchez-Medina, 2010). A rest interval of 3 to 5 minutes was allowed between each attempt. Execution of the BS was standardized to include an erect posture of the trunk, feet separated approximately at hip width with the hips having a slight external rotation, avoidance of knee valgus, stable support of the foot and the bar resting on the upper trapezius. Participants were required to descend until the hips were at the same level as the knees. The correct technique was validated by two assistants, who determined the depth of the BS using a Halo digital goniometer (Halo Medical Devices, Subiaco, Western Australia), to ensure that the knee angle was 90° in each participant. The protocol followed the recommendations described by McGuigan (McGuigan, 2016) and the squat technique by Caulfield and Berninger (Caulfield & Berninger, 2016). Additionally, once the evaluation of the 1 RM in BS, to ensure that the protocols were well understood we proceeded to perform 2 to 3 series of 8-10 test repetitions, including quadriceps palpation when it corresponded to the IF protocol. After the first session, participants were randomly assigned to perform the IF and EF protocols in sessions two and three (www.randomizer.org).

Experimental sessions

As mentioned, the experimental sessions began with a warm-up, which was similar as that described in the familiarization phase. Thereafter, the IF and EF protocols took place in randomized fashion (fig. 2). All participants performed both protocols seven days apart. The protocol consisted of 3 sets of 10 repetitions in the BS at 60% of the 1RM was calculated for the application of the protocols, which have been shown to generate more electrical activity when IF is applied (Calatayud et al., 2016). Participants performed each repetition until reaching 90° parallel to the floor, with a tempo of 1 second in the concentric phase and 2 seconds in the eccentric controlled by a metronome (App Metronome M1), adjusted to 60 rpm with a ¾ beat in both protocols. A, 1 minute rest period was provided in between sets. The position of the rack and the grip of the bar was the same as in the familiarization session. For IF, participants were instructed to "focus on contracting the quadriceps as much as you can and for the entire duration of the set," while for EF, the cue was to "focus on pushing the floor as hard as you can" as per Halperin et al. (Halperin, Williams, Martin, & Chapman, 2016).

All testing sessions were supervised by the research team. In this case, one researcher was placed on one side of the rack monitoring the correct technique and other one recording the data using the LPT.

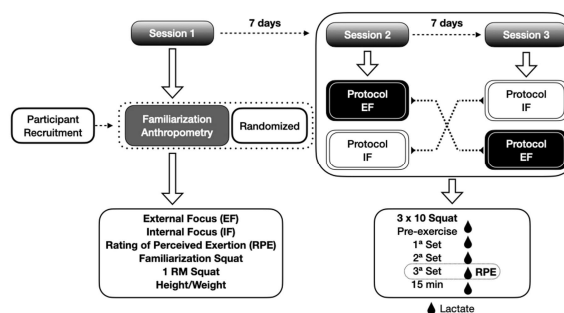


Figure 1. Study design

Blood samples were taken for measurement of the [bLa-] before the test began, while in a seated and fully relaxed position. They were then taken again just after the end of each of the three sets, and 15 minutes after the end of the third set. The blood collection between sets and at the end was also done with the participants seated and relaxed. Samples were taken from the earlobe, a conventional sampling location (Forsyth & Farrally, 2000; Scherr et al., 2013), after the earlobe was cleaned and sterilized with 70% ethanol. A blood sample ($\geq 0.5 \mu\text{l}$) was collected and then analyzed with a lactate measurement device (Lactate Scout +, SensLab GmbH, Leipzig, Alemania).

Additionally, we obtained RPE values on a scale of 1 to 10, as described by Robertson et al. (Robertson et al., 2003). Specifically, participants were instructed to report their perceived exertion level immediately at the end of the three sets of each protocol. They were told that the numerical value 2 corresponded to easy, 3-4 somewhat easy, 6 somewhat hard, 8-9 hard, and 10 extremely hard. To facilitate understanding, there was a visual illustration of the scale all times.

Analysis

Results are expressed as mean (X), standard deviation (SD) and 95% confidence intervals (95% CI). The normality of the data was determined with the Shapiro-Wilk test. Repeated measures ANOVA was used to established intra-subject comparison, with unilateral significance values, between the time factor of the 5 measurements obtained from each protocol (Pre, 1, 2, 3, post 15 min). Greenhouse-Geisser correction was used to establish the principal effect of *time* and *time x group* and post hoc analysis with the Bonferroni test considering the partial eta squared value (η^2p) and Cohen's d test (*d*) as a measure of ES.

ANOVA test of independent measurements was used to established Inter-subject comparisons between the two protocols. The comparison between RPE was performed with the paired t-test. The effect size (ES) was calculated by Cohen's d test for intra-group interactions. The significance level assumed for all tests was 0.05. Statistical analysis was performed with SPSS (Version, 25, SPSS, IBM Corporation,

Armonk, New York, USA) and the graphics were processed with el Software GraphPad version 6 (GraphPad Software, California, E.U).

Results

To test difference between training protocols blood lactate concentration levels, 13 participants with experience in resistance training, were assessed, in two different moments, in a first instance using the IF protocol, the results shown in the lactate test showed statistically significant values of $F = 38.9$, $p < 0.01$ y $\eta^2 = 0.76$, the results are shown in figure 2(A). For the EF protocol, we obtained values of $F = 65.53$, $p < 0.01$ y $\eta^2 = 0.84$, the results are shown in figure 2(A). Mean and SD are shown in table 2. For inter-protocol comparisons the results of the tests performed were; LacPre $F = 0.038$, $p = 0.848$, $d = 0.08$, Lac1 $F = 0.004$, $p = 0.951$, $d = 0.03$, Lac2 $F = 1.460$, $p = 0.239$, $d = 0.47$, Lac3 $F = 0.630$, $p = 0.435$, $d = 0.31$, Lac4 $F = 0.625$, $p = 0.437$, $d = 0.30$, no difference was found between protocols. Mean and SD are shown in table 2. Figure 2(B).

The RPE showed significantly greater effects for IF compared to EF = 2.42; $p 0.032$] y ($d = 0.47$), indicating that the perceived effort was higher when using the IF protocol (see Table 3 and Figure 2 C).

Table 1. Intra-subject comparison

		X ± SD	F	p	η^2
IF	PRE	1.48 ± .62	38.91	0.000***	0.76
	1	3.40 ± .81			
	2	6.03 ± 1.95			
	3	7.72 ± 2.44			
	4	4.36 ± 1.43			
EF	PRE	1.53 ± .58	65.53	0.000***	0.84
	1	3.43 ± 1.05			
	2	5.21 ± 1.44			
	3	7.02 ± 2.03			
	4	3.96 ± 1.18			

Results are expressed as mean (X), standard deviation (SD). IF: Internal Focus, EF: External Focus. Values; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 2. Inter-subject comparison

		X + SD	F	p	d
Lac Pre	IF	1.48 ± .62	0.038	0.848	0.08
	EF	1.53 ± .58			
Lac 1	IF	3.40 ± .81	0.004	0.951	0.03
	EF	3.43 ± 1.05			
Lac 2	IF	6.03 ± 1.95	1.460	0.239	0.47
	EF	5.21 ± 1.44			
Lac 3	IF	7.72 ± 2.44	0.630	0.435	0.31
	EF	7.02 ± 2.04			
15 min	IF	4.36 ± 1.43	0.625	0.437	0.30
	EF	3.96 ± 1.18			

Results are expressed as mean (X), standard deviation (SD). Lac: Lactate. IF: Internal Focus, EF: External Focus. Values; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 3. t-test for RPE

	IF	EF	g	t	p	d
RPE	8.50 ± .57	8.15 ± .87	12	2.42	0.032*	0.47

Values of bilateral significance in; * $p < .05$; ** $p < .01$; *** $p < .001$.

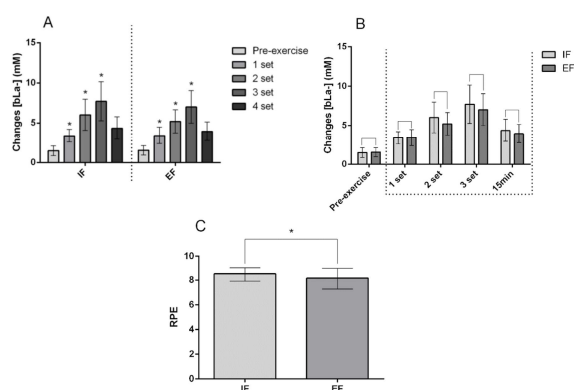


Figure 2. Results

Discussion

Our study aimed to evaluate the effects of attention focus on [bLa-] and RPE in BS. We presumed that an IF would generate higher values of [bLa-] and RPE compared to an EF. Our results partially support our hypothesis, since the RPE values were higher in the IF protocol. Alternatively, although both protocols generated significant increases in [bLa-], there were no significant differences between them. In this way, relationships between [bLa-] and motor unit recruitment have been found (Gladden, 2004) in fact (Dankel et al., 2017) concluded that the main role behind muscle hypertrophy attributed to the production of metabolites lies in the ability to increase muscle activation. Therefore, it can be assumed that increases in [bLa-] would optimize muscle hypertrophy. However, we did not find significant results in favor of IF in [bLa-] but, if there are higher RPE values.

Given that investigations with larger samples (Vargas-Molina, Martin-Rivera, et al., 2020), 40 participants did find a correlation between RPE-[bLa-] we can assume that the limitation of 13 participants in our investigation would negatively affect the statistical results, in fact, the trend is in favor of the IF in LA, as we can see with a difference in the size of the effect at the end of the second and third series and at 15 minutes ($d = 47$; $d = 31$; $d = 30$).

Effects of IF and EF on hypertrophic measures have been evaluated directly by ultrasound (Schoenfeld et al., 2018), who reported greater muscle thickness changes of the elbow flexors in favor of an IF versus EF following an 8-week training intervention (12.4% vs. 6.9% respectively). Alternatively, no significant between-group differences were observed in the quadriceps. Therefore, an advantage is seen in the FI in analytical exercises, such as the bicep curl, probably in multi-joint exercises the mind-muscle connection is difficult. For example, the BS involves the combined activation of multiple muscles including the quadriceps, knee flexors, gluteal, and plantar flexors, as well as involving numerous stabilizers (Schoenfeld, 2010b). Consequently, there are no

clear data because it's easier to direct focus internally during single-joint movements. Additionally, it should be noted that the favorable hypertrophic benefits of IF shown by Schoenfeld et al. (Schoenfeld et al., 2018) were exclusive to upper body exercises (biceps curl). Alternatively, changes in muscle thickness were similar irrespective of attentional focus in the lower body musculature, despite the fact that an isolated exercise was used (leg extension). Indirectly, we did not find [bLa-] significantly in a lower limb exercise, although, in this case it was a multi-joint exercise like BS.

On the other hand, the RPE is a way of quantifying the internal load (Bourdon et al., 2017). Positive relationships between active muscle RPE and overall body RPE have been found with surface electromyography (EMG) in the rectus femoris, vastus lateralis, and vastus medialis muscles (Duncan, Al-Nakeeb, & Scurr, 2006), and the biceps brachii (Lagally, Robertson, Gallagher, Goss, et al., 2002) and increased muscle activation, would indirectly favor muscle hypertrophy by recruiting more motor units.

Additionally, if the mechanical stress (MT) is composed of the load and the time under tension (Schoenfeld, 2010a), higher loads mean more MT, thus, in the investigations of Day, McGuigan, Brice, & Foster (2004) and Lagally & Robertson (2006) more percentages of loads were related to more high RPEs. For this reason, one might think that higher rates of exertion may benefit the hypertrophic stimulus. However, when total work is matched, RPE is related to intensity (30% -60% -90% RM) with training volume being the primary programming variable for generating hypertrophy Morton et al., 2019. (Duncan et al., 2006; Lagally, Robertson, Gallagher, Gearhart, & Goss, 2002)

Consequently, although there was no difference between the groups in [bLa-], the effect sizes favoured IF. Furthermore, the RPE was higher for IF ($p > 0.032$; $d = 0.47$). And if we take into account the overlap found between [bLa-] and RPE (Aniceto et al., 2015; Kraemer et al., 1987; Vargas-Molina, Martin-Rivera, et al., 2020) IF could be more favourable. Also, the small sample size and the difficulty of isolating the target muscle in multi-joint exercises may explain why no significant effects were obtained in [bLa-] in favour of IF.

Conclusion

Our results suggest that the application of IF generates a significant increase in EPR and a favourable trend in [bLa-], although no significant differences in this parameter were found. Further studies should be conducted to determine the potential of IF to cause hypertrophy.

Authors' contributions

S.V.M served as study coordinator. S.V.M and F.M.R

conceived and designed the experiments. S.V.M and M.G.S served as lab coordinator and project manager for the study coordination, respectively. SV and M.G.S assisted in data collection. S.V.M and U.S analyzed the data. S.V.M, F.M.R., M.G.S., L.C, and U.S assisted in analysis, and manuscript review. S.V.M wrote the paper. S.V.M., F.M.R., M.G.S and L.C assisted in the statistics advice, discussion analysis, and manuscript preparation. All authors read and approved the final manuscript.

Conflict of Interests

There are no conflicts of interest declared by the author.

References

- Aniceto, R. R., Ritti-Dias, R. M., Dos Prazeres, T. M., Farah, B. Q., de Lima, F. F., & do Prado, W. L. (2015). Rating of Perceived Exertion During Circuit Weight Training: A Concurrent Validation Study. *J Strength Cond Res*, 29(12), 3336-3342. doi:10.1519/JSC.0000000000000998
- Blázquez, J. A., García, S., Ferriz, A., Olaya, J., (2021). Quantification of training and competition load: comparative analysis by position in a Spanish Golden Basketball League team. *Retos*, 42(4), 882-889.
- Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., . . . Cable, N. T. (2017). Monitoring Athlete Training Loads: Consensus Statement. *Int J Sports Physiol Perform*, 12(Suppl 2), S2161-S2170. doi:10.1123/IJSPP.2017-0208
- Calatayud, J., Vinstrup, J., Jakobsen, M. D., Sundstrup, E., Brandt, M., Jay, K., . . . Andersen, L. L. (2016). Importance of mind-muscle connection during progressive resistance training. *Eur J Appl Physiol*, 116(3), 527-533. doi:10.1007/s00421-015-3305-7
- Candotti, C. T., Loss, J. F., Melo Mde, O., La Torre, M., Pasini, M., Dutra, L. A., . . . de Oliveira, L. P. (2008). Comparing the lactate and EMG thresholds of recreational cyclists during incremental pedaling exercise. *Can J Physiol Pharmacol*, 86(5), 272-278. doi:10.1139/y08-020
- Caulfield, S., & Berninger, D. (2016). Exercise technique for free weight and machine training. In: Haff GG, Triplett NT (I. H. K. Essentials of Strength training and conditioning. Champaign Ed.).
- Dankel, S. J., Mattocks, K. T., Jessee, M. B., Buckner, S. L., Mouser, J. G., & Loenneke, J. P. (2017). Do metabolites that are produced during resistance exercise enhance muscle hypertrophy? *Eur J Appl Physiol*, 117(11), 2125-2135. doi:10.1007/s00421-017-3690-1
- Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *J Strength Cond Res*, 18(2), 353-358. doi:10.1519/R-13113.1
- Duncan, M. J., Al-Nakeeb, Y., & Scurr, J. (2006). Perceived exertion is related to muscle activity during leg extension exercise. *Res Sports Med*, 14(3), 179-189. doi:10.1080/15438620600854728

- Forsyth, J. J., & Farrally, M. R. (2000). A comparison of lactate concentration in plasma collected from the toe, ear, and fingertip after a simulated rowing exercise. *Br J Sports Med*, 34(1), 35-38. doi:10.1136/bjbm.34.1.35
- Gladden, L. B. (2004). Lactate metabolism: a new paradigm for the third millennium. *J Physiol*, 558(Pt 1), 5-30. doi:10.1113/jphysiol.2003.058701
- Gonzalez-Badillo, J. J., & Sanchez-Medina, L. (2010). Movement velocity as a measure of loading intensity in resistance training. *Int J Sports Med*, 31(5), 347-352. doi:10.1055/s-0030-1248333
- Halperin, I., Chapman, D. W., Martin, D. T., & Abbiss, C. (2017). The effects of attentional focus instructions on punching velocity and impact forces among trained combat athletes. *J Sports Sci*, 35(5), 500-507. doi:10.1080/02640414.2016.1175651
- Halperin, I., Williams, K. J., Martin, D. T., & Chapman, D. W. (2016). The Effects of Attentional Focusing Instructions on Force Production During the Isometric Midthigh Pull. *J Strength Cond Res*, 30(4), 919-923. doi:10.1519/JSC.0000000000001194
- Halperin, I., Emanuel, A. (2019). Rating of Perceived Effort: Methodological Concerns and Future Directions. *Sports Med* 50, 679-687. doi: 10.1007/s40279-019-01229-z
- Kraemer, W. J., Noble, B. J., Clark, M. J., & Culver, B. W. (1987). Physiologic responses to heavy-resistance exercise with very short rest periods. *Int J Sports Med*, 8(4), 247-252. doi:10.1055/s-2008-1025663
- Lagally, K. M., & Robertson, R. J. (2006). Construct validity of the OMNI resistance exercise scale. *J Strength Cond Res*, 20(2), 252-256. doi:10.1519/R-17224.1
- Lagally, K. M., Robertson, R. J., Gallagher, K. I., Gearhart, R., & Goss, F. L. (2002). Ratings of perceived exertion during low- and high-intensity resistance exercise by young adults. *Percept Mot Skills*, 94(3 Pt 1), 723-731. doi:10.2466/pms.2002.94.3.723
- Lagally, K. M., Robertson, R. J., Gallagher, K. I., Goss, F. L., Jakicic, J. M., Lephart, S. M., . . . Goodpaster, B. (2002). Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. *Med Sci Sports Exerc*, 34(3), 552-559; discussion 560. doi:10.1097/00005768-200203000-00025
- McGuigan, M. (2016). Administration, scoring, and interpretation of selected tests. In: Haff GG, Triplett NT, editors.
- Morton, R. W., Colenso-Semple, L., & Phillips, S. M. (2019). Training for strength and hypertrophy: an evidence-based approach. *Current Opinion in Physiology*, 10, 90-95. doi:https://doi.org/10.1016/j.cophys.2019.04.006
- Ozaki, H., Loenneke, J. P., Buckner, S. L., & Abe, T. (2016). Muscle growth across a variety of exercise modalities and intensities: Contributions of mechanical and metabolic stimuli. *Med Hypotheses*, 88, 22-26. doi:10.1016/j.mehy.2015.12.026
- Robertson, R. J., Goss, F. L., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J., . . . Andreacci, J. (2003). Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc*, 35(2), 333-341. doi:10.1249/01.MSS.0000048831.15016.2A
- Scherr, J., Wolfarth, B., Christle, J. W., Pressler, A., Wagenpfeil, S., & Halle, M. (2013). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol*, 113(1), 147-155. doi:10.1007/s00421-012-2421-x
- Schoenfeld, B. J. (2010a). The mechanisms of muscle hypertrophy and their application to resistance training. *J Strength Cond Res*, 24(10), 2857-2872. doi:10.1519/JSC.0b013e3181e840f3
- Schoenfeld, B. J. (2010b). Squatting kinematics and kinetics and their application to exercise performance. *J Strength Cond Res*, 24(12), 3497-3506. doi:10.1519/JSC.0b013e3181bac2d7
- Schoenfeld, B. J. (2013). Potential mechanisms for a role of metabolic stress in hypertrophic adaptations to resistance training. *Sports Med*, 43(3), 179-194. doi:10.1007/s40279-013-0017-1
- Schoenfeld, B. J., Vigotsky, A., Contreras, B., Golden, S., Alto, A., Larson, R., . . . Paoli, A. (2018). Differential effects of attentional focus strategies during long-term resistance training. *Eur J Sport Sci*, 18(5), 705-712. doi:10.1080/17461391.2018.1447020
- Snarr, B. D., Howell, P. L., & Sheppard, D. C. (2018). Hoisted by their own petard: do microbial enzymes hold the solution to treating and preventing biofilm infections? *Future Microbiol*, 13, 395-398. doi:10.2217/fmb-2017-0243
- Snyder, B. J., & Fry, W. R. (2012). Effect of verbal instruction on muscle activity during the bench press exercise. *J Strength Cond Res*, 26(9), 2394-2400. doi:10.1519/JSC.0b013e31823f8d11
- Snyder, B. J., & Leech, J. R. (2009). Voluntary increase in latissimus dorsi muscle activity during the lat pull-down following expert instruction. *J Strength Cond Res*, 23(8), 2204-2209. doi:10.1519/JSC.0b013e3181bb7213
- Vargas, S., Petro, J. L., Romance, R., Bonilla, D. A., Florido, M. A., Kreider, R. B., . . . Benitez-Porres, J. (2019). Comparison of changes in lean body mass with a strength- versus muscle endurance-based resistance training program. *Eur J Appl Physiol*, 119(4), 933-940. doi:10.1007/s00421-019-04082-0
- Vargas-Molina, S., Martin-Rivera, F., Bonilla, D. A., Petro, J. L., Carbone, L., Romance, R., . . . Benitez-Porres, J. (2020). Comparison of blood lactate and perceived exertion responses in two matched time-under-tension protocols. *PLoS One*, 15(1), e0227640. doi:10.1371/journal.pone.0227640
- Vargas-Molina, S., Petro, J. L., Romance, R., Kreider, R. B., Schoenfeld, B. J., Bonilla, D. A., & Benitez-Porres, J. (2020). Effects of a ketogenic diet on body composition and strength in trained women. *J Int Soc Sports Nutr*, 17(1), 19. doi:10.1186/s12970-020-00348-7
- WMA. (2013). World medical association declaration of helsinki ethical principles for medical research involving human subjects. *JAMA*, 310(20):, 2191-2194. doi:https://doi.org/10.1001/jama.2013.281053
- Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology*, 6 (1), 77-104.
- Wulf, G., Hoss, M., & Prinz, W. (1998). Instructions for motor learning: differential effects of internal versus external focus of attention. *J Mot Behav*, 30(2), 169-179. doi:10.1080/00222899809601334