©Journal of Sports Science and Medicine (2021) **20,** 56-61
http://www.jssm.org

Research article

Electromyographic Comparison of Five Lower-Limb Muscles between Single- and Multi-Joint Exercises among Trained Men

Nicolay Stien ✉, Atle Hole **Saeterbakken and Vidar Andersen**
Faculty of Education, Arts and Sports, Western Norway University of Applied Sciences, Norway

Abstract

Resistance-training exercises can be classified as either single- or multi-joint exercises and differences in surface electromyography (EMG) amplitude between the two training methods may identify which muscles can benefit from either training modality. This study aimed to compare the surface EMG amplitude of five hip- and knee extensors during one multi-joint (leg press) and two single-joint exercises (knee extension and kickback). Fifteen resistance-trained men completed one familiarization session to determine their unilateral six repetitions maximum (6RM) in the three exercises. During the following experimental session, EMG amplitudes of the vastus lateralis, vastus medialis, rectus femoris, gluteus maximus and biceps femoris of the left leg were measured while performing three repetitions on their respective 6RM loads. The multi-joint exercise leg press produced higher EMG amplitude of the vastus lateralis (ES = 0.92, $p = 0.003$) than the single-joint exercise knee extension, whereas the rectus femoris demonstrated higher EMG amplitude during the knee extension (ES = 0.93, $p = 0.005$). The biceps femoris EMG amplitude was higher during the single-joint exercise kickback compared to the leg press (ES = 2.27, $p < 0.001$), while no significant differences in gluteus maximus (ES = 0.08, $p = 0.898$) or vastus medialis (ES = 0.056, $p = 0.025$ were observed between exercises. The difference in EMG amplitude between single- and multi-joint exercises appears to vary depending on the specific exercises and the muscle groups tested. Leg press is a viable and time-efficient option for targeting several hip- and knee extensors during resistance training of the lower limbs, but the single-joint exercises may be preferable for targeting the rectus femoris and biceps femoris.

Key words: Muscle activity, leg press, knee extension, kickback, EMG, strength.

Introduction

Exercise selection is of primary importance when designing resistance-training programs (ACSM, 2009; Sale and MacDougall, 1981). Resistance training exercises can be classified as either multi-joint (MJ) or single-joint (SJ) exercises (Paoli et al., 2017). SJ exercises are considered easier to learn for beginners, posing less risk of injury and being better suited for targeting specific muscles, which may be desirable for bodybuilders aiming to increase muscle size of certain muscles (ACSM, 2009; Gentil et al., 2016; Kraemer and Ratamess, 2004). MJ exercises are more complex as they involve several muscle groups and joints while allowing a higher external load to be lifted. MJ training may also be more beneficial as it more closely mimics activities of daily living and sport-specific movements (Augustsson and Thomee, 2000; Kraemer and Ratamess, 2004; Paoli et al., 2017).

While most muscles surrounding the knee and hip joints are activated either as prime movers, synergists, or antagonists during lower limb exercises, the relative contribution of the involved muscles vary depending on the specific movement (Andersen et al., 2006; Khaiyat and Norris, 2018; Krause et al., 2018). For example, higher EMG amplitude of the rectus femoris muscle has been reported while performing isometric and dynamic knee extension (SJ) compared to leg press (MJ) (Ema et al., 2016; Enocson et al., 2005; Stensdotter et al., 2003), likely due to the biarticular function of the muscle. Another potential explanation may be that the stress on individual muscles is reduced when several synergists assist in the movement (Gentil et al., 2016). Regarding the remaining, monoarticular quadriceps muscles, several researchers have reported similar EMG amplitudes of the vasti muscles during dynamic or isometric knee extension and leg press (Alkner et al., 2000; Ema et al., 2016; Enocson et al., 2005; Escamilla et al., 1998; Wilk et al., 1996).

Consistent with the aforementioned findings for the vasti muscles, Alkner et al. (2000) reported no difference in biceps femoris muscle activity during isometric knee extension and leg press. To the authors' knowledge, only one study (Wilk et al., 1996) has compared the biceps femoris EMG activity during dynamic SJ and MJ exercises. The authors reported no difference in biceps femoris EMG activity between leg press and knee extension, but performed the testing using a very low load (four repetitions using the 12 RM load). Further, the EMG amplitude of the semitendinosus and semimembranosus might be inhibited when combining extension of the knee and hip (Fujiwara and Basmajian, 1975; Yamashita, 1988). Regarding the hip extensor gluteus maximus, the only known study comparing EMG amplitude during back squats and hip extensions reported similar activity during the two exercises (Cochrane et al., 2019).

As perceived lack of time is one of the most frequently reported barriers to participation and adherence to exercise (Choi et al., 2017; Gómez-López et al., 2010), performing one MJ exercise rather than two SJ exercises may be more feasible for many people. Since the EMG amplitude of the medial hamstrings are inhibited during concurrent knee- and hip extension (Fujiwara and Basmajian, 1975; Yamashita, 1988), the same phenomenon might occur for the biceps femoris while acting as both a synergist (hip extension) and antagonist (knee-extension). Moreover, to the authors' best knowledge, no previous study has compared EMG amplitudes during the leg press, knee extension and kickback exercises. The aim of this study was to assess the EMG amplitude of five superficial hip- and

Received: 04 June 2020 / Accepted: 06 December 2020 / Published (online): 01 March 2021

knee-extensors during knee extension, kickback and leg press, as well as to compare the recorded EMG amplitude between exercises. It was hypothesized that the leg press and knee extension would evoke similar EMG amplitudes in the vasti muscles, whereas the rectus femoris would demonstrate higher activity during the knee extension. It was also expected that biceps femoris EMG amplitude would be facilitated while performing the kickback, and that the gluteus maximus activity would not be different between the kickback and leg press exercises.

Methods

Participants

Fifteen resistance-trained men (age: 27.0 ± 6.4 years; body mass: 79.8 ± 7.9 kg; height: 1.82 ± 0.05 m; resistance-training experience: 8.0 ± 5.9 years) volunteered to participate in the study. Anthropometric characteristics of the study population are presented in Table 1. Participants were required to have at least one year of resistance-training experience, be without illnesses or injuries that could affect their performance and be able to leg press more than their own body mass for six repetitions using one leg. All participants were familiar with the three exercises examined in this study. The mean 6RM in the leg press, knee extension and kickback were 98.3 ± 14.7, 43.2 ± 6.4 and 60.7 ± 5.9 kg, respectively. All participants were informed of the potential benefits and risks of the study verbally and in writing before signing an informed consent form prior to data collection. The consent form and the testing procedures were approved by the National Centre for Research Data (858361), conformed to the standards of treatment of human participants in research as outlined in the latest Declaration of Helsinki, and were in accordance with the ethical guidelines of the university. The research was also conducted ethically according the standards as described for the International Journal of Sports Medicine (Harriss et al., 2019).

Table 1. Anthropometric data, resistance-training (RT) experience and relative leg press 6RM strength (6RM×body mass^{-1}) of the subjects. Values are given as mean (±SD).

Body mass (kg)	RT experience (yrs)	Relative leg press 6RM
79.8 (7.9)	8.0 (5.9)	1.2 (0.2)

Experimental design

A cross-sectional study was conducted to examine the surface EMG amplitude of rectus femoris, vastus lateralis, vastus medialis, biceps femoris and gluteus maximus while performing unilateral leg press, kickback and knee extension. The participants performed three repetitions using their respective 6RM load to avoid involuntary changes in the kinematic pattern when nearing fatigue (Welsch et al., 2005), which have been previously reported during bench press (Duffey and Challis, 2007). Following one familiarization session determining the participants' 6RM, the experimental session was conducted performing the tests in a standardized order (leg press – kickback – knee extension). The order of the exercises was standardized to avoid displacement of the posterior electrodes by sitting on the electrodes while performing the knee extension before the kickback. All exercises were performed unilaterally using the left leg due to the design of the machines and one previous comparable study (Cochrane et al., 2019).

Procedures

All participants performed one familiarization session approximately one week prior to the experimental test. In the familiarization session, the participants' individual 6RMs were determined. Prior to testing, the participants performed four warm-up sets of unilateral leg press with a progressive load based on their self-reported estimation of 1RM. Since the participants were resistance-trained and performed the leg press regularly, they were able to predict their 1RM very accurately. The warm-up consisted of the following procedure: 1) 20 repetitions at 30%, 2) 12 repetitions at 50%, 3) 6 repetitions at 70%, and 4) 2 repetitions at 80% (Bazyler et al., 2015; Saeterbakken et al., 2011). The high number of repetitions was chosen to ensure sufficient warm-up despite the sub-maximal loads and repetition ranges used. Three minutes rest were given between sets throughout the experiment (Bazyler et al., 2015; Paoli et al., 2017). Identical warm-up procedures and rest periods were used in the experimental test. Since a metronome (2.5 seconds intervals) was to be used during the experimental session, the participants were given a familiarization to the metronome during this warm-up.

Measurements

The participants performed the experimental test in standard commercial training machines (Technogym Selection; Cesena, Italia). The start positions for all exercises are shown in Figure 1. While the leg press machine allowed for concurrent extension of the hip- and knee joints, the two joints were isolated during the kickback and knee extension. Great care was taken to ensure a standardized execution of the lifts. In all exercises, the participants were instructed to allow the weight plates to slightly touch between repetitions. Verbal encouragement and feedback were given to ensure motivation and full range of motion in every repetition. White adhesive tape was also placed on the weight magazines, indicating where a full extension was reached. Participants were instructed to use 2.5 seconds in each full concentric-eccentric repetition, as controlled using a metronome. After completing one full repetition, the next repetition began immediately without pausing in the bottom position.

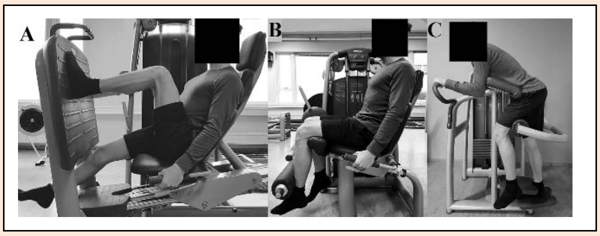

Figure 1. The start positions for the (A) leg press, (B) knee extension and (C) kickback.

For the leg press, the starting position was 90° and 60° flexion in the knee and hip joints, respectively (Figure 1A). One repetition was completed by extending the knee and hip joints to 180° and 150°, respectively, before lowering themselves back to the start position. The knee extension started with a 90° knee flexion (Figure 1B) and was performed to a full extension (180°) before lowering the leg to the starting position. Finally, the kickback started from a standing position with the iliac crest resting on the front bolster of the machine with a 90° angle in the hip joint and the knee semi-extended (170°; Figure 1C). The concentric phase lasted until the leg was aligned with the upper body (180° in the hip joint).

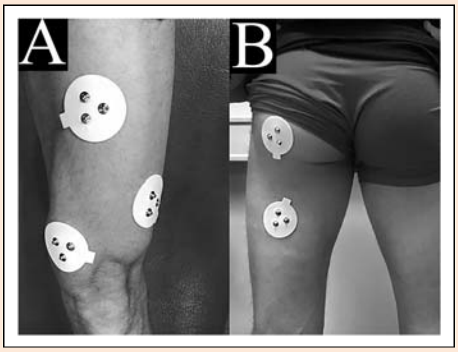

Figure 2. Electrode placements. A) the rectus femoris, vastus lateralis, vastus medialis, B) biceps femoris of the left leg.

During the tests, a linear encoder (ET-Enc-02, Ergotest Innovation A/S, Porsgrunn, Norway) was placed directly below the weight plates, identifying the start and end position for each repetition with a resolution of 0.075 mm and 10 ms pulse interval (Bosquet et al., 2010). The encoder was synchronized with EMG measures using a MuscleLab 6000 system and analyzed with a MuscleLab v.10.5.67 software (Ergotest Innovation A/S, Porsgrunn, Norway). Gel-coated electrodes (Dri-stick silver circular sEMG Electrodes AE-131, NeuroDyne Medical, USA) with an 11-mm contact diameter and a 2-cm center-to- center distance were used to measure the EMG activity during the lifts. Following careful preparation of the skin (i.e. shaving, abrasion and cleaning with alcohol) in accordance with the recommendations of SENIAM, the electrodes were placed along the presumed muscle fiber direction of the rectus femoris, vastus lateralis, vastus medialis, biceps femoris and gluteus maximus of the left leg (Hermens et al., 2000; Aagaard et al., 2002) (Figure 2). To minimize noise from the surroundings, the raw EMG signals were amplified and filtered using a preamplifier located near to the sampling point. The preamplifier had a common mode rejection ratio of 106 dB and an 8 - 600 Hz sampling frequency. The raw EMG signals were sampled at a 1000 Hz frequency and band pass filtered (fourth order Butterworth filter) with a cutoff frequency of 20 Hz and 500 Hz. The EMG signals were converted to root mean square (RMS) signals using a hardware circuit network (frequency response 450 kHz, averaging constant 12 ms, total error ± 0.5 %). The mean EMG amplitudes of the three whole repetitions (eccentric and concentric phases) in the dynamic tests were used for the calculation of the RMS values used in the analyses (Saeterbakken and Fimland, 2012).

In accordance with previous studies and recommendations (Hermens et al., 2000; Saeterbakken et al., 2019), the recorded EMG amplitudes (average across three repetitions) during the dynamic tests were normalized to the respective values collected during the maximum voluntary isometric contraction (MVIC). The MVIC EMG activity was measured with the machines fixed in a 1) 90° knee angle in the knee extension machine for the vastus lateralis, vastus medialis and rectus femoris (Pincivero et al., 2004), 2) 150° hip angle (180° = full extension) in the kickback machine for the gluteus maximus, and 3) 170° knee angle in a leg curl machine (Technogym Selection; Cesena, Italia) for the biceps femoris (Kellis et al., 2017) (Figure 3). The joint angle during the gluteus maximus MVIC was chosen because 150° was the greatest common angle that could be tested dynamically during both kickback and leg press. Three attempts were given in each exercise with two minutes rest between. The MVIC EMG was recorded while exerting maximal force for five seconds, of which the mean of the three seconds with the highest EMG amplitude from the best attempt was used for normalization (Saeterbakken et al., 2019). The normalization was performed by dividing the average EMG amplitude across three repetitions by the recorded MVIC EMG and multiplying by 100 ((dynamic EMG / MVIC EMG) × 100).

Figure 3. Positioning during the leg curl maximum voluntary isometric contraction for the biceps femoris muscle.

Statistical analyses

SPSS version 25.0 (SPSS, Inc., Chicago, Illinois, USA) was used for statistical analyses. Shapiro-Wilk tests demonstrated the data to be normally distributed (p=0.138-0.776). Paired samples *t*-tests were used to compare the EMG amplitude between exercises. As five comparisons were made (one for each muscle, between two exercises), statistical significance was accepted at $P \leq 0.01$. The results are presented as means with 95% confidence interval (95% CI) and Cohen's *d* effect size (ES) for the difference between exercises. The ES were interpreted as follows: trivial, < 0.2; small, 0.2 - 0.5; medium, 0.5 - 0.8; and large, > 0.8 (Cohen, 1988).

Results

When comparing leg press and kickback, the EMG amplitude of gluteus maximus was not significantly different between the exercises (p = 0.898), whereas biceps femoris demonstrated a 76.0 % (95% CI = 50.8 – 101.2 %; p <

0.001) higher activity during the kickback compared to the leg press (see Table 2).

For vastus lateralis 17.6 % (95% CI = 7.2 – 27.9 %; *p* = 0.003) higher EMG amplitude was observed during the leg press compared to the knee extension. For rectus femoris, the knee extension demonstrated a 24.3 % (95% CI = 10.5 – 38.1 %; *p* = 0.002) higher activity than the leg press. No significant difference was wound between the exercises for vastus medialis (see Table 2).

Table 2. Normalized EMG values (percent of maximal voluntary isometric contraction) in the three exercises.

	Leg press	Kickback	Knee extension	*p* value	Effect size
Gluteus maximus	88.0 (47.7 - 128.3)	77.0 (53.4 - 100.7)	.	0.898	0.08
Biceps femoris	30.6 (19.7 - 41. 4)	106.5 (72.4 - 140.7)	.	<0.001*	2.27
Vastus lateralis	105.5 (92.7 - 118.3)	.	87.9 (79.7 - 96.2)	0.003*	0.92
Vastus medialis	92.9 (75.0 - 110.8)	.	78.8 (67.5 - 90.1)	0.025	0.56
Rectus femoris	69.5 (57.7 - 84.2)	.	93.8 (81.8 - 105.8)	0.002*	0.93

Values are given as mean (95% confidence interval) with *p*-value and Cohen's *d* effect size for the between-exercise difference.
* = statistically significant difference (p < 0.01)

Discussion

The present study assessed and compared the EMG amplitudes of the superficial hip and knee extensors during the leg press, kickback, and knee extension. In agreement with the hypothesis and previous observations (Ema et al., 2016; Enocson et al., 2005; Stensdotter et al., 2003), EMG amplitudes of the biarticular rectus femoris muscle was reduced during the leg press compared to the knee extension. As contraction of the muscle contributes to hip flexion as well as knee extension (Ema et al., 2016), it is not surprising that the muscle activity is down-regulated during leg press to allow for simultaneous knee- and hip extension. A novel finding of the present study was that the same phenomenon occurred for the biarticular biceps femoris muscle. The biceps femoris EMG amplitude is likely reduced during the leg press to allow for simultaneous knee- and hip extension, as previously postulated for the semimembranosus and semimembranosus (Fujiwara and Basmajian, 1975; Yamashita, 1988). Moreover, higher biceps femoris activation has been observed in near full knee extension compared to smaller knee angles during isometric knee flexion (Beyer et al., 2019). While a 170° knee joint angle was only reached near the top position during the leg press, the knee was in a constant 170° angle throughout the movement during the kickback, allowing for a longer duration in the position allowing for the highest EMG amplitude.

As expected, vastus medialis demonstrated no difference in activation between exercises. In contrast with the hypothesis, however, higher EMG amplitude of the monoarticular knee extensor vastus lateralis was observed during the leg press compared to the knee extension. This finding contrasted with several previous investigations that have reported similar EMG amplitude of the vasti muscles during knee extension and leg press or back squat (Alkner et al., 2000; Ema et al., 2016; Enocson et al., 2005; Escamilla et al., 1998; Wilk et al., 1996). It could be argued that the higher total load lifted in the leg press compared to the knee extension (98.3 *vs.* 43.2 kg) caused the higher activity of the vastus lateralis (Lawrence et al., 2018). However, since the relative loads used in the two exercises were identical, the load should not affect the outcome (Andersen et al., 2014; Saeterbakken and Fimland, 2013). Alternatively, since the exercises were performed unilaterally, a higher EMG amplitude of the vastus lateralis could have been produced to stabilize the knee joint while performing the leg press. Finally, the rectus femoris EMG amplitude was reduced during the leg press and the muscle acts as both an agonist (hip extension) and antagonist (knee extension) in this exercise. Hence, it can be speculated that its contribution in the movement was reduced, thereby placing a greater stress on the vasti muscles, especially the vastus lateralis, for extending the knee in this exercise.

In line with the hypothesis for the gluteus maximus, similar EMG amplitude was observed during the leg press and the kickback. It should be noted that although the change in hip joint angle was identical for the leg press and kickback (Δ=90°), the bottom and top positions were different for the two exercises (90-180° for the kickback and 60-150° for the leg press). The similar EMG amplitude observed during the two exercises suggests that utilizing the final 30° of hip extension during the kickback may not produce a higher activity of the gluteus maximus when compared with the leg press. Since the available equipment limited the range of motion that could be examined for the gluteus maximus in the leg press (see Figure 1), future studies should examine the gluteus maximus EMG amplitude using identical joint angles between exercises. Although one should use caution when prescribing resistance training recommendations based on surface EMG findings (Vigotsky et al., 2018), the current results could indicate that performing the kickback exercise to target the gluteus maximus is redundant if a leg press variation is included in the training program. This speculation is supported by previous findings suggesting that the incorporation of SJ exercises to a MJ training program will not produce additional benefits (Gentil et al., 2013). Importantly, the current results do support the use of single-joint exercises for targeting rectus femoris and biceps femoris. These findings could have implications for bodybuilders other physique-oriented people, as well as for individuals wishing to increase muscle activity in specific muscles (Stronska et al., 2020).

There were some potential limitations to the present study that should be noted. First, only resistance-trained men were recruited, and the findings may not be generalizable to other populations. Likewise, these findings only reflect the muscle activation of the five superficial hip- and thigh muscles tested, while the activity of other muscles (e.g., semimembranosus, semitendinosus or vastus intermedius) may be different during the three exercises. Furthermore, only machine-based exercises were examined in this study and the results may not be transferable to similar exercises targeting the same muscles (e.g., barbell hip thrust, barbell back squat or machines utilizing other joint angles). Importantly, the experimental tests were conducted using submaximal loads (i.e., three repetitions using the 6RM loads) and none of the participants reported feeling fatigued during the testing. Finally, when interpreting surface EMG results, one should always be wary of the risk of cross talk between neighboring muscles generating inaccurate measurements (Winter et al., 1994).

Conclusion

The present findings demonstrated higher EMG amplitude of the monoarticular vastus lateralis, but not the vastus medialis, during the MJ exercise leg press compared to the SJ exercise knee extension. Conversely, the biarticular rectus femoris and biceps femoris muscles demonstrated greater activity during the SJ exercises, whereas no difference in gluteus maximus activity was found between exercises. Although one should use caution when using surface EMG results to prescribe resistance exercises (Vigotsky et al., 2018), the findings may suggest that the leg press could be a time efficient approach for targeting the gluteus maximus, vastus lateralis and vastus medialis either more or equally as effective as a combination of kickback and knee extension. In order to target the biceps femoris and rectus femoris specifically, the single-joint exercises may be preferable options. These findings could have implications for bodybuilders and other physique-oriented people who wish to target specific muscles in their training to emphasize site-specific muscle growth. However, it should be noted that the combination of knee- and hip extension during the leg press might be more transferable to daily tasks (e.g., raising from a chair or climbing stairs) and sport movements (e.g., running or jumping). Longitudinal studies should examine how the different muscle activation affects the long-term adaptations to the different exercises.

Acknowledgements

The authors would like to thank Matthew Peter Shaw for proof-reading the language of this paper. The authors also thank the volunteers who participated in the study. This study was conducted without and funding from companies, manufactures or outside organizations. The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to declare.

References

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, P. and Dyhre-Poulsen, P. (2002) Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology* **93,** 1318-1326.

ACSM. (2009) American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise* **41,** 687-708.

Alkner, B.A., Tesch, P.A. and Berg, H.E. (2000) Quadriceps EMG/force relationship in knee extension and leg press. *Medicine and Science in Sports and Exercise* **32,** 459-463.

Andersen, L.L., Magnusson, S.P., Nielsen, M., Haleem, J., Poulsen, K. and Aagaard, P. (2006) Neuromuscular Activation in Conventional Therapeutic Exercises and Heavy Resistance Exercises: Implications for Rehabilitation. *Physical Therapy* **86,** 683-697.

Andersen, V., Fimland, M.S., Brennset, O., Haslestad, L.R., Lundteigen, M.S., Skalleberg, K. and Saeterbakken, A.H. (2014) Muscle activation and strength in squat and Bulgarian squat on stable and unstable surface. *International Journal of Sports Medicine* **35,** 1196-1202.

Augustsson, J. and Thomee, R. (2000) Ability of closed and open kinetic chain tests of muscular strength to assess functional performance. *Scandinavian Journal of Medicine and Science in Sports* **10,** 164-168.

Bazyler, C.D., Beckham, G.K. and Sato, K. (2015) The use of the isometric squat as a measure of strength and explosiveness. *Journal of strength and conditioning research* **29,** 1386-1392.

Beyer, E.B., Lunden, J.B. and Russell Giveans, M. (2019) Medial and lateral hamstrings response and force production at varying degrees of knee flexion and tibial rotation in healthy individuals. *International journal of sports physical therapy* **14,** 376-383.

Bosquet, L., Porta-Benache, J. and Blais, J. (2010) Validity of a Commercial Linear Encoder to Estimate Bench Press 1 RM from the Force-Velocity Relationship. *Journal of Sports Science and Medicine* **9,** 459-463.

Choi, J., Lee, M., Lee, J.-K., Kang, D. and Choi, J.-Y. (2017) Correlates associated with participation in physical activity among adults: a systematic review of reviews and update. *BMC Public Health* **17,** 356-356.

Cochrane, D.J., Gabriel, E. and Harnett, M.C. (2019) Evaluating gluteus maximus maximal voluntary isometric contractions for EMG normalization in male rugby players. *Journal of Physical Therapy Science* **31,** 371-375.

Cohen, J. (1988) *Statistical Power for the Behavioral Sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Duffey, M.J. and Challis, J.H. (2007) Fatigue effects on bar kinematics during the bench press. *Journal of Strength and Conditioning Research* **21,** 556-560.

Ema, R., Sakaguchi, M., Akagi, R. and Kawakami, Y. (2016) Unique activation of the quadriceps femoris during single- and multi-joint exercises. *European Journal of Applied Physiology* **116,** 1031-1041.

Enocson, A.G., Berg, H.E., Vargas, R., Jenner, G. and Tesch, P.A. (2005) Signal intensity of MR-images of thigh muscles following acute open- and closed chain kinetic knee extensor exercise – index of muscle use. *European Journal of Applied Physiology* **94,** 357-363.

Escamilla, R.F., Fleisig, G.S., Zheng, N., Barrentine, S.W., Wilk, K.E. and Andrews, J.R. (1998) Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Medicine and Science in Sports and Exercise* **30,** 556-569.

Fujiwara, M. and Basmajian, J.V. (1975) Electromyographic study of two-joint muscles. *American journal of physical medicine* **54,** 234-242.

Gentil, P., Fisher, J. and Steele, J. (2016) A Review of the Acute Effects and Long-Term Adaptations of Single- and Multi-Joint Exercises during Resistance Training. *Sports Medicine* **47,** 843-855.

Gentil, P., Soares, S.R., Pereira, M.C., da Cunha, R.R., Martorelli, S.S., Martorelli, A.S. and Bottaro, M. (2013) Effect of adding single-joint exercises to a multi-joint exercise resistance-training program on strength and hypertrophy in untrained subjects. *Applied Physiology, Nutrition, and Metabolism* **38,** 341-344.

Gómez-López, M., Gallegos, A.G. and Extremera, A.B. (2010) Perceived barriers by university students in the practice of physical activities. *Journal of Sports Science and Medicine* **9,** 374-381.

Harriss, D.J., MacSween, A. and Atkinson, G. (2019) Ethical Standards in Sport and Exercise Science Research: 2020 Update. *International Journal of Sports Medicine* **40,** 813-817.

Hermens, H.J., Freriks, B., Disselhorst-Klug, C. and Rau, G. (2000) Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology* **10,** 361-374.

Kellis, E., Galanis, N., Kofotolis, N. and Hatzi, A. (2017) Effects of hip flexion angle on surface electromyographic activity of the biceps femoris and semitendinosus during isokinetic knee flexion. *Muscles, Ligaments and Tendons Journal* **7,** 286-292.

Khaiyat, O.A. and Norris, J. (2018) Electromyographic activity of selected trunk, core, and thigh muscles in commonly used exercises for ACL rehabilitation. *Journal of Physical Therapy Science* **30,** 642-648.

Kraemer, W.J. and Ratamess, N.A. (2004) Fundamentals of resistance training: progression and exercise prescription. *Medicine and Science in Sports and Exercise* **36,** 674-688.

Krause, D.A., Elliott, J.J., Fraboni, D.F., McWilliams, T.J., Rebhan, R.L. and Hollman, J.H. (2018) Electromyography of the hip and thigh muscles during two variations of the lunge exercise: A cross-sectional study. *International Journal of Sports Physical Therapy* **13,** 137-142.

Lawrence, M.A., Ostrowski, S.J., Leib, D.J. and Carlson, L.A. (2018) Effect of Unstable Loads on Stabilizing Muscles and Bar Motion During the Bench Press. *Journal of Strength and Conditioning Research.* Aug 21.Online ahead of print.

Paoli, A., Gentil, P., Moro, T., Marcolin, G. and Bianco, A. (2017) Resistance Training with Single vs. Multi-joint Exercises at Equal Total Load Volume: Effects on Body Composition, Cardiorespiratory Fitness, and Muscle Strength. *Frontiers in Physiology* **8,** 1105.

Pincivero, D.M., Salfetnikov, Y., Campy, R.M. and Coelho, A.J. (2004) Angle- and gender-specific quadriceps femoris muscle recruitment and knee extensor torque. *Journal of Biomechanic* **37,** 1689-1697.

Saeterbakken, A.H., Chaudhari, A., van den Tillaar, R. and Andersen, V. (2019) The effects of performing integrated compared to isolated core exercises. *PLOS one* **14,** e0212216.

Saeterbakken, A.H. and Fimland, M.S. (2012) Muscle activity of the core during bilateral, unilateral, seated and standing resistance exercise. *European Journal of Applied Physiology* **112,** 1671-1678.

Saeterbakken, A.H. and Fimland, M.S. (2013) Effects of body position and loading modality on muscle activity and strength in shoulder presses. *Journal of strength and conditioning research* **27,** 1824-1831.

Saeterbakken, A.H., Van Den Tillaar, R. and Fimland, M.S. (2011) A comparison of muscle activity and 1-RM strength of three chest-press exercises with different stability requirements. *Journal of Sport Science* **29,** 533-538.

Sale, D. and MacDougall, D. (1981) Specificity in strength training: a review for the coach and athlete. *Canadian Journal of Applied Sport Sciences.* **6,** 87-92.

Stensdotter, A.K., Hodges, P.W., Mellor, R., Sundelin, G. and Hager-Ross, C. (2003) Quadriceps activation in closed and in open kinetic chain exercise. *Medicine and Science in Sports and Exercise* **35,** 2043-2047.

Stronska, K., Golas, A., Wilk, M., Zajac, A., Maszczyk, A. and Stastny, P. (2020) The effect of targeted resistance training on bench press performance and the alternation of prime mover muscle activation patterns. *Sports Biomech* 1-15, May 28. Online ahead of print.

Vigotsky, A.D., Halperin, I., Lehman, G.J., Trajano, G.S. and Vieira, T.M. (2018) Interpreting Signal Amplitudes in Surface Electromyography Studies in Sport and Rehabilitation Sciences. *Frontiers in Physiology* **8,** 985.

Welsch, E.A., Bird, M. and Mayhew, J.L. (2005) Electromyographic activity of the pectoralis major and anterior deltoid muscles during three upper-body lifts. *Journal of strength and conditioning research* **19,** 449-452.

Wilk, K.E., Escamilla, R.F., Fleisig, G.S., Barrentine, S.W., Andrews, J.R. and Boyd, M.L. (1996) A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *American Journal of Sports Medicine* **24,** 518-527.

Winter, D.A., Fuglevand, A.J. and Archer, S.E. (1994) Crosstalk in surface electromyography: Theoretical and practical estimates. *Journal of Electromyography and Kinesiology* **4,** 15-26.

Yamashita, N. (1988) EMG activities in mono- and bi-articular thigh muscles in combined hip and knee extension. *European Journal of Applied Physiology and Occupational Physiology* **58,** 274-277.

Key points

- The differences in EMG amplitudes between single- and multi-joint exercises appears to vary depending on the specific exercises and the muscle groups tested.
- Leg press may be a time efficient approach for targeting the gluteus maximus, vastus lateralis and vastus medialis either more or equally as effectively as a combination of kickback and knee extension.
- Knee extension and kickback may be preferable options for targeting the biceps femoris and rectus femoris specifically.

AUTHOR BIOGRAPHY

Nicolay STIEN

Employment

Scientific assistant (Department of Sport, Food and Natural Sciences, Western Norway University of Applied Sciences, Sogndal, Norway)

Degree

MSc

Research interests

Exercise physiology and sports; strength training

E-mail: nicolay.stien@hvl.no

Atle Hole SAETERBAKKEN

Employment

Associate professor (Department of Sport, Food and Natural Sciences, Western Norway University of Applied Sciences, Sogndal, Norway)

Degree

PhD

Research interests

Exercise physiology and sports; strength training

E-mail: atle.saeterbakken@hvl.no

Vidar ANDERSEN

Employment

Associate professor (Department of Sport, Food and Natural Sciences, Western Norway University of Applied Sciences, Sogndal, Norway)

Degree

PhD

Research interests

Exercise physiology and sports; strength training

E-mail: vidar.andersen@hvl.no

✉ **Nicolay Stien**

Faculty of Education, Arts and Sports, Western Norway University of Applied Sciences, Norway