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RESEARCH ARTICLE

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Quadriceps and gluteus medius activity during stable and unstable loading exercises in athletes. A cross-sectional study

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Abstract

The aim of this study was to evaluate the muscle activation of the vastus medialis, vastus lateralis, and gluteus medius during different strength and stability exercises with a water tank compared with a sandbag. A cross-sectional study was conducted in the Functional Anatomy Laboratory, and the sample consisted of 28 athletes. The main outcome measures were surface electromyography (dependent variable), water tank and sandbag, and exercise type (independent variables): Isometric Single Leg Stance (ISLS), One Leg Deadlift (OLDL), Front Rack Forward Lunge (FRFL), and Lateral Lunge (LL). Repeated measures analysis of variance (ANOVA) revealed a significant Group × Time interaction in gluteus medius root mean square (RMS) ($F = 14.198$, $p < 0.001$, $\eta 2 = 0.35$), vastus lateralis RMS ($F = 24.374$, $p < 0.001$, $\eta 2 = 0.47$), and vastus medialis RMS ($F = 27.261$, $p < 0.001$, $\eta 2 = 0.50$). In the between-group analysis, statistically significant differences were observed in gluteus medius RMS in the ISLS: 28.5 ± 15.8 water tank and 20.8 ± 12.6 sandbag ($p < 0.001$, $\eta 2 = 0.08$) and OLDL: 29.7 ± 13.3 water tank and 26.5 ± 13.1 sandbag ($p < 0.001$, $\eta 2 = 0.01$). In vastus lateralis in ISLS: 30.4 ± 37.6 water tank and 19.0 ± 26.7 sandbag ($p < 0.001$, $\eta 2 = 0.03$). In vastus medialis in ISLS: 14.2 ± 13.0 water tank and 7.0 ± 5.6 sandbag ($p < 0.001$, $\eta 2 = 0.12$), OLDL: 21.5 ± 16.9 water tank and 15.5 ± 10.7 sandbag ($p = 0.002$, $\eta 2 = 0.04$), and LL: 51.8 ± 29.6 water tank and 54.3 ± 29.3 sandbag ($p = 0.017$, $\eta 2 = 0.00$). These results confirm significantly greater activation of the gluteus medius and vastus medialis in the ISLS and OLDL exercises, and of the vastus lateralis in the water tank ISLS exercise. However, the vastus medialis shows greater activation in the LL exercise.

KEYWORDS

electromyography, knee, sandbag, water tank

Carlos López-de-Celis and Núria Sánchez-Alfonso contributed equally to this study.

1 | INTRODUCTION

The anterior cruciate ligament,[1,2] the knee instability,[3] and the patellofemoral pain[4] are three of the most common knee pathologies. The capacity of activation and reaction to stimuli of the lower limb musculature, especially the quadriceps and gluteus muscles, is highly correlated with these pathologies.[5] In addition, these lack of activation of the musculature can appear before and after the injury[6,7] and may persist for more than 20 years.[8] In relation to the gluteus medius, it has been found to have an important relationship with knee alignment.[9] In fact, gluteus medius activation problems could lead to increased knee valgus, and may produce anterior knee pain, instability, and an increased risk of anterior cruciate ligament injury.[1,9]

Performing single-leg exercises is of paramount importance to improve knee functionality.[10] These specific exercises help strengthen and stabilize the muscles in the lower extremities, thereby enhancing coordination and neuromuscular control.[11] By working unilaterally, it is possible to identify and correct muscle imbalances and asymmetries in leg and trunk coordination, which is particularly relevant in the context of an anterior cruciate ligament injury and its rehabilitation.[12] Moreover, single-leg exercises challenge the body in a different way, as they require greater effort to maintain balance and stability, thereby improving proprioception and the ability to respond to perturbations.[13] Collectively, these exercises promote greater knee functionality,[14] helping to prevent future injuries and enhance performance in daily activities and high-impact sports.[15]

Unstable loads without using surface-induced instability are commonly used in muscle rehabilitation for various injuries,[16] as the muscle adaptations that occur contribute to increased strength and neuromuscular coordination.[16] Water tank is a novel device that generates greater destabilization. This device is used to generate minor but rapid perturbations due to inertial changes in the movement of the water inside the tube. During exercise and/or training with this device, the internal redistribution of the water within the device creates conditions where the muscle has to activate quickly to maintain stability.[16]

Not many studies have been carried out with the water tank. Ditroilo et al.,[16] studied core muscle activation during the squat with the water tank and observed higher activation of the trunk stability muscles during squat execution compared with the traditional barbell. Glass et al.[17] studied core muscle activation during the unstable biceps curl using the water tank and found superior activation to other studies in the paraspinal and abdominal muscles compared with a conventional barbell. Furthermore, this same author in 2018 found similar results in core activation during the overhead squat exercise with the water tank compared with a conventional barbell overhead squat.[18]

To date, the level of activation of the vastus medialis, vastus lateralis, and gluteus medius muscles when rehabilitation exercises are performed with a higher unstable load (water tank) is unknown. Therefore, the aim of this study is to evaluate the muscle activation of the vastus medialis, vastus lateralis, and gluteus medius during the execution of different strength and stability exercises with a water tank in comparison with exercises with a stable load.

2 | METHODS

2.1 | Design and participants

A cross-sectional study was conducted in the research laboratory of Universitat Internacional de Catalunya. With level 3 of evidence.

The local ethics committee of Universitat Internacional de Catalunya–CER (Comitè Ètic de Recerca) approved the study protocol (study Code: FIS-2022-08).

The study procedures were conducted following the declaration of Helsinki.[19] Informed consent was obtained from all participants.

Between September 2021 and May 2022, 32 athletes from the Faculty of Medicine and Health Sciences of the Universitat Internacional de Catalunya were selected for meeting the eligibility criteria to participate voluntarily after signing the informed consent form. The inclusion criteria were people between 18 and 35 years of age who exercised at least three times a week. Exclusion criteria were not being injured or in the process of recovering from an injury and not understanding the information provided by the physiotherapist. Finally, 28 (18 men, and 10 women) satisfied all eligibility criteria and agreed to participate. The description of the sample is in Table 1.

TABLE 1 Description of the sample.

	Mean ± SD or *n* (%)
Age (years)	24.5 ± 4.0
Weight (Kg)	71.5 ± 7.8
Height (cm)	174.4 ± 6.2
BMI (Kg/m^2)	23.5 ± 1.9
Dominance	
Right, *n* (%)	19 (67.9%)
Left, *n* (%)	9 (32.1%)
Type of sport	
Fitness	14 (50%)
Running	14 (50%)
Training days per week	
3	15 (53.6%)
4	5 (17.9%)
5	6 (21.4%)
6	2 (7.1%)

Abbreviation: BMI, body mass index.

2.2 | Sample size

The main variable was surface electromyography, based on a similar study by Calatayud et al.[20] The sample size was calculated using the GRANMO 7.12 program, performing a two-sided test analysis, and assuming an α risk of 0.05 and a β risk of 0.20. The common standard deviation and the minimum differences to be detected between interventions (water tank and sandbag) were determined based on the study by Calatayud et al.[20] on the comparison of different training methods and electromyographic muscle activity. A common standard deviation of 5.9 and a minimum difference to be detected of 7.0 were used. The result was that 28 subjects.

2.3 | Randomization and allocation

The randomization was carried out in relation to the order in which the different exercises were performed. All subjects performed all exercises but in a different order. For the randomization process, an external evaluator generated a randomization list before recruiting the athletes with a computer program (www.random.org) that generated a list of sequential numbers (1–28). The randomization was kept in a concealed envelope until the time of the exercise.

2.4 | Procedures

2.4.1 | Electromyography

The reliable and validated surface electromyography (sEMG) mDurance® system (mDurance Solutions SL) was used to record muscle activity during a functional task (ICC = 0.916; 95% confidence interval [CI] = 0.831–0.958).[21] The muscles assessed were the vastus lateralis, vastus medialis, and gluteus medius of the dominant limb. The method used to determine the dominance limb was self-report.[22]

The mDurance® system consists of an EMG Shimmer3 unit (Realtime TechnologiesLtD). This unit is a bipolar surface electromyography bipolar sensor for the acquisition of muscle activity. The common mode rejection ratio was 110 dB. Each Shimmer3 has two channels, with a sampling rate of 1024 Hz applying a bandwidth of 8.4 Hz, and a 24-bit signal with an overall amplification of 100e10000 V/V.[21]

On the other hand, the mDurance Android app receives the data from the Shimmer3 and sends them to a cloud service[21] where the data are stored, filtered, and analyzed.[21]

For the processing and filtering of the raw data, both isometric and dynamic tests were filtered using a fourth-order Butterworth bandpass filter with a cut-off frequency of 20–450 Hz. The signal was smoothed using a window size of 0.025 s root mean square (RMS) and an overlapping of 0.0125 s between windows.[21] The Maximal Voluntary Isometric Contraction (MVIC) was calculated using the peak of the RMS signal during an isometric test, which is carefully explained below. The principal variable recorded for muscle activity was mean RMS expressed as % of MVIC. A moving RMS smoothing filter was applied to the EMG signals, implemented with a 500 ms window (250 ms backward and 250 ms forward) for each signal sample. The signal was analyzed by the average.[21]

The subject's skin was cleaned with alcohol and was dried before the electrodes were placed. If hair impeded the correct adhesion of the electrodes to the skin, the particular site was shaved. Self-adhesive 5 cm Valutrode® surface electrodes were placed on the muscle belly according to the SENIAM project recommendations[23] and with an interelectrode distance of 20 mm.[21]

In vastus lateralis, electrodes were placed at 2/3 on the line from the anterior iliaca superior to the lateral side of the patella.[23] In vastus medialis, electrodes were placed at 80% on the line between the anterior spina iliaca superior and the joint space in front of the anterior border of the medial ligament.[23] In gluteus medius, electrodes were placed at 50% on the line between the anterior crista iliaca to the trochanter.[23] The reference electrode was placed o the head of the fibula.[23]

Before performing the different types of exercise, a maximal voluntary isometric contraction test was performed to normalize the data. Participants performed a 5-s maximal contraction against a fixed strap to ensure that maximal force was always isometric.[9] They were positioned lying on their side to perform hip abduction (gluteus medius) and seated with 90° knee flexion for knee extension (vastus medialis and vastus lateralis).[9] The MVIC of each muscle was obtained from the mean of three maximal repetitions leaving 30 s of recovery between each repetition.

2.4.2 | Water tank

It is a cylindrical instrument in which water is introduced. Thanks to this water, an instability that disturbs the position of the body in a dynamic position without the need to modify the support base of the subject itself is produced. The disruptive and unpredictable forces that are provided by water tanks require continuous body stabilization, especially when high speeds are used.[20]

2.4.3 | Sandbag

In the case of the sandbag, it is also a cylindrical instrument. The main difference is that it is filled with sand instead of water and the load is stable.

In this case, the instability that occurs in the subject is less than with the water tank because the sand is more stable than the water.

2.4.4 | Types of exercise

All exercises were performed with the subject barefoot and with eyes open. All exercises were performed with both the water tank and the sandbag. All participants performed the four exercises with the water tank and the four exercises with the sandbag in randomized order. Both the water tank and the sandbag weighed 10 Kg. At the beginning of each exercise, the water in the water tank was motionless. Subjects were informed to take the tank as shown in Figure 1. Participants rested 3 min between each type of exercise.[24]

Isometric Single Leg Stance (ISLS): With the dominant leg in contact with the ground, a 10-s isometric stance was maintained. The dominant leg was in contact with the ground and the other extremity at 90° of hip flexion with knee at 90° flexion and ankle at 90° dorsal flexion[25] (Figure 1A).

One Leg Deadlift (OLDL): With the dominant leg in contact with the ground, the subject performed a hip flexion for a subsequent hip extension with the left leg in knee extension. The movement was controlled with approximately 2 s in the concentric phase and two in the eccentric phase. The subject kept the cervical spine in line with the thoracic region. A series of 10 repetitions was performed[26] (Figure 1B).

Front Rack Forward Lunge (FRFL): This exercise consisted of performing large strides without displacement. The dominant leg was placed forward and the nondominant leg behind. The knee of the back leg had to touch the ground on each repetition. The execution time was 1 s for each muscle contraction phase. Knee valgus was controlled. A series of 10 repetitions were performed.[24] The distance that the subjects stepped forward during the lunge was adjusted to 65% of their leg length[27] (Figure 1C).

Lateral Lunge (LL): From a bipodal position, the subject sought to perform a unilateral triple flexion-extension movement to the side and return to the initial position. The leg that did not perform the triple flexion-extension remained in knee extension. A series of 10 repetitions were performed.[24] The distance that the subjects stepped sideways during the lunge was adjusted to 80% of their leg length[27] (Figure 1D).

2.4.5 | Study procedure

Once the patient decided to participate in the study and signed the informed consent, the principal investigator checked the randomization of that subject.

A second investigator asked the subject for different baseline characteristics (age, sex, weight, height, body mass index, and lower extremity dominance). In addition, the subjects were asked about the sport he/she practiced and the days he/she practiced it per week.

Next, each subject had 15 min to perform a short warm-up according to his or her needs. They were allowed to perform joint mobility and/or stretching. They then had another 15 min led by the therapist to familiarize themselves with the exercises and with the water tank and the sandbag. In these 15 min, the different exercises were explained to the athletes, and they performed a maximum of two repetitions per exercise.

Next, the second investigator placed the electrodes as previously explained. The normalization was performed through MVIC (knee extension for vastus lateralis/medialis and hip abduction for gluteus

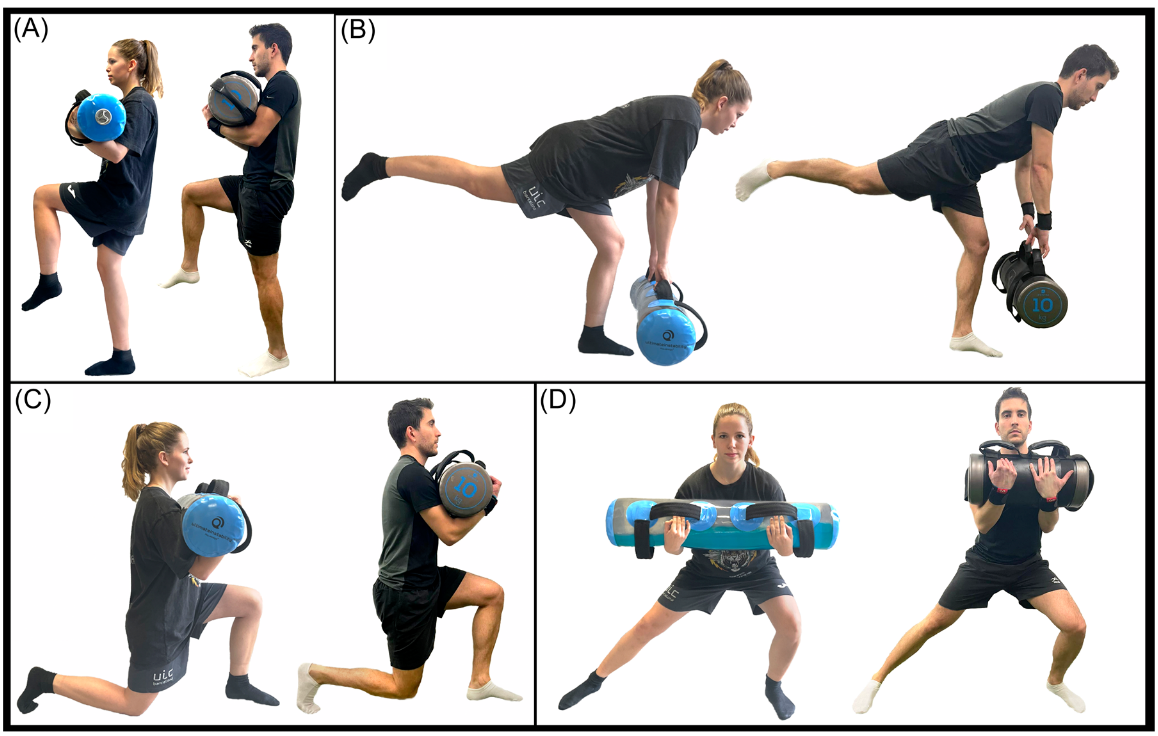

FIGURE 1 Types of exercise. (A) Isometric Single Leg Stance with water tank (left) and sandbag (right). (B) Single Leg Deadlift with water tank (left) and sandbag (right). (C) Front Rack Forward Lunge with water tank (left) and sandbag (right). (D) Lateral Lunge with water tank (left) and sandbag (right).

medius). Immediately afterwards, the different types of exercises were performed. The principal investigator oversaw guiding the exercises and the second investigator oversaw controlling the surface electromyography.

2.4.6 | Statistical analysis

Statistical analysis was performed using the SPSSv.20 statistical package. The Shapiro–Wilk test was used to assess the normal distribution of the variables. Descriptive statistics were performed for all the variables. A linear mixed model (ANOVA) with type of exercise (ISLS, OLDL, FRFL, and LL) and group (water tank/Sandbag) was conducted for determine changes in electromyography. Effect sizes were calculated using eta squared (η^2). Considering an effect size >0.14 as large; around 0.06 are medium; and <0.01 small.[28] If significant differences existed, the Bonferroni post hoc correction was performed to determine differences between the type of exercise and group. The statistical analysis was performed on an intention-to-treat basis. The level of significance was set at $p < 0.05$.

3 | RESULTS

Table 2 shows RMS differences between water tank and sandbag in the different exercises. Figure 2 shows the activation level (RMS) for each exercise.

The repeated measures ANOVA revealed significant Group × Time interaction in gluteus medius RMS ($F = 14.198$, $p < 0.001$, $\eta^2 = 0.35$), in vastus lateralis RMS ($F = 24.374$, $p < 0.001$, $\eta^2 = 0.47$) and in vastus medialis RMS ($F = 27.261$, $p < 0.001$, $\eta^2 = 0.50$).

In the within-group analysis of gluteus medius RMS we only found statistically significant differences in the Sandbag group between ISLS and OLDL ($p < 0.001$, $\eta^2 = 0.05$).

In the within-group analysis of vastus lateralis RMS there were statistically significant differences in the Sandbag group between ISLS and OLDL ($p < 0.001$, $\eta^2 = 0.03$), ISLS and LISK ($p < 0.001$, $\eta^2 = 0.24$), ISLS and FRFL ($p < 0.001$, $\eta^2 = 0.23$), OLDL and LISK ($p = 0.029$, $\eta^2 = 0.05$), OLDL and FRFL ($p = 0.009$, $\eta^2 = 0.05$). For the water tank group, we found statistically significant differences between ISLS and FRFL ($p = 0.004$, $\eta^2 = 0.05$), OLDL, and FRFL ($p = 0.022$, $\eta^2 = 0.03$).

Finally, in the within-group analysis of vastus medialis RMS there were statistically significant differences in the Sandbag group between ISLS and OLDL ($p < 0.001$, $\eta^2 = 0.20$), ISLS and LISK ($p < 0.001$, $\eta^2 = 0.56$), ISLS and FRFL ($p < 0.001$, $\eta^2 = 0.63$), OLDL and LISK ($p < 0.001$, $\eta^2 = 0.44$), OLD and FRFL ($p < 0.001$, $\eta^2 = 0.47$). For the water tank group, we found statistically significant differences between ISLS and OLDL ($p = 0.006$, $\eta^2 = 0.06$), ISLS and LISK ($p < 0.001$, $\eta^2 = 0.41$), ISLS and FRFL ($p < 0.001$, $\eta^2 = 0.50$), OLDL and LISK ($p < 0.001$, $\eta^2 = 0.28$), OLDL and FRFL ($p < 0.001$, $\eta^2 = 0.32$).

In the between-group analysis, we found statistically significant differences in RMS in gluteus medius in ISLS ($p < 0.001$, $\eta^2 = 0.08$) and OLDL ($p < 0.001$, $\eta^2 = 0.01$). In vastus lateralis in ISLS ($p < 0.001$, $\eta^2 = 0.03$). In vastus medialis in ISLS ($p < 0.001$, $\eta^2 = 0.12$), OLDL ($p = 0.002$, $\eta^2 = 0.04$) and LL ($p = 0.017$, $\eta^2 = 0.00$).

4 | DISCUSSION

This study aimed to evaluate the muscle activation of the vastus medialis, vastus lateralis, and gluteus medius during the execution of different exercises with water tank compared with a stable load

TABLE 2 Differences between water tank and sandbag.

		Water tank Mean ± SD	Sandbag Mean ± SD	Diferencia [95%CI]	p	η^2
Gluteus medius RMS	ISLS	28.5 ± 15.8	20.8 ± 12.6	7.6 [4.2; 11.1]	<0.001	0.08
	OLDL	29.7 ± 13.3	26.5 ± 13.1	3.3 [1.9; 4.6]	<0.001	0.01
	LL	24.5 ± 9.4	25.2 ± 9.7	−0.7 [−1.6; 0.2]	0.111	0.00
	FRFL	27.0 ± 1.6	26.4 ± 13.0	0.6 [−2.5; 1.3]	0.518	0.00
Vastus lateralis RMS	ISLS	30.4 ± 37.6	19.0 ± 26.7	11.5 [6.2; 16.7]	<0.001	0.03
	OLDL	33.7 ± 39.9	31.1 ± 39.3	2.6 [−0.3; 5.7]	0.080	0.00
	LL	44.4 ± 21.5	45.9 ± 20.9	−1.5 [−3.2; 0.3]	0.108	0.00
	FRFL	45.4 ± 25.6	46.3 ± 23.1	−0.9 [−3.3; 1.5]	0.441	0.00
Vastus medialis RMS	ISLS	14.2 ± 13.0	7.0 ± 5.6	7.1 [3.8; 10.5]	<0.001	0.12
	OLDL	21.5 ± 16.9	15.5 ± 10.7	6.0 [2.5; 9.6]	0.002	0.04
	LL	51.8 ± 29.6	54.3 ± 29.3	−2.5 [−4.5; −0.5]	0.017	0.00
	FRFL	45.4 ± 18.1	47.1 ± 20.8	−1.6 [−3.8; 0.6]	0.138	0.00

Abbreviations: η2, eta square effect size; FRFL, Front Rack Forward Lunge; ISLS, Isometric Single Leg Stance; LL, Lateral Lunge; OLDL, One Leg Deadlift.

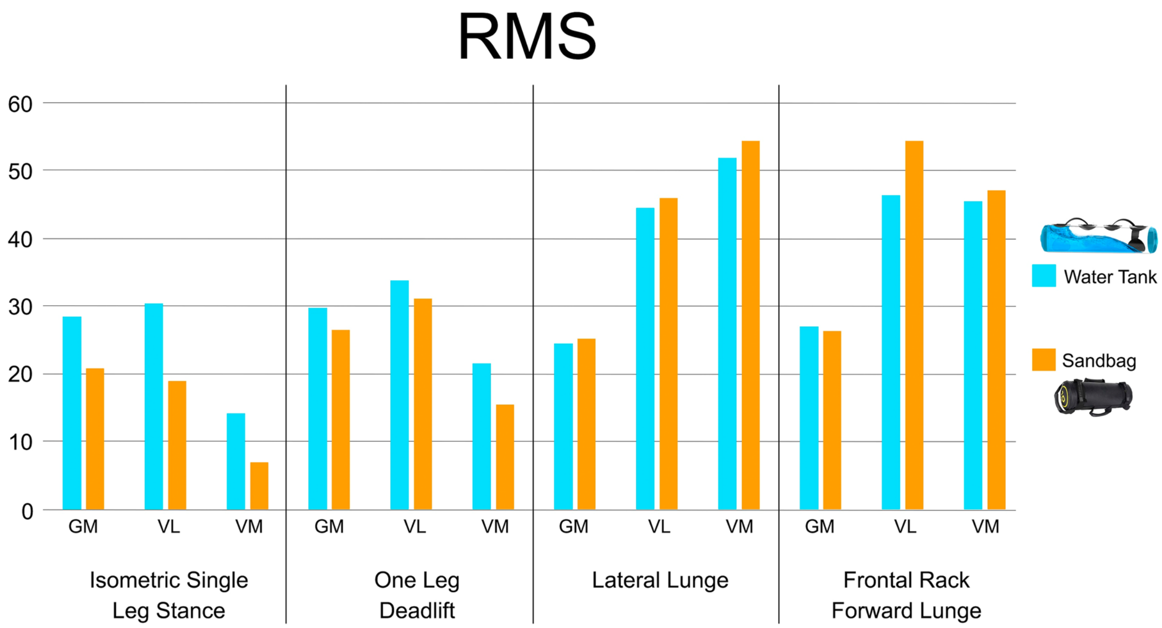

FIGURE 2 Activation level (RMS) for each exercise. FRFL, Front Rack Forward Lunge; GM, Gluteus Medius; ISLS, Isometric Single Leg Stance; LL, Lateral Lunge; OLDL, One Leg Deadlift; VL, Vastus Lateralis; VM, Vastus Medialis.

(sandbag). The results show that there is higher activation of gluteus medius and vastus medialis in ISLS and OLDL exercises and a higher activation of vastus lateralis in ISLS exercise with water tank compared with sandbag. However, there is a higher activation of the vastus medialis in LL exercise with sandbag. In FRFL there is no differences between water tank and sandbag in any muscle evaluated.

Training with external components that cause instability is designed to provide real-time perturbations to the body, requiring instantaneous compensatory adjustments in muscle activation.[16,29] The water tank generates a different weight distribution during exercise due to the unpredictable movements of the water and requires muscle activation to compensate and keep the tube stable during exercise.[17] The gluteus medius plays a fundamental role as a hip stabilizer during different functional activities and contributes to maintaining good balance.[30–32] In relation to activation levels, Muyor et al. 2020[24] performed exercises like those performed in our study but with 5RM (60% of the maximum weight). The results of our study show a greater activation of the gluteus medius with the water tank than that obtained in the study of Muyor et al. 2020[24] with the 5RM. These results reinforce the hypothesis that an unstable load promotes the activation of stabilizing musculature such as the gluteus medius.

Vastus lateralis and vastus medialis are considered the main global motors and power generators in knee extension.[24,33] In the case of the quadriceps musculature, other studies[24,33] observed a higher activation than we found in our study. It is possible that this trend is because these studies use loads close to 80%[24] or even close to 1RM (100% of the maximum weight),[33] which promotes the activation of musculature considered as potentiating. These results suggest that exercises performed with unstable loads such as the water tank or with low stable loads such as the sandbag, can be useful for the different phases of recovery where progressive load management is required.[34] An important result is that a higher activation of all muscles is observed when the exercise is monopodial (ISLS and OLDL). However, when the exercise is bipodal (LL and FRFL) we observed practically any difference between stable and unstable loading. Within unipodal exercises, in the case of the ISLS exercise, gluteus medius activation is similar to other studies with unstable.[35]

If we focus on bipodal exercises (LL and FRFL), our study has shown increased muscle activation compared with the same exercises performed without loading.[36] These findings suggest that there is greater muscle recruitment when including the sandbag and water tank. In addition, FRFL has been observed to show vastus lateralis and medialis activation with water tank similar to other studies using stable loads with a 5RM.[24] These findings could be interesting for training and rehabilitation of patients who are unable to perform exercises with high weight loads. This result seems logical since in monopodial positions the subject's balance is lower and a greater imbalance produced by the water tank will generate a higher muscular response. There are studies that observed higher muscle electromyographic activation in isometric exercises compared with dynamic exercises,[37] especially when concerns exercise to improve balance and ankle motor control.[38] In this study, in both ISLS and OLDL exercises, the subject kept the dominant leg constantly in contact with the ground while the other limb was not in contact with the ground. Probably, this situation increases the need for balance.

It is common to find deficits in muscle activation after a knee injury.[7,39,40] Groppa et al.[41] found that decreased cortical excitability means that knee-injured patients need more stimulation to yield sufficient excitation in the primary motor cortex to generate muscle activation. For this reason, with the results obtained, it seems interesting to use exercises with unstable loads to increase muscle activation in these patients.

Several studies suggest that there is a decreased rate of quadriceps torque development which would limit rapid force production in knee-injured populations.[42,43] This may be due to an increased neural processing time or a delay in the transmission of force within the muscle and/or tendon.[44,45] Rapid force production may be more relevant to daily life activities and sports than maximum strength, as most of these activities require a quick muscle response.[42,43] Therefore, the rate of torque development may be an important descriptor of muscle function[7] and exercises with unstable loads seem to be an incentive to increase muscle activation and reaction to external stimuli.

Regarding the increased gluteus medius activation in monopodial exercises (ISLS and OLDL) with the water tank, there is a relationship with knee alignment.[9] For that reason, increased gluteus medius activation with these exercises may contribute to a decrease in knee valgus, and thus to a reduced risk of knee injury.[1,9]

There are other studies that have obtained similar results to ours in other regions of the body. Baritello et al.[46] found that training with an unstable weight mass elicited higher muscle activity in the shoulder muscles when compared with a weight with stable mass behavior. Lawrence et al.[47] observed that suspending barbell weights with elastic bands can increase trunk stabilizing muscle activity more than free weights.

Our study found several limitations. No kinematic analysis of the lower limbs or trunk was performed to give more relevant information on joint angles and velocities. Electromyography has not been performed on other knee stabilizing muscles, such as the hamstrings, gastrocnemius, and soleus due to the lack of electromyographic channels. The authors decided not to protocolize the first 15 min of mobility since each athlete has his or her own way of warming up. Although the following 15 min of activation were the same for all athletes, this condition could make a difference during the performance of the exercises. The authors suggest future studies with training programs in patients with knee injuries with stable and unstable loads. In this way, we will be able to know the improvement in muscle activation and prevention of new injuries in these patients.

4.1 | Practical applications

This study found that exercises with unstable loads generate greater muscle activation in vastus lateralis and gluteus medius in exercises with monopodial support and greater activation in vastus medialis with stable load. In bipodal support, no differences are observed between stable and unstable loads.

After a knee injury, there is an activation deficit, so it would be interesting to use this resource to improve muscle activation in these patients. In addition, these patients may benefit from the increased stimulation caused by the instability generated by the water tank and stable with the sandbag. Improving gluteal muscle activity with monopodial exercises using unstable loads could reduce the risk of injury. With these data, any medical or performance personnel associated with athletics or physically active individuals will be able to select stable or unstable loads depending on the musculature that prefers to stimulate for the athletes.

5 | CONCLUSION

In conclusion, there is a significantly higher activation of gluteus medius and vastus medialis in ISLS and OLDL exercises and a significantly higher activation of vastus lateralis in ISLS exercise with unstable load compared with stable load. However, there is a higher activation of the vastus medialis in LL exercise with stable load compared with unstable load.

AUTHOR CONTRIBUTIONS

Carlos López-de-Celis: Investigation; methodology; project administration; resources; writing—original draft; writing—review and editing. **Núria Sánchez-Alfonso**: Investigation; methodology; project administration; resources; supervision; writing—original draft; writing—review and editing. **Jacobo Rodríguez-Sanz**: Data curation; formal analysis; writing—original draft; writing—review and editing. **Sergi Romaní-Sánchez**: Investigation; writing—review and editing. **Noé Labata-Lezaun**: Data curation; formal analysis; resources; writing—review and editing. **Max Canet-Vintró**: Investigation; resources; writing—review and editing. **Ramon Aiguadé**: Investigation; writing—review and editing. **Albert Pérez-Bellmunt**: Investigation; methodology; project administration; resources; supervision.

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