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Sport Performance

Effects of Whole Body Electromyostimulation Training on Maximum and Explosive Strength of Trained Female. A Pilot Study

Efectos de la Electromioestimulación Integral en la Fuerza Máxima y Explosiva en Mujeres Entrenadas. Un Estudio Piloto

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RESUMEN

Este estudio tuvo como objetivo explorar el impacto del entrenamiento con electroestimulación integral (WB-EMS) en la fuerza máxima y explosiva de mujeres físicamente activas y con experiencia en entrenamiento de fuerza. Participaron en el estudio diez mujeres con experiencia en entrenamiento. Realizaron entrenamiento de fuerza durante 6 semanas asignadas al azar al grupo control o WB-EMS. Las participantes realizaron dos sesiones de entrenamiento por semana, consistiendo en press de banca, remo, peso muerto y sentadilla con una carga del 85% de la repetición máxima (1RM), y usaron un transductor de posición lineal para monitorizar la velocidad de movimiento deteniendo el ejercicio cuando la velocidad bajó un 10%. La frecuencia de electroestimulación se estableció en 85Hz, el pulso fue de 350µs y tipo de pulso de onda rectangular bipolar. Los datos mostraron que la fuerza máxima, la velocidad máxima y el número máximo de repeticiones bajo una carga específica aumentaron significativamente ($P \leq 0.05$) en press de banca, sentadilla, remo y peso muerto en el grupo de entrenamiento con WB-EMS en comparación con el grupo control. Además, el rendimiento de salto en salto squat (SJ), salto con contra movimiento (CMJ) y salto Abalakov (ABK) fue significativamente mayor en comparación con el grupo control ($P \leq 0.01$). Podemos concluir que el entrenamiento de fuerza con WB-EMS durante 6 semanas mejoró la fuerza máxima y explosiva de mujeres físicamente activas y con experiencia en entrenamiento de fuerza, en comparación con el grupo control.

Palabras Clave: WB-EMS, entrenamiento de resistencia, fuerza máxima, fuerza explosiva

ABSTRACT

This study aimed to explore the impact of whole body electromyostimulation training (WB-EMS) on the maximum strength and explosive power of physically active and experienced in strength training women. Ten females with a sport training background participated in the study. They performed strength training for 6 weeks randomly assigned to either WB-EMS group or control group. Participants performed two training sessions per week, consisted in bench press, rowing, deadlift and squat with a load of 85% one repetition maximum (1RM), and using a linear position transducer to monitor the movement velocity to stop exercise when velocity dropped 10%. WB-EMS frequency was set at 85 Hz, pulse 350 µs, and bipolar rectangular wave pulse type. Data showed that the maximum strength, maximum velocity and maximum number of repetitions under a specific load were significantly increased ($P \leq 0.05$) in bench press, squat, rowing and deadlift in the WB-EMS group compare to the control group. Also, Squat Jump (SJ), Counter Movement Jump (CMJ) and Abalakov Jump (ABK) jumping performance was significantly greater compared to control group ($P \leq 0.01$). We can conclude that WB-EMS strength training for 6 weeks enhanced physically active and experienced in strength training women’s maximum and explosive strength compare to control.

Keywords: WB-EMS, resistance training, maximum strength, explosive strength

INTRODUCTION

Strength training is playing an important role in most sport disciplines, and it has been widely used in sports training. At the same time, strength is also an indispensable part of the victory of competitive sports (Mujika et al., 2016). As all we know, the load intensity is controlled at 65% to 85% of the maximum intensity mainly to increase the muscle fiber hypertrophy, the load intensity exceeds 85% of the maximum intensity mainly due to improve in coordination between the muscles and the maximum strength (Maijiu tian, et al., 2012). However, based on existing research it’s difficulty to reach higher levels of strength and power when the performance level of the athlete is already high. In high-level competitive sports, only minor changes could lead a significant impact on the achievement of the competition (Beattie et al., 2017). There is a chance to use technology to increase the performance threshold in resistance training in order to increase the athlete's opportunity of winning in the competitions.

Electrical stimulation is a technology that applies direct current to muscles or motor nerves that terminate in muscles instead of nerve impulses from the brain to cause muscles to contract. The principle of WB-EMS is the same as that of local electrical stimulation. Both of them use pulse currents of specific frequency, waveform and intensity to replace the nerve impulses from the human brain which is designed according to human requirements. The difference between muscle tension and regular contraction is that local electric stimulation strength training only performs on one or several muscles of the body, and the most common stimulation site is the quadriceps (Jianshe et al., 2000).

Originally, electrical stimulation was a physical therapy method used for injury or muscle repair after surgery. In 1960, when people's muscles and nerves were damaged and unable to carry out normal activities, they often used electrical stimulation of the muscles to prevent muscle atrophy. With the developing of electrical stimulation technology, it is increasing popular for the treatment of secondary central nervous system injury or brain injury. Since 1980, researchers have developed higher-capacity devices that can adjust various forms of electric waves to generate currents that can effectively stimulate nerves that innervate muscles（Porcari et al., 2002). Electrical stimulation has been used to increase the strength of athletes. Since electrical stimulation does not impose a load, it can’t affect human joints. It is a relatively soft training method, which greatly reduces the risk of injury（Kemmler et al., 2010). Especially in physical therapy, neuromuscular electrical stimulation can help atrophied muscle reconstruction due to injury or immobilization (Adams et al., 2018). Functional electrical stimulation means that electrical stimulation is combined with functional movements for training to reduce pain and slow down muscle atrophy（Roessler et al., 2012).

WB-EMS can stimulate multiple muscle groups at the same time through an electrode belt or sports vest system (for example, Miracle Suit, Seoul, Korea), which can activate the thighs, arms, buttocks, abdomen, upper back, lower back and side areas muscle. In recent years, Miracle Suit has overcome the limitations and inconveniences of the past system, and its functions and performance have been further updated. For example, the tedious operation procedure of spraying water on clothes or wearing wet clothes makes the current flow through the human body and has been inserted by silicone clothing conductive replacement. In addition, the previous use of wires to connect electrodes to electrical stimulation devices has been replaced by wireless sensors. The Bluetooth connection can make the wireless sensor's range of activity up to 40 meters (von Stengel et al., 2015). The improvement of technology makes the multi-muscle group electrical stimulation training device more comfortable, easier to use and faster to restore the muscles of skeletal muscle patients, as well as improve the body composition and muscle function of ordinary people (Kemmler et al., 2016; von Stengel et al., 2015;).

In recent years, the WB-EMS has been welcomed in sports field. Many scholars have different conclusions on the influence of systematic electrical stimulation training. Some researchers showed that the WB-EMS can effectively improve the maximum strength in a short period of time (Kemmler, et al., 2018). Some studies pointed out that systematic electrical stimulation training can improve the explosive power of athletes (Gondin et al., 2011), and some scholars believe that athletes have no significant differences compared to the effects of traditional strength training, but after the experiment ending two weeks, the WB-EMS group appeared increasing of strength (Kemmler et al., 2016). In 2020 year, we conducted a 6-week WB-EMS strength training for physically active and experienced in strength training women in Madrid, Spain. We hypothesis WB-EMS could increase the maximum strength and explosive power of female athletes.

METHODS

Participants

Table 1. *Anthropometric data of two groups*

	N (female)	Age (years old)	Height (cm)	Weight (kg)
EG	5	28.0 ± 4.4	166.6 ± 7.1	60.9 ± 7.9
CG	5	25.8 ± 2.9	162.3 ± 5.6	59.5 ± 3.2

(mean values ± SD).

The present study included 10 participants characteristics are presented in Table 1. Participants come from different countries, with different sports training backgrounds. All of the participants were randomly divided into WB-EMS group and control group. All participants had previous experience in resistance training during 3-5 days per week. And all of them didn’t have any training experience with WB-EMS.

Ethical statement

Participants were provided with verbal and written information about the goal and risks of whole experimental procedures, they participated voluntarily and signed an informed consent prior to begin with the experiment. This study was approved by the Research Ethics Committee of the University Hospital Fundación Alcorcón (HUFA 19 52) and was executed in compliance with the standards recognized by the Helsinki Declaration of the World Medical Association (59th General Assembly, Seoul, Korea, October 2008), as well as the Standards of Good Clinical Practice, and complying with Spanish legislation on biomedical research (Law 14/2007).

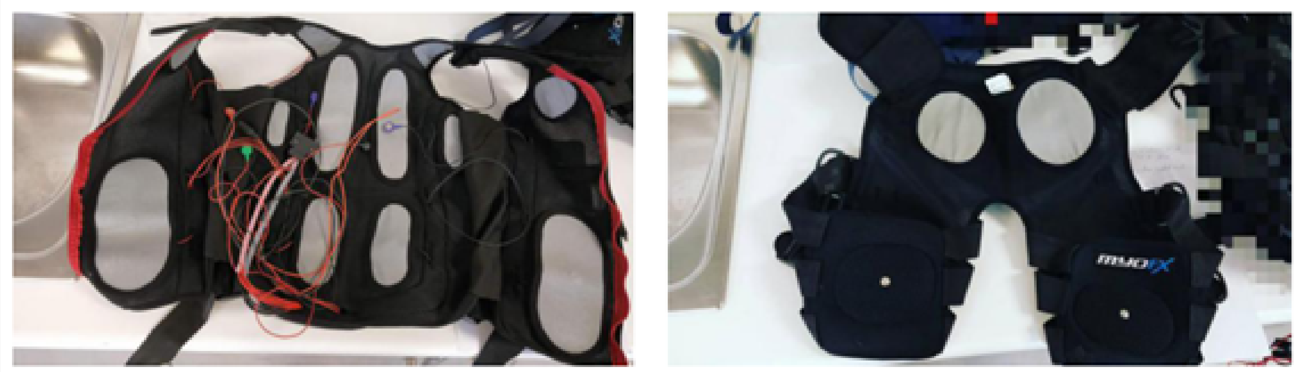

Figure 1. *Electromyostimulation vest and shorts*
Position of electrodes in electromyostimulation device stimulation body parts (trapezius, pectoral muscle, rectus abdominis, latissimus dorsi, erector spinae, gluteus maximus, quadriceps, biceps femoris).

Experimental Protocol

The study was designed as a randomly controlled experiment to compare the influence of strength training with and without WB-EMS (MyoFX EMS System, Madrid, Spain) on maximum strength, jump height of three different type of jumps, repetitions, and maximum movement velocity. We recruited 12 participants, one participant felt knee pain during the pre-test therefore withdrew from the experiment, one participant stopped the experiment because of the conflict between the experimental time and the class time, the data of these two subjects will not be used. 10 participants completed 12 resistance training sessions in 6 weeks. Besides, all subjects were required to finish 3 sessions per week of 40 minutes aerobic exercise (heart rate of 120 to 140 per minute). To determine training effects, maximum strength, jump height of three different type of jumps were individually tested in Training laboratory with stabilized environment, directly before and after the training program. After pre-test, the participants were randomly assigned to WB-EMS group or control group. In order to avoid the effect of additional training loads, both groups were required to refrain habitual physical activity. In addition, all participants were asked to maintain their normal dietary intake and avoid dietary supplements during the study.

Table 2. *Training schedule*

Warming-up	**Content**	**Loads**	**Intensity**	**Sets**	**Resting time**
15-20 minutes	Bench press	85%1RM	Maximum velocity dropped 10%	5	90 Seconds
	Row	85%1RM	Maximum velocity dropped 10%	5	90 Seconds
	Deadlifts	85%1RM	Maximum velocity dropped 10%	5	90 Seconds
	Squat	85%1RM	Maximum velocity dropped 10%	5	90 Seconds

Experimental procedure

After an initial assessment of maximum strength, jump height of three different type of jumps, both groups conducted training for 6 weeks, twice a week, 12 sessions. Each session was last around one hour (10-20 minutes of warming up and 30-40 minutes of training). One group trained without WB-EMS and the other with WB-EMS, the training in the two groups were equal in terms of duration and intensity (i.e. 85% 1RM intensity). During the training time, after aerobic exercise (20 minutes) warming-up followed by 5 sets of bench press, row, deadlift and squat were performed respectively with the monitoring of bar displacement velocity using a linear position transducer (Speed4Lift TM, Madrid, Spain). Participants performed as much repetitions as they could until bar displacement velocity dropped 10% from the maximum velocity monitored at the beginning of each set. We recorded the number of repetitions, the maximum velocity and stopping velocity. Participants rested 90 seconds between sets. WB-EMS stimuli was set as follows: current frequency was set at 85Hz, current pulse was set at 350μs, and the wave pulse type was bipolar rectangular. Impulse intensity was individually set according to personal tolerance threshold, ranging from 60 to 100% of the device capacity.

Figure 2 Training in different movement

Maximum Strength Test

Measuring with Speed4lifts, subjects used the Smith rack to perform bench press, row, deadlift, and squat respectively. Each project test was performed under 4 different loads, the same level of load repeated 4 times, and the load was increased gradually. Speed4lifts was fixed vertically on the right end of the barbell, installing the Speed4lifts software on the mobile phone, and connecting the Speed4lifts network. Input loads in the software and then clicked to start the test, the velocity of the subject under the loads was displayed on the software while the subject was performing. Same load was repeated 4 times and selecting the fastest speed to save. When all the different loads were completed, the Speed4lifts software showed the maximum force (1RM) automatically.

Jump Test

Vertical jump performance was assessed by using the squat jump (SQ), counter movement jump (CMJ) and Abalakov jump (ABK) tests. Optojump system (Microgate; Bolzano, Italy) was used to calculate the jumping height from flight time. To test SQ height, the subjects were guided to start jump from squatting down position at a knee angel 90 degrees approximately, simultaneously, subjects were required to place their hands on the hip in order to reduce the effect of arms swing and then subjects jumped up as high as possible in vertical direction. To perform CMJ, subjects were guided to start jump from an upright position, squatting down to around 90 degrees, at the same time, subjects were required to place their hands on the hips in order to reduce the effect of arms swing and then subjects jumped up as high as possible in vertical direction. To test ABK height, subjects were guided to start jump from an upright standing position with arms swing, others process were similar with CMJ. Each different type of jump was performed twice and the highest jump height was recorded.

RESULTS

Table 3. *Performance outcomes before and after the 6 weeks training program with and without WB-EMS.*

Maximum Strength in Four Different Movements					
		Pre-test (N)	Post-test (N)	Increase %	P value
Bench press	EG	42.36 ± 7.82	43.28 ± 7.83	2.16%	0.028
	CG	36.69 ± 4.39	37.07 ± 4.40	1.03%	0.045
Row	EG	47.87 ± 7.04	50.94 ± 7.06	6.4%	<0.01
	CG	42.99 ± 7.15	43.19 ± 7.20	0.48%	0.172
Squat	EG	90.99 ± 11.17	92.05 ± 10.80	1.17%	0.012
	CG	75.29 ± 14.64	75.33 ± 14.66	0.45%	0.122
Deadlift	EG	108.16 ± 13.27	110.49 ± 13.16	2.15%	<0.01
	CG	95.56 ± 27.09	95.57 ± 27.08	0.67%	0.023
Jump Height in Three Different Movements					
		Pre-test (cm)	Post-test (cm)	Increase %	P value
SJ	EG	27.42 ± 4	28.30 ± 4.13	3.21%	<0.01
	CG	24.68 ± 3.74	24.86 ± 3.72	0.73%	0.037
CMJ	EG	28.96 ± 4.23	29.54 ± 4.29	2.01%	<0.01
	CG	26.72 ± 3.74	26.80 ± 3.66	0.3%	0.405
ABK	EG	33.04 ± 5.17	33.60 ± 5.23	1.69%	<0.01
	CG	30.90 ± 6.18	31.12 ± 5.98	0.71%	0.207
Number of repetitions					
		Pre-test (times)	Post-test (times)	Increase %	P value
Bench press	EG	2.8 ± 0.69	4.48 ± 0.99	59%	0.003
	CG	3.08 ± 0.46	3.60 ± 0.55	17%	0.025
Row	EG	3.32 ± 0.74	4.40 ± 0.54	33%	0.006
	CG	3.48 ± 0.54	4.24 ± 0.52	22%	0.121
Squat	EG	2.76 ± 0.43	4.44 ± 0.17	61%	0.001
	CG	3.16 ± 0.17	3.88 ± 0.70	22.8%	0.079
Deadlift	EG	3.60 ± 0.60	5.16 ± 0.38	43%	0.005
	CG	3.56 ± 0.89	4.52 ± 0.77	27%	0.042
Maximum movement velocity (m/s)					
		Pre-test (m/s)	Post-test (m/s)	Increase %	P value
Bench press	EG	0.450 ± 0.061	0.476 ± 0.065	5.8%	<0.001
	CG	0.448 ± 0.032	0.456 ± 0.032	1.8%	0.031
Row	EG	0.566 ± 0.055	0.588 ± 0.049	3.8%	0.019
	CG	0.510 ± 0.079	0.518 ± 0.084	1.6%	0.028
Squat	EG	0.512 ± 0.013	0.534 ± 0.008	4.3%	0.008
	CG	0.460 ± 0.078	0.474 ± 0.081	3.0%	0.018
Deadlift	EG	0.472 ± 0.065	0.494 ± 0.067	4.7%	0.008
	CG	0.428 ± 0.031	0.434 ±0.033	1.4%	0.016

Data are mean values ± SD. EG:whole-body electromyostimulation group, N=5, CG:control group , N=5. Result of Pre-test and Post-test in four different movements of maximum strength respectively. SJ=squat jump; CMJ=counter movement jump; ABK = Abalakov . We selected session1 information as pre-test, session 12 information as post-test, the mean value of five sets of repetitions and maximum movement velocity from experimental group and control group respectively.

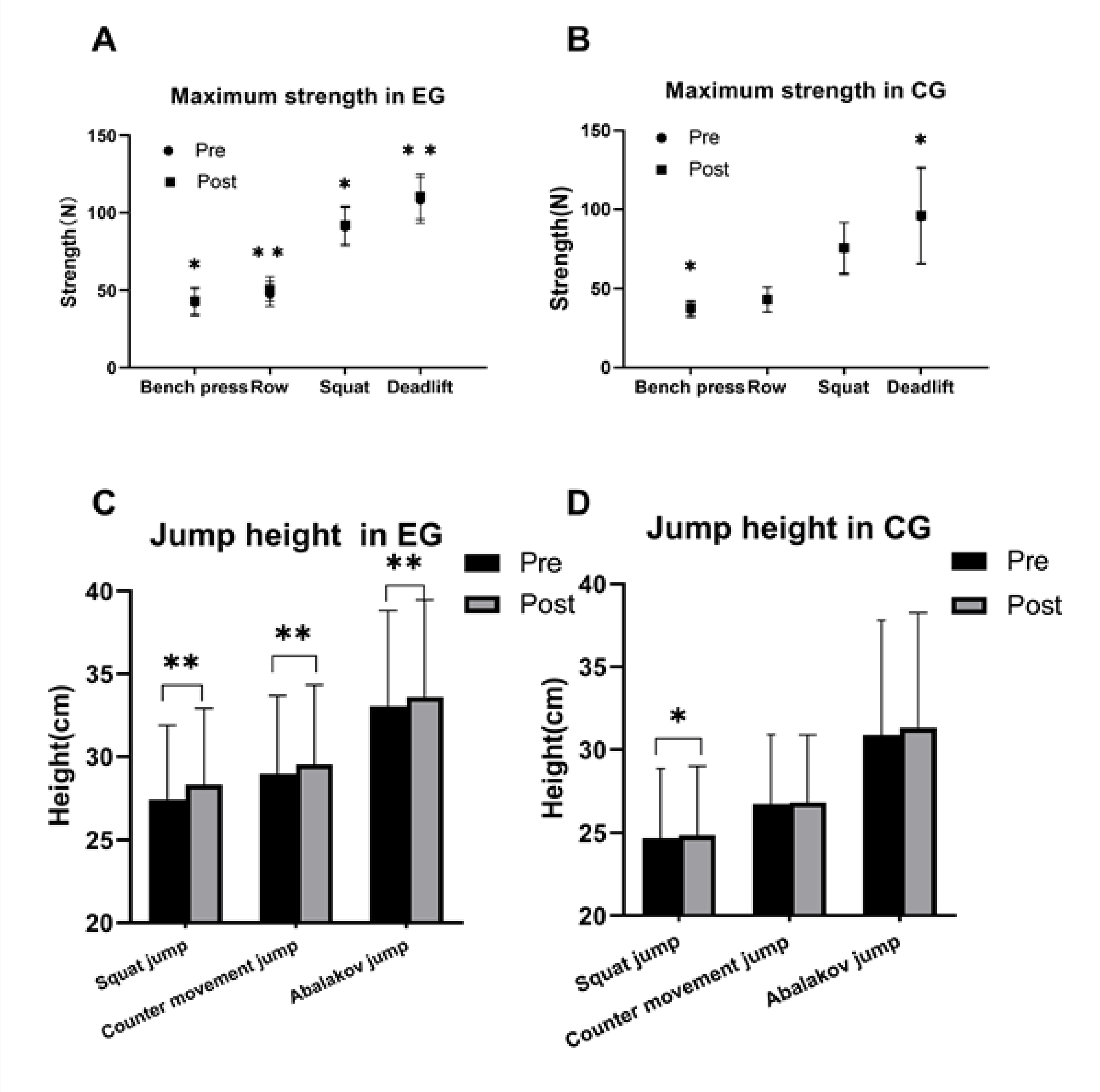

Figure 3. *Maximum strength and jump height*
□□ P ≤ 0.01, □ P ≤ 0.05, significant influence.

Table 3 and Figure 3 A and B show maximum strength in EG and CG, it has significantly improved in EG, bench press increased 2.16% ($P \leq 0.05$), row 6.4% ($P \leq 0.01$), squat 1.17% ($P \leq 0.05$), deadlift 2.15% ($P \leq 0.01$) respectively. It also enhanced significantly in CG, bench press increased 1.03% ($P \leq 0.05$) and deadlift 0.67% ($P \leq 0.05$). Compare with WB-EMS group, control group had less increasing percentage, and WB-EMS had a significant influence on maximum strength of female athletes. Figure 3, C and D show the jump height in two groups, we can clearly see that height has a significantly improved in EG from pre to post, SJ has risen 3.21% ($P \leq 0.01$)□CMJ 2.01% ($P \leq 0.01$)□ABK 1.69% $P \leq 0.01$). Squat jump has risen 0.73% ($P \leq 0.05$) in CG. Similar with maximum strength, EG had a higher increasing percentage compared with CG, and WB-EMS had a significant influence on jump height of female athletes.

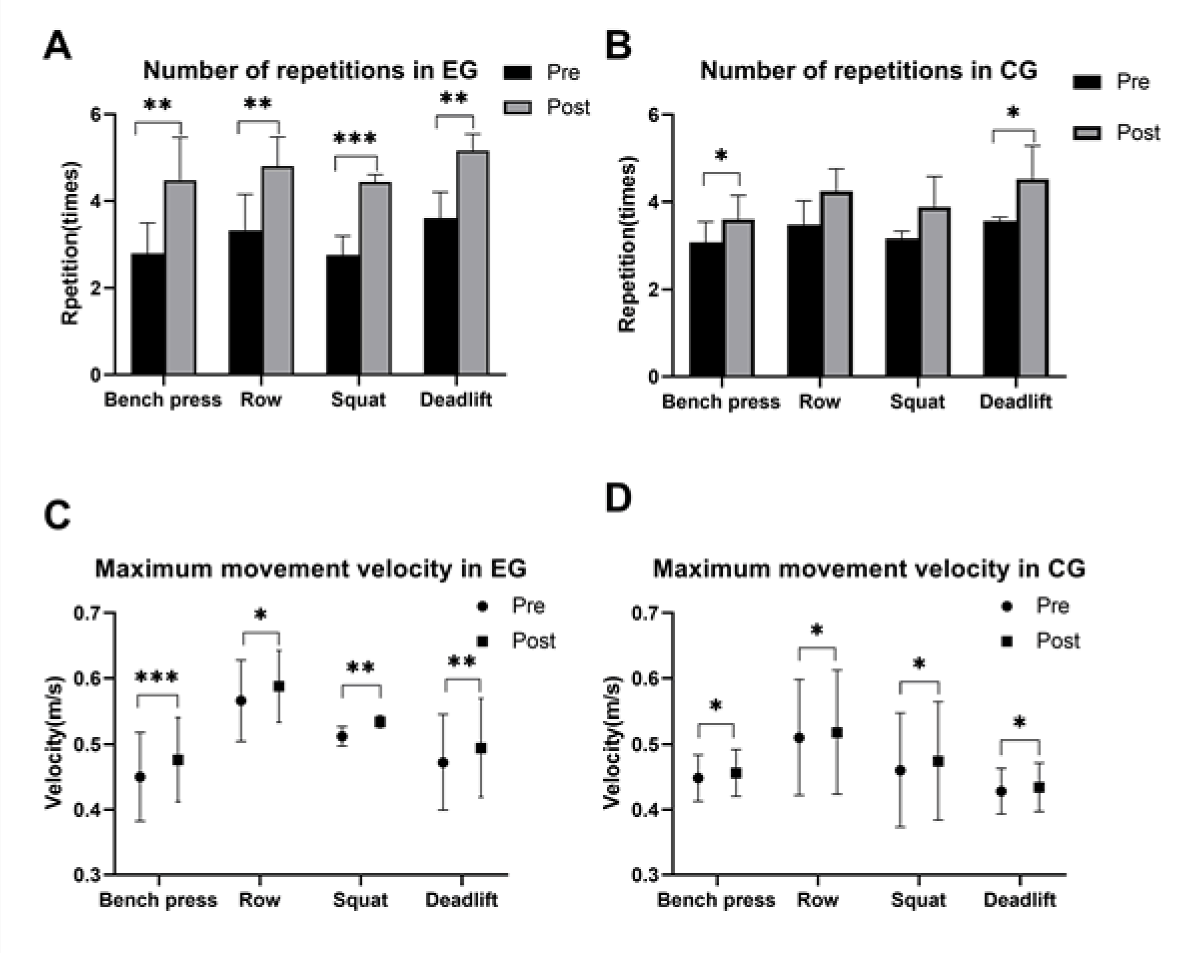

Figure 4. *Number of repetitions and maximum movement velocity*
Pre: data from session 1, Post: data from session 12. □□□ P ≤ 0.001, □□ P ≤ 0.01, □ P ≤ 0.05, significant influence.

Table 3 and Figure 4 A and B show the number of repetitions in both WB-EMS group and control group. Bench press had significant influence in two groups, increasing 59% and 17% respectively (EG: $P \le 0.01$, CG: $P \le 0.05$). Row increased significantly in EG 33% ($P \le 0.01$), CG increased 22%, but there was no significant influence. Squat improved in EG 61% ($P \le 0.001$), and CG 22.8% without significant influence. Both group of EG and CG had significant increased number of repetitions in deadlift 43% ($P \le 0.01$), 27% ($P \le 0.05$) respectively. Increasing of number of repetitions showed the strength increased in EG with four different movements. And strength improved in CG with Bench press and deadlift. C and D show the maximum movement velocity in both WB-EMS group and control group. There was a significant increasing in both groups, bench press improved in EG 5.8% ($P \le 0.001$) and CG 1.8% ($P \le 0.05$). Row in EG 3.8% ($P \le 0.05$), CG 1.6% ($P \le 0.05$). Squat in EG 4.3% ($P \le 0.01$), CG 3.0% ($P \le 0.05$). Deadlift in EG 4.7% ($P \le 0.01$), CG 1.4% ($P \le 0.05$) respectively. Strength training had a significant influence in EG and CG, and it was clearly that the maximum movement velocity increasing percentage WB-EMS group is higher than control group. Maximum movement velocity can reflect the explosive power, and it has indicated that WB-EMS could improve explosive power than control group.

DISCUSSION

The present research showed that female participants, that were physically active and experienced in strength training, better improve their performance after 6 weeks of strength training with the use of WB-EMS technology. As a strength of the present research, we used a linear position transducer (Speed4lifts) to monitor the training velocity and controlled the training volume to movement velocity loss of 10%, which made the experimental data precise and effective (Sanchez-Medina et al., 2011). Further, the study results were persuasively avoiding all subjects in traditional training methods to carry out the same repetition training thus causes over or low of training intensity (Tøien et al., 2018).

Previous study (Filipovic et al., 2019) found that soccer players performed 3 × 10 squat jumps superimposed with WB-EMS twice per week combined with specific resistance training can serve as a time efficient training method to augment strength capacities and type II fiber myofiber growth. (Pano-Rodriguez et al., 2019) Showed it can increase the greatest strength with 4 weeks WB-EMS. In our study, subjects performed bench press, row, squat, and deadlift and the experimental conducted 6 weeks, results showed maximum strength with WB-EMS training group is greater than the traditional training group. Squat improved the most, that because many muscle groups were involved in the squat exercise, especially the gluteus maximum and the quadriceps biceps and it also can activate more rope muscles during training with WB-EMS. However, our research didn’t show training 4 weeks that subjects could get the best benefits of strength, about the training period leads to the maximum benefits we still need to do a longer-term research.

Jumping ability is an indicator of explosive strength. Wirtz and col. (Wirtz et al., 2019) performed a study where 112 subjects participated in a dynamic WB-EMS and dynamic athletic training without WB-EMS for 4–8 weeks with 2 training sessions per week with 70% of the individual pain threshold amperage, findings indicated that superimposed WB-EMS did not lead to superior effects of jumping performance. Our study outcomes showed that WB-EMS group greater improved SJ, CMJ and ABK than control group, this may lead to we have less samples, experimenter could more concentrate on personal subject, in addition, the individual pain threshold amperage decided by subjects themselves, we didn’t specify pain threshold amperage, each training session turned out more accurate and effective. Furthermore, barbell velocity movement in all exercises also increased more after training with WB-EMS compare to control.

(Silinskas et al., 2017) A previous study with 10 training sessions and each session involved 10 seconds of stimulation and 50 seconds of rest for a total of 10 minutes, result showed an effect on the strength of the foot flexion muscles and on the performance of 10-m sprinting with both a standing and a running start. In our research, jump ability had a significant improvement, both researches increased with explosive strength. The difference is that we put the whole equipment on subjects until the training session completed, and the process at least last 30 minutes, which stimulated more muscle groups and longer time. Here we couldn’t specify the best stimulation time, but we need to do a further study about the stimulation time range in order to gain the best benefits from WB-EMS technology.

It had been previously stated that, when EMS was applied to beginners, a maximum intensity tolerance plateau was reached after three adaptation sessions (Berger et al., 2020). They found a significant relationship for the maximum current intensity tolerance and skinfold thickness for the gluteus in female and for the lower back in male with WB-EMS training. The participants of the present study were also beginners in WB-EMS training. However, since they completed the 12 training sessions, familiarization process was overcome. avoiding a possible effect of motion learning with the WB-EMS equipment in the training results. In this line, we can assume that the improved maximum strength and power levels observed in the participants after the training program were the result of adding the electrical stimulation (frequency 85Hz, pulse intensity 80μs) to the training load (85% 1RM). The maximum strength and explosive power of the experimental group have improved, indicating that the training load and electrical stimulation frequency are reasonable, although the current stimulation frequency was set to 85Hz, but each subject's muscles were different to the tolerance of current stimulation, according to the adaptation of electrical stimulation and tolerance adjust the size of the stimulus, taking into account the individual differences of subjects and finding a personal configuration in sports training.

Our study is not out of limitations. Despite it was a pilot study, the number of participants was reduced, thus, the information provided in the present study, although promising about WB-EMS use in training, must be taken cautiously. Hence, more studies focusing on the use of WB-EMS in females strength training are needed. Additionally, although the current stimulation frequency and pulse were set to 85Hz and 80μs, the intensity of the stimulus was individually set, and it ranged from 60 to 100% of the device capacity. This mean that individual tolerance thresholds were wide different, and thus, it could be possible that the magnitude of the WB-EMS on the training effects was not similar to each participant.

CONCLUSIONS

For physically active women, 6 weeks of strength training with WB-EMS (85Hz frequency and bipolar rectangular wave pulse of 350μs) can effectively improve maximum strength load and explosive power compare to the same training program without WB-EMS.

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