Original Article

Comparison between traditional resistance training and whole-body electrical stimulation in improving muscular strength

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Abstract

Background: Greater muscular strength can enhance the ability to perform general sports skills such as jumping, sprinting, and direction tasks. Resistance Training (RT) is broadly applied by strength and conditioning coaches to increase strength. However, Whole-Body Electromyostimulation (WB-EMS) recently served as an alternative method to increase muscular strength in high-performance athletes. This study aimed to examine the effects of two different training modalities on muscular strength.

Methods: Sixty female collegiate softball players (Age = 23.52 ± 1.89 years; Height = 156.20 ± 1.71 cm; Mass= 53.21 ± 3.17 kg) were randomly assigned into 3 groups. All groups trained as usual for 8 weeks, with the first group performed 100 repetitions of dry swing (normal bat swing practice in softball). The second and third group performed a combination of dry bat swing with RT and WB-EMS, respectively. Muscular strength (upper body and lower body) for the 3 groups was evaluated before and after the 8-week program.

Results: The main results showed that after the eight-week training, the upper and lower body strength significantly increased in both RT and WB-EMS groups compared to the control group ($p = 0.000$, and $p = 0.000$, respectively). While both groups contributed to the increase in muscular strentgth following 8 weeks of training, it was the RT that resulted in a larger magnitude of increase in strength.

Conclusion: This study concluded that RT should be emphased in high performance athlete training while recognizing the potential benefit of WB-EMS in enhancing muscular strength.

Key Words: Electromyostimulation, intensity, repetition maximum, strength

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INTRODUCTION

Over the past 30 years, resistance training (RT) has been utilised to increase muscular strength amongst high school, collegiate, amateur and professional athletes (Szymanski et al. 2008; 2009). It is reported that the typical RT takes up to 60 min per session (Fisher et al. 2011; Nybo et al. 2010). However, in recent times, coaches have limited time to train their athletes. Consequently, they usually neglect the conditioning practice and focus more on the techniques and tactics of the game. These practices lead to players having a weak strength base and only worsen their sports performance (Sugimoto et al. 2017). Recently, electromyostimulation (EMS) has been applied to increase muscular strength in athletes and healthy adults over 4–12 weeks of training (Filipovic et al. 2016; 2011; 2012).

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A previous meta-analysis of the EMS method revealed that this training method works effectively as an alternative to the RT for developing maximal strength performance in athletes (Filipovic et al. 2012). Several studies also reported a significant change in strength (Billot et al. 2010; Girold et al. 2012). Furthermore, EMS has also shown positive effects on sports performance such as swimming (Girold et al. 2012), kicking a soccer ball (Billot et al. 2010) and rugby (Babault et al. 2007).

Numerous studies examined the effect of EMS on strength gain have been conducted on athletes (Dehail et al. 2008). For example, isolated stimulation of the quadriceps femoris, gluteus maximus and triceps surae muscles in rugby players resulted in a significant increase in the strength and power of these muscles over a 12-week period (Babault et al. 2007). However, these improvements did not benefit the players' technical skills such as scrummaging and sprinting. In another study, a combination of electrostimulation and plyometric training improved quadriceps femoris maximal strength, vertical jump and sprint (Herrero et al. 2006). However, electrostimulation alone decreased sprint velocity and its benefits were generally less significant than those observed when combined with plyometric training.

In addition, electrostimulation incorporated with fast concentric (1808/s) or eccentric training has been shown to increase the maximal concentric moment in a recent review (Dehail et al. 2008). The reviews show that all these studies applied single electrode EMS to specific muscles. Nevertheless, several muscle groups can be trained simultaneously through electrode belt and vest system with the new generation of EMS devices.

This new technology will be handy for all coaches who have limited time for physical conditioning. Yet, in comparison to the single electrode EMS, very few studies have applied the whole-body EMS (WB-EMS) methods on athletes (Filipovic et al. 2016). WB-EMS has been applied in training to improve muscle mass and decrease abdominal fat (Kemmler and von Stengel 2013), improve energy expenditure (Kemmler et al. 2012) improve resting metabolic rate and body composition (Kemmler et al. 2010), amongst sedentary and older female adults. However, to date, there is only one applied study measuring the effect of WB-EMS on strength, sprinting, jumping and kicking capacity in elite soccer players. In addition, there is a noticeable lack of studies conducted on the effects of WB-EMS on applied sports performance. This study aimed to compare RT and WB-EMS programme on maximal strength among female collegiate softball players in light of this knowledge gap.

METHODOLOGY

Participants

Sixty healthy female collegiate softball players (age: M = 23.52, standard deviation [SD] =1.89 years old, height: M = 156.20, SD = 1.71 cm, weight: M = 53.21, SD = 3.17 kg) were recruited in this study. The participants' characteristics were that they must be in the official collegiate softball team roster, have experience in RT, and have no self-reported sickness, neurological problems, mental illness, or significant current and past injuries that could place them at risk while performing exercises and training.

Experimental design and procedures

A randomised pre-test-post-test control group design was applied to measure the effects of interventions on muscular strength. Group one (CTR) implemented a regular swing training programme (100 swings using 24-oz bat) adopted from Szymanski et al. (2009) study. This program demonstrated an improvement in batting velocity among baseball players. Furthermore, this program is also being utilised by the coaches during daily softball training. Even though this training group can be classified as the control group, the participants must also go through several sets of swing training. Each exercise session began with a warm-up session by swinging a standard bat for tw sets with ten repetitions. The participants then must swing 20 times for five sets. Thus, the participants trained using a standard bat for the whole 8-week period.

The second group was RT, in which all the players in this group performed the same swing training as the CTR group. Per contra, this group performed additional resistance exercise using free weights dumbbells and machines in the gymnasium [Table 1]. This training was programmed according to a stepwise periodisation method, similar to previous RT practice (Stone et al. 2000; Szymanski et al. 2007; 2004). This training started with a low training volume (high repetition, low intensity) to a high training volume (low repetitions, high intensity). During the 1st week, the intensity was prescribed at 65% of the estimated one repetition maximum (1RM) obtained during 3RM pre-testing. This training intensity was increased by 5% (as tolerated) each week before reaching 80% of the estimated 1RM in the 4th week. Then, the 3RM testing was re-conducted at the end of the 4th week to determine the new predicted 1RM. From the 5th week onwards, the intensity started at 85% of predicted 1RM and increased by 5% between the 6th and 8th weeks. Within the 8 weeks of training, the intensity was increased incrementally if the participant could complete more than the prescribed repetitions. When the individual could not complete the repetitions, the resistance was reduced by the smallest amount possible during the next exercise session.

The third group was WB-EMS, in which all the players in this group performed the same swing training as CTR and RT group. On the other hand, after completing the swing training, this group performed additional electrical stimulation training using WB-EMS by Miha Bodytec in the gym's studio. The WB-EMS group exercised for 3 days each week using prescribed electrical stimulation (biphasic rectangular wave pulsed currents-85 Hz; impulse width of 350 µs), and the maximally tolerated intensity was varied between 50 and 80 milliampere (mA) depending on the week [Table 2]. Every impulse for a single lift in each exercise went on for 5 s, followed by another 5 s of rest. This training was programmed according to a stepwise periodical method which is similar to the RT group. This training started with a low training volume (high repetition, low intensity) to a high training volume (low repetitions, high intensity). Since the unit of measurement for loading is different in both training

Table 1: Dry swing and resistance training program

Variables	Week 1-4			Week 5-8		
	Sets		Reps	Sets		Reps
Warm-up	2		10	2		10
Swing practice	5		20	5		20
	Sets	**Reps**	**Percentage RM**	**Sets**	**Reps**	**Percentage RM**
Warm-up	2	10	50-60	2	10	50-60
Parallel squat	3	6-8	65-80	3	2-6	85-90
Stiff leg deadlift	3	6-8	65-80	3	2-6	85-90
Barbell bench press	3	6-8	65-80	3	2-6	85-90
Triceps push down	2	10-12	50-65	2	8-12	70-75
Dumbbell biceps curl	2	10-12	50-65	2	8-12	70-75
Seated row	2	10-12	50-65	2	8-12	70-75
Medicine ball exercise	**Sets**	**Reps**	**Load (kg)**	**Sets**	**Reps**	**Load (kg)**
Hitters throw	2	6	5	2	8	4
Standing figure of 8	2	6	5	2	8	4
Speed rotation	2	6	5	2	8	4
Standing side throw	2	6	5	2	8	4
Squat and throw	2	6	5	2	8	4

Reps: Repetitions, RM: Repetition maximum

Table 2: Dry swing and whole-body electromyostimulation training program

Variables	Week 1-week 4			Week 5-8		
	Sets		Reps	Sets		Reps
Warm-up	2		10	2		10
Swing practice	5		20	5		20
Whole-body Electromyostimulation Exercise	**Sets**	**Reps**	**% RMM**	**Sets**	**Reps**	**% RMM**
Warm-up	2	10	50-60	2	10	50-60
Parallel squat	3	6-8	65-80	3	2-6	85-90
Stiff leg deadlift	3	6-8	65-80	3	2-6	85-90
Barbell bench press	3	6-8	65-80	3	2-6	85-90
Triceps push down	2	10-12	50-65	2	8-12	70-75
Dumbbell biceps curl	2	10-12	50-65	2	8-12	70-75
Seated row	2	10-12	50-65	2	8-12	70-75
Medicine ball exercise	**Sets**	**Reps**	**% RMM**	**Sets**	**Reps**	**% RMM**
Hitters throw	2	6	80	2	8	75
Standing figure of 8	2	6	80	2	8	75
Speed rotation	2	6	80	2	8	75
Standing side throw	2	6	80	2	8	75
Squat and throw	2	6	80	2	8	75

Reps: Repetitions, RMM: Repetition maximum milliampere

methods, the maximum repetition milliampere (RMM) was conducted following the procedure published elsewhere (Hussain et al. 2016). This test was conducted to determine the appropriate voltage intensity during EMS training. The intensity was prescribed at 65% of the 1RM obtained during one RMM (1RMM) pre-testing during the 1st week. The training intensity was increased by 5% (as tolerated) each week before reaching 80% of 1RMM in the 4th week. Then, the 1RMM testing was re-conducted at the end of the 4th week to determine the new 1RMM. The intensity started at 85% of 1RMM from the 5th week and increased by 5% from the 6th week to the 8th week. Within the 8 weeks of training, the intensity was increased incrementally if the participant could complete more than the prescribed repetitions. If the individual could not complete the repetitions, the resistance was reduced by the smallest number possible during the following exercise session.

Estimations of 1RM for upper body and lower body strength were made by performing 3RM tests (maximum weight lifted 3 times) on the bench press and squat test. Multiple RM prediction models are considered valid ($r = 0.84$–0.92), safe and reliable methods to predict 1RM (Ruivo et al. 2016). The procedure of conducting multiple RM tests for bench press and squat was suggested by Baechle et al. (2004). The estimated 1RM was subsequently predicted using Bryzcki's equation (Ruivo et al. 2016).

Data analysis

The KolmogorovSmirnov test of normality was conducted before the analysis, and all parameters were normally distributed. Baseline and after week-8, differences of predicted 1RM between groups were investigated using the paired sample *t*-test. The assumption of homogenous variances was tested using Levene's test. Finally, a one-way analysis of variance (ANOVA) on gain (mean difference) score was employed to identify the significant difference between all training groups. All the data were analysed using SPSS version 23 (IBM®, Armonk, NY, USA), with the statistically significant value was set at an alpha level of $p \leq 0.05$.

RESULTS

After 8 weeks of training, both RT and WB-EMS groups showed improvement in pre-test and post-test for upper and lower body strength with a significance value of 0.000 for both bench press and squat tests [Table 3] compared to the CTR group ($p \geq 0.05$).

Further analysis was conducted to determine which group show more significant improvement in both upper and lower body strength. Table 4 shows a statistically significant difference between groups in the bench press as determined by one-way ANOVA (F [2, 57] =120.038, p = 0.000). A Tukey *post-hoc* test revealed that the upper body strength was statistically significantly improved in RT (7.37 ± 1.63 kg, p = 0.000) and WB-EMS (2.37 ± 1.72 kg, p = 0.000) groups compared to the CTR group (−0.68 ± 1.62 kg). There was a statistically significant difference between groups in the bench press in lower body strength as determined by one-way ANOVA (F (2, 57) = 61.81, p = 0.000). A Tukey *post-hoc* test revealed that the upper body strength was statistically significantly improved in RT (8.40 ± 1.29 kg, p = 0.000) and WB-EMS (3.97 ± 2.74 kg, p = 0.000) groups compared to the CTR group (0.45 ± 2.49 kg). Multiple comparison tests were conducted to identify which group elicit greater changes in both upper and lower body strength, and Table 5 shows a statistically significant difference between the RT and WB-EMS (p = 0.000) in both upper and lower body strength. Therefore, it can be identified that the RT group elicit noticeable changes in muscular strength compared to the WB-EMS group.

DISCUSSION

The main findings of this study were that three RT and WB-EMS sessions in addition to 100 regular swing training sessions per week over 8 weeks (for a total of 24 sessions) were sufficient to demonstrate an enhancement of muscular strength in collegiate level female softball players. In addition, both RT and WB-EMS groups showed significant increases in mean predicted 1RM bench press and squat after 8 weeks of training for predicted maximal strength. This result was in parallel with a previous study that showed an increment in muscular strength after following RT (Kraemer et al. 2000; Sale 1988) and single muscle attachment of electrical stimulation (Colson et al. 2000; Enoka 1988; Martin et al. 1993). Furthermore, previous studies stated that the improvement of neural adaptation was a possible reason for the increase of muscular strength in RT (Moritani and Devries 1980) and WB-EMS (Gondin et al. 2006; Maffiuletti et al. 2000). Moritani and Devries (1980) used an integrated electromyogram (IEMG) in illustrating their method for the evaluation of percent contribution of neural factors and hypertrophy. This method demonstrated when strength was increased by neural factors such as learning to disinhibit, and it should be seen through an increase in maximal muscle activation level without any changes in force per fibre or motor unit innervated. Following 8 weeks of strength training, they found that their participants achieved the strength gain by virtue of neural factors as indicated by the increases in the maximal IEMG in the absence of significant hypertrophy. This finding was also further confirmed by the fact that there were no significant changes in the cross-sectional area or the electromyography (EMG) slope coefficient over the 8-week training period. Gondin et al. (2006) previously examined neuromuscular adaptations induced by 4 and 8 weeks of EMS training programme of the knee extensor muscles. The muscle activation estimated using the twitch interpolation technique was used to assess neural adaptations, and they found there was a significant increase by 6% after training, thus indicating that EMS training enhanced the overall activity of the quadriceps muscle.

Strength improvement was usually associated with changes occurring in the central nervous system (e.g. increased neural drive) and/or at the muscle level (e.g. hypertrophy). Although no EMG or cross-sectional area was measured in this study in order to confirm the strength improvement through central nervous system or muscle level context, it was assumed that WB-EMS training had produced neural adaptation compared to muscular adaptation. The reason is that it was commonly accepted that, during the first few weeks (3–5) of RT and EMS training, there were no modifications at the muscle level (Aldayel 2010). Furthermore, the electrical stimulation mechanism resulted in the excitation of intramuscular branches of the nerve and not directly the muscle fibres (Aldayel 2010).

It has been said that by transcutaneous peripheral nerve stimulation, direct muscle electrostimulation causes muscle contraction. This contraction can be induced directly by depolarising motoneurons or indirectly by depolarising sensory afferents (Collins 2007).

Table 3: Pretest and post-test for upper and lower body strength

Groups	Pre-mean (SD)	Post-mean (SD)	Mean difference	t	Significant
Bench press					
CTR	25.10 (3.02)	25.33 (2.88)	0.23	1.45	0.163
RT	25.67 (3.40)	33.04 (4.29)	7.37	20.18	0.000
WB-EMS	24.08 (3.50)	26.46 (3.07)	2.38	6.18	0.000
Squat					
CTR	42.71 (2.15)	42.83 (1.93)	0.11	0.561	0.582
RT	43.06 (2.68)	51.46 (2.76)	8.40	29.01	0.000
WB-EMS	42.04 (2.53)	46.01 (2.36)	3.97	6.47	0.000

RT: Resistance training, WB-EMS: Whole-body electromyostimulation, SD: Standard deviation

The stimulation recruits motor units distinct from physiological muscle recruitment during voluntary contraction, which may explain the strength gain observed following electrostimulation training in healthy subjects. Electrostimulation was frequently thought to recruit motor units in the reverse order of voluntary drive, contradicting Hennemann's "size principle." According to this principle, slow motor units associated with small-diameter motoneuron axons are active before fast motor units associated with larger-diameter axons.

Contrary to voluntary contraction, the current view acknowledges that recruitment is non-selective for the type of motor unit and occurs in synchrony (Dehail et al. 2008). The recruitment pattern appears to depend on the electrode location, surface, type and stimulated muscle, all of which affect the conductive volume and current density. When repeated electrical stimulations are employed, such as during muscle training, the adaptation of muscle physiology is observed in healthy subjects. The cross-sectional area of Type I muscle fibres or the entire muscle group that was trained increased (Gondin et al. 2006; Herrero et al. 2006). This finding was associated with an increase in the IIa isoform of myosin's heavy chains (Maffiuletti et al. 2006) and appeared to be more significant when the voluntary contraction was incorporated with stimulation (Sanchez et al. 2005). These changes are dependent on the type of stimulation adopted and may be associated with an increase in the trained muscle's maximal strength and electrical activity (Gondin et al. 2006; Maffiuletti et al. 2006; Sanchez et al. 2005).

In addition, the training programme given to both training groups involved the principle of progressive overload. Progressive overload is one of the most critical factors in increasing sports performance. It has also been shown that altering the training load does affect acute metabolic (Ratamess et al. 2009; 2007) and neural (Ratamess et al. 2009), hormonal (Kraemer and Ratamess 2005; Kraemer et al. 2006) and cardiovascular (Ratamess et al. 2009) responses towards exercise. The training load was started at low intensity. This intensity was increased weekly up to 90% of 1RM at the end of the training period.

Table 4: Analysis of variance for strength

	Sum of squares	df	Mean square	*F*	Significant
Bench press					
Between groups	660.789	2	330.395	120.038	0.000
Within groups	156.888	57	2.752		
Total	817.677	59			
Squat					
Between groups	635.256	2	317.628	61.810	0.000
Within groups	292.910	57	5.139		
Total	928.166	59			

Increasing the load imposed on skeletal muscle elicits adaptations that result in increased muscle size and changes in contractile characteristics (Bird et al. 2005). Consequently, it can be suggested that the principle of overload leads to muscular strength adaptation, and this adaptation leads to the increment of dynamic strength. This statement supports the significant improvement in dynamic strength shown in previous studies which applied the principle of progressive overload in their RT programme (Szymanski et al. 2009; Szymanski et al. 2007; Szymanski et al. 2007).

This study has also provided support for adopting WB-EMS as an alternative or supplementary training method in improving batting velocity. Therefore, as a practical recommendation for softball players, it is suggested that coaches adopt additional WB-EMS in enhancing their players' batting velocities across 8 weeks of training.

CONCLUSION

The present study demonstrated that inducing RT and WB-EMS intervention in addition to regular softball training over a period of 8 weeks resulted in increased muscular strength. Furthermore, this current study revealed that amongst the two training modes conducted in this study, RT demonstrated a more considerable improvement in both upper and lower body strength compared to WB-EMS. Although this study reached some conclusions about the effectiveness of both RT and WB-EMS training, the underlying mechanism of the training was not fully explored, and the derived conclusion is that RT has improved muscular strength. However, there is no conclusive evidence that the most fitting training mode can be contrived. Thus, further investigation related to EMG analysis and study at the cell level is needed to explain the possible underlying mechanisms effect of WB-EMS training. These studies could help justify the changes that occur in the human body after following WB-EMS.

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Table 5: Multiple comparison

Variables	(I) Group	(J) Group	Mean difference	SE	Significant
Bench press	RT	WB-EMS	4.99*	0.525	0.000
		CTR	8.05*	0.525	0.000
Squat	RT	WB-EMS	4.43*	0.717	0.000
		CTR	7.95*	0.717	0.000

*The mean difference is significant at the 0.05 level. SE: Standard error, WB-EMS: Whole-body electromyostimulation

Conflicts of interest

There are no conflicts of interest.

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