

# Scheduled and unscheduled resistance training effect on men's functional and electrophysiological characteristics

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## ABSTRACT

**Introduction:** Resistance exercises are the important part of an exercise program in most sports, which has a role in preventing injury and rehabilitation. The aim of the present research was to compare 9 weeks of linear, and wave scheduled and unscheduled resistance exercise on strength and endurance as well as neuromuscular performance of the upper and lower torso muscles in men. **Methods:** Thirty men with the mean age of ( $21.87 \pm 3.06$  years), height ( $173.55 \pm 6.14$ ) and weight ( $73.35 \pm 13.56$ ) were randomly divided into three groups of unscheduled ( $n = 10$ ), linear ( $n = 10$ ) and wave ( $n = 10$ ) scheduled exercise. The exercise protocol was for 9 weeks exercise and three sessions per week. At the end, the strength and endurance of the muscles were measured. The electromyography activity of the quadriceps muscle was recorded by an electromyographic device. The two-way ANOVA statistical test was used for data analysis. **Findings:** Data analysis showed that the strength and endurance of the upper and lower torso muscles and the amplitude of the electromyographic wave had a significant increase in all three groups compared to before doing the exercises ( $P < 0.05$ ). Intergroup results showed that wave exercises had a significant effect on strength and endurance and the amplitude of electromyographic wave compared to linear and unscheduled exercises ( $P < 0.05$ ). **Discussion:** The results of this research showed that by using a wave exercise program concurrent with paying attention to saving time and energy compared to other exercise programs, significant results in gaining muscular strength and endurance, as well as further call for motor units and neuro-muscular adaptation can be achieved.

**Keywords:** Wave Scheduled Resistance Exercise, Linear Scheduled Resistance Exercise, Electromyography Wave Amplitude, Muscular Strength, Muscular Endurance.

## Introduction

Resistance exercises are important part of exercise programs in most sports, which through increasing strength, power, speed, hypertrophy and muscular endurance, motor function, balance and muscular coordination, have important role in improving

athletic performance that to achieve these purposes in the resistance exercise program, proper designing of an exercise program is an essential issue <sup>[1]</sup>.

Increasing the muscular strength and endurance resulting from doing resistance exercises is very important for improving the general health and physical fitness of people, and improves people's ability to participate in the daily activities of life <sup>[2]</sup>. In a way that any factor that can increase the capabilities of the muscular system and lead to better and stronger performance of athletic activities is considered by coaches and athletes <sup>[3]</sup>.

Studies have shown that in order to achieve the desired goals of resistance exercises, at any level of physical fitness and with any age conditions and in the shortest time, change in exercise load and effective scheduling of resistance exercises has special

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importance<sup>[1]</sup>. Change in exercise load is determined by manipulating the amount of exercise (number of sets, repetitions, and sessions), the amount of weight used, rest between sets or exercises, and the type of contraction used<sup>[4]</sup>. Changing and manipulating these exercise variables, called scheduling the exercise or scheduled exercise programs<sup>[5]</sup>, is one of the methods that coaches can use to achieve the desired exercise goals, including exercise monotony avoidance, achieving maximum strength, hypertrophy, muscular endurance and power<sup>[6]</sup>.

Scheduled exercise programs to achieve predetermined goals have shown better results than unscheduled exercise programs<sup>[2]</sup>. There are various models of scheduling exercises; however, researchers have mainly focused their researches on two models<sup>[5, 7]</sup>. The most common scheduling programs are daily linear and wave scheduling, that during the linear scheduling exercises, in every four weeks the intensity and volume of exercises are gradually increased and decreased respectively once<sup>[5]</sup>. But, on the contrary and during the daily wave scheduled exercises, the intensity and volume of exercises will be changed on a daily basis<sup>[5, 7, 8]</sup>. And because of difference in exercise characteristics between scheduled and unscheduled exercises (for example difference in repetition, intensity, volume), difference in mechanical pressures can be possible<sup>[9, 10]</sup>.

Researchers measure muscular contractions and performance and muscle activation during resistance exercises by surface electromyography (EMG), so that the EMG amplitude shows a reflection of the number of active motor units and their firing ratio during muscular contractions<sup>[11]</sup>. So, knowing the changes that as a result of dynamic contractions during resistance exercises are recorded by EMG will increase our understanding about the neural and muscular needs of this type of exercises. Accordingly, the purpose of this research is to investigate the point that which of the wave and linear scheduled and unscheduled resistance exercise programs can better increase the strength and endurance of the lower and upper torso muscles?

## Methods

In order to conduct the research, 30 healthy men with the age range of 20 to 30 years with the characteristics listed in Table 1 were selected as subjects and were divided into the three exercise groups of linear scheduled (n =10), daily wave scheduled (n =10) and unscheduled (n =10). Subjects were selected based on certain criteria such as not participating in resistance exercises in the last year before the start of research, availability, the lack of injury and performance limitation, as well as not consuming dietary supplements or any blood pressure and psychotropic drugs before and during the exercises. Also, one of the reasons for choosing the male sex in the present research was the low subcutaneous fat of men compared to women to measure electromyographic wave with higher quality. This study was conducted in accordance with the Helsinki Declaration, and prior

to entering the study, written consent letters were taken from all individuals.

**Table 1: Age, Height, and Weight of Subjects in Three Groups of the Research**

Groups/Statistics	Age (Year)	Height (Cm)	Weight (Kg)
Unscheduled Exercises	22.75±2.71	172.88±5.4	74.61±13.2
Linear Scheduled Exercises	21.73±3.21	172.89±7	73.25±15.32
Daily Wave Scheduled Exercises	21.12±3.27	174.88±6.01	72.2±12.16

## Exercise Protocol

**Experimental Plan and Exercise Program:** The exercise program included 9 weeks of linear scheduled, wave scheduled, and unscheduled resistance exercises. All subjects performed strength and endurance tests before and after 9 weeks of exercise. All three exercise groups practiced accurately and under controlled conditions three times a week and on non-consecutive days. Before each exercise session, subjects performed a 10-minute warm-up period, and after finishing the exercises, performed 5 minutes of gentle running and inactive stretching movements to return to the original state. Then the maximum strength of the upper and lower torso muscles of the subjects was measured using One Repetition Maximum (1RM) test<sup>[12]</sup> in the correct movements of the leg press and chest press. Then, muscular endurance was also measured by performing the maximum possible repetition up to the limit of voluntary exhaustion with an intensity of 60% of maximum power in leg press and chest press movements<sup>[1, 13]</sup>.

**Resistance Exercises:** Subjects performed the program of unscheduled resistance exercise, linear scheduled and wave scheduled in each session, in 8 stations as upper torso muscles exercises (chest, forearm, armpit and back arm press) and lower muscles movements (knee extension and flexion exercises, Scott movement and leg press) (Table 2). The total volume of the two types of linear scheduled, and wave scheduled resistance exercises were calculated using the multiplication result of the repetitions in the sets and the amount of load shifted per movement (a percentage of one repetition maximum)<sup>[5]</sup>. Also, in order to observe the principle of overload, the subjects were tested for one repetition maximum once every two weeks, and based on the percentage of new one repetition maximum, the weights were selected, and the repetitions were performed.

**Table 2: Unscheduled Exercise Program**

Week	1	2	3	4	5	6	7	8	9
Number of Sets	3	3	3	3	3	3	3	3	3
Repetitions	10-12	10-12	10-12	10-12	10-12	10-12	10-12	10-12	10-12
Number of Stations	8	8	8	8	8	8	8	8	8
Rest between Sets (Second)	60-90	60-90	60-90	60-90	60-90	60-90	60-90	60-90	60-90
Intensity Based on 1RM Percentage	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
Rest between Stations (Second)	60-120	60-120	60-120	60-120	60-120	60-120	60-120	60-120	60-120
Sessions per Week	3	3	3	3	3	3	3	3	3

**Table 3: Linear Scheduled Exercise Program**

Week	1	2	3	4	5	6	7	8	9
Exercise Stage	Hypertrophy	Hypertrophy	Hypertrophy	Strength	Strength	Strength	Power	Power	Power
Number of Sets	3	4	4	3	4	5	3	3	3
Repetitions	10-12	10-12	10-12	3-5	3-5	3-5	8-10	8-10	8-10
Number of Stations	8	8	8	8	8	8	8	8	8
Rest between Sets (Second)	60-90	60-90	60-90	60-120	60-120	60-120	60-180	60-180	60-180
Intensity Based on 1RM Percentage	70-75	70-75	70-75	85-90	85-90	85-90	65-70	65-70	65-70
Rest between Stations (Second)	60-120	60-120	60-120	60-120	60-120	60-120	60-120	60-180	60-180
Sessions per Week	3	3	3	3	3	3	3	3	3
Run Speed	Medium	Medium	Medium	Medium	Medium	Medium	High	Explosive	Explosive

**Table 4: Wave Scheduled Program**

Week	1	2	3	4	5	6	7	8	9
Exercise Stage	Hypertrophy	Strength	Power	Hypertrophy	Strength	Power	Hypertrophy	Strength	Power
Number of Sets	3	3	3	4	4	3	4	5	3
Repetitions	10-12	3-5	8-10	10-12	3-5	8-10	10-12	3-5	8-10
Number of Stations	8	8	8	8	8	8	8	8	8
Rest between Sets (Second)	60-90	60-120	60-180	60-90	60-120	60-180	60-90	60-120	60-180
Intensity Based on 1RM Percentage	70-75	85-90	65-70	70-75	85-90	65-70	70-75	85-90	65-70
Rest between Stations (Second)	60-120	60-120	60-180	60-120	60-120	60-180	60-120	60-120	60-180
Sessions per Week	3	3	3	3	3	3	3	3	3

### Recording Electromyographic Activities

To measure the electromyographic activity of the quadriceps muscle, surface electrodes (Ag-AgCl electrodes) with a 28 mm guidance area in the bipolar composition of the electrode distance placed on the skin surface were used, and to record the resulting signals, a 64-channel electromyographic device made by the Italian company of Bioelettronica<sup>1</sup> was used. In order to determine the exact location of the electrodes, the boundary between the inner, the anterior and the outer surfaces of the thigh patella with the Iliac Cres were measured. The bipolar electrodes were then placed at the boundary of 10% between the inner, the anterior, and the outer surfaces of the thigh patella with the Iliac Cres on the Vastus Medialis, Rectus Femoris, and Vastus Lateralis muscles respectively<sup>[14]</sup>. Using absolute values of the mean of one-sided signals in the 250 milliseconds time ranges for three quadriceps muscles (Vastus Medialis, Vastus Lateralis, and Rectus Femoris) during the 5-second isometric

voluntary maximum contraction, the EMG wavelength was calculated and the mean was taken. Then, the highest mean value of the signal in 250 milliseconds time range was selected for each muscle within 5 seconds and was considered as the reference value.

The Kolmogorov–Smirnov test was used to investigate the data normality, and the independent t-test and the two-way ANOVA were used to compare the data. The MATLAB version 2017 software was used to process and compute the electromyographic signal. Data analysis was also performed using SPSS software version 22 and the significance level was considered as  $p < 0.05$ .

### Findings

In Tables 5 and 6 the mean and standard deviation of muscular strength and endurance of subjects in the pre-test and post-test

<sup>1</sup> EMG amplifier, EMG-16LISiN-oT Bio Elettronica, Torino Italy

have been shown. The results showed that the maximum strength and muscular endurance increased significantly in all three exercise groups in the upper and lower torso muscles. Also, it was specified that the maximum strength and muscular

endurance in the upper and lower torso movements in the wave scheduled exercise group was significantly higher than other groups.

**Table 5:** Comparison of Lower Torso and Upper Torso Muscular Strength

Variable	Group	Mean ± Standard Deviation		Within Groups		Between Groups	
		Pre-Test	Post-Test	T	P	F	P
Lower Torso Strength	Unscheduled Group	115.45± 22.27	*231.56 ±56.6		0.001		
	Linear Scheduled Group	113.96±27	*230.98±54.19		0.001	0.16	0.001
	Wave Scheduled Group	114.69 ±38.4	#271.15 ± 47.38		0.001		
Upper Torso Strength	Unscheduled Group	33.67± 10.09	*40.48±7.89		0.001		
	Linear Scheduled Group	32.49±7.81	*41.33±10.16		0.001	0.001	0.002
	Wave Scheduled Group	32.64±9.93	#*76.38±13.04		0.002		

\* p <0.05: The difference of the group before exercise and after exercise

#p <0/05: The difference between the three exercise groups

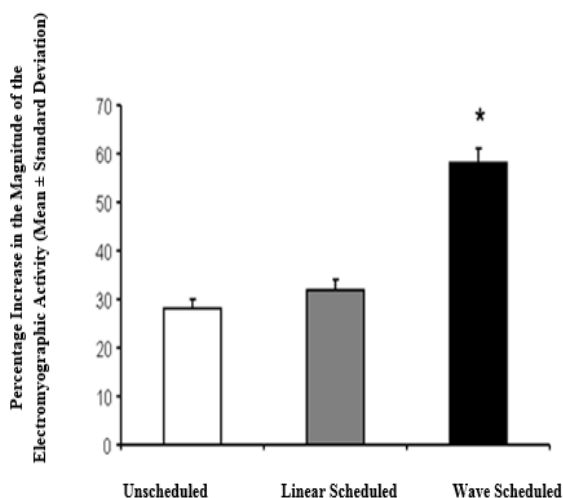
**Table 6:** Lower Torso and Upper Torso Muscular Strength Comparison

Variable	Group	Mean and Standard Deviation;		Within Group P-Value	Between Groups P-Value;	
		Pre-test	Post-Test		Pre-Test	Value; Post-Test
Lower Torso Resistance	Unscheduled Group	16.96± 7.09	*41.89 ±23.64	0.004		
	Linear Scheduled Group	16.72±6.31	*40.85±17.15	0.001	0.44	0.03
	Wave Scheduled Group	17 ±10.79	#271.15 ± 47.38	0.001		
Upper Torso Resistance	Unscheduled Group	13.43± 5.25	*22.93±6.59	0.001		
	Linear Scheduled Group	14±4.48	*21.69±2.7	0.001	0.19	0.001
	Wave Scheduled Group	15.71±8.59	#*32.75±11.21	0.002		

\* p <0.05: The difference of the group before exercise and after exercise

#p <0/05: The difference between the three exercise groups

Also, based on the results obtained from Figure 1, it was specified that there was a significant difference in the magnitude of the electromyographic activity of the quadriceps muscle of the wave scheduled resistance exercise group compared to the linear scheduled and unscheduled groups (p <0.05).



**Figure 1:** Percentage Increase in the Magnitude of Electromyographic Activity of the Quadriceps Muscle after Wave Scheduled Exercises, Linear Scheduled Exercises, and Unscheduled Exercises

## Discussion

The wave scheduled, linear scheduled and unscheduled resistance exercises have significant difference with each other in terms of effect on the strength and endurance of upper and lower torso muscles. Based on the results of the present study, a significant increase in maximum strength in all tested upper torso (chest, forearm, armpit, and triceps press) and lower torso (the exercises of knee extension, knee flexion, Scott movement and leg press) after 9 weeks of doing wave scheduled resistance exercises was observed.

According to the present study, several studies have shown an increase in maximum strength after scheduled resistance exercises [15-17]. In a study, Peterson et al. (2008) have reported that wave scheduled resistance exercise increases more strength in the upper and lower torso muscles as well as jumping strength [18]. Monteiro et al. (2009) also stated that after 12 weeks of wave scheduled exercise, it will lead to increasing higher strength than linear scheduled exercises and unscheduled exercise programs [19]. In addition, Foschini et al. (2010) showed that wave scheduled exercise compared to linear scheduled exercise significantly improved some of the risk factors for metabolic syndrome in obese adolescents [20]. In line with the present results, these results highlight the superiority of wave scheduled

exercises, with this difference, that in the present study the intensity and volume exercise parameters varied weekly.

In general, supporters of scheduled exercises models have stated that by manipulating the volume and intensity of this exercise model, more muscular strength will be achieved. The risk of over exercise can also be reduced by increasing the rest time and adequate recovery between the scheduled program of exercise sessions, while preventing the creation of muscular injury<sup>[18, 21]</sup>. Studies have shown that the firing rate of motor units, neural stimulations increase, reduction of the activity of opposing muscles and the activation of satellite cells are considered as effective factors in increasing strength as a result of scheduled exercises<sup>[22-24]</sup>. A study by Kraemer *et al.* (2004) specified that an increase in initial strength (1 to 8 weeks after doing resistance exercises) was primarily due to the increase in neural adaptations<sup>[17]</sup>, indicating that the nervous system has a very important role in increasing the strength resulting from resistance exercises and then after this period, the increase in strength is affected by the increase in muscular mass<sup>[17]</sup>.

Muscular endurance has also been shown to be a combination of two biomotor abilities that are strength and endurance<sup>[25]</sup>, and it seems that there is a relationship between an increase in strength and muscular endurance<sup>[26]</sup>. In the present study, it was specified that wave scheduled resistance exercises increase the maximum endurance of the upper and lower torso muscles. In this regard, it has been observed that improvement in muscular endurance have been a result of a wave scheduled program through a series of adjustments such as myofibrils involvement while doing exercise and possibly change in the type of muscle fibers, mitochondrial enzymes increase, and an increase in the number and size of mitochondria, lipolysis increase, traumatic and plasma volume increase, and glycogen storage increase<sup>[2, 12]</sup>. In the study of Rhea *et al.* (2003), no significant difference was observed in muscular endurance in the two groups of wave and linear scheduled resistance exercises<sup>[5]</sup>; however due to the difference in effective exercise factors such as the method of doing exercise, duration and intensity of exercise, exercise history and the age of participants, planning the training sessions and selecting dependent variables, it is difficult to compare the results of studies with the present study<sup>[27]</sup>.

Studies have reported that progress in muscle strength may improve endurance performance after resistance exercise<sup>[28, 29]</sup>. In another study performed by Miranda *et al.* (2011), it has been specified that periodic resistance exercises can be an effective way to increase the strength and endurance of muscles<sup>[30]</sup>. In addition, in several studies after doing resistance exercises, short-term<sup>[28, 29]</sup> and long-term endurance<sup>[28, 31]</sup> has increased. Hickson *et al.* (1998) also suggested in a study that increasing the strength of the quadriceps after resistance exercise could improve endurance performance<sup>[28]</sup>. This increase is probably due to the decrease in muscular blood flow obstruction at the time of contraction<sup>[31]</sup>, and an increase in capillary density per muscular fiber and the activity of citrate synthase in the quadriceps muscle<sup>[32]</sup>.

Izquierdo *et al.* (2003) in a study on various resistance exercise protocols for 8 weeks, with resistances with (60-80% of one repetition maximum and with 5-12 repetitions per set), and (40-70% of one repetition maximum and 10-15 repetitions per set) did not observe improvement in the endurance performance of the exercised subjects<sup>[33]</sup>. They attributed the reason of this lack of impact to the subjects' exercise history. Kraemer *et al.* (1981) also specified that resistance exercises were effective in increasing the aerobic capacity of people who had no exercise history<sup>[34]</sup>. These observations indicate that exercise history is a determining factor in the development of muscular endurance during a period of resistance exercises, which probably the difference in the results of studies is this determining factor.

According to Figure 1, the EMG amplitude of the quadriceps muscle was significantly larger after 9 weeks of wave resistance exercises than other resistance exercise programs. Researchers attribute the increase in EMG amplitude after resistance exercise to an increase in the amount of motor unit discharge rate to create maximum muscular tension<sup>[35, 36]</sup>. Previous studies have repeatedly reported that the muscles strength increase followed by resistance exercises is associated with significant changes in motor unit discharge rate<sup>[37]</sup> and the muscle fiber conduction velocity<sup>[38]</sup>. In line with previous studies<sup>[39, 40]</sup>, the findings of the present study showed that the manipulation of exercise parameters has a significant effect on increasing neuromuscular activity. In the present research, we found out that the daily wave scheduled resistance program compared to other programs will lead to the EMG activity increase, which it can be said that this observed increase in the EMG amplitude after the wave scheduled resistance program due to the repeated changes in the intensity and volume on a weekly basis is justifiable.

As skeletal muscle is often exposed to more muscular pressures during a wave scheduled exercise program, this type of athletic program may be effective in using fast-twitch motor units. The fast-twitch motor units, which are characterized and considered by higher firing speed, and guidance, create a wider amplitude of EMG and muscular tension<sup>[41]</sup>. In addition, repeated changes in exercise parameters (intensity and volume) during the wave scheduled program (in the present study) may lead to greater cortical excitability<sup>[42]</sup>; so it can strengthen nerve stimulation from a higher motor center towards the muscular fibers, which in turn creates greater EMG activity during maximum contraction.

## Conclusion

The results of this study showed that resistance exercise using the wave scheduled resistance program is effective compared to other resistance programs for gaining muscular strength and endurance and neuromuscular activity. Due to the fact that in the wave scheduled resistance program, weekly manipulation method was used in exercise parameters, it is usually used for maximum optimization in the muscular strength and endurance ratio and neuromuscular performance of skeletal muscle, especially for sports that require explosive movements.

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