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The Effects of 6- Week Strength and Speed Training Program on Some Physical and Physiological Parameters in Adolescent Boxers[1]

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ORIGINAL ARTICLE

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Abstract

The objective of this study was to determine the effects of a six-week strength and speed training program on physical and physiological parameters in adolescent boxers. Twenty-nine healthy male boxers aged 15-17 years, with a minimum of four years of athletic experience, voluntarily participated in the study. The participants were divided into two experimental groups, maximal strength (n: 10), maximal speed (n: 10), and a control group (n: 9). Boxers in the experimental groups underwent strength and speed training, respectively, in addition to boxing training three days per week during the six-week training period. The SPSS program was used in the statistical analysis of the data. Comparing intra-group values for the maximal strength group before and after the training period, significant differences were found in favor of the post-test results for right-hand grip, left-hand grip, and back strength ($p < .05$), while no significant differences were observed for the other parameters ($p > .05$). In the maximal speed group, there were significant differences in visual reaction times for both right and left hands, left-hand grip strength, and the 20 m shuttle run in favor of the post-test results ($p < .05$), while no significant differences occurred in the other parameters ($p > .05$). In the control group, a significant difference in visual reaction time for the right hand was detected ($p < .05$), while there were no significant differences in the other parameters ($p > .05$). In conclusion, the six weeks of maximal strength and maximal speed training undergone by adolescent male boxers had a positive effect on certain physical and physiological parameters.

Keywords: Adolescence, Boxing, Maximal Strength, Maximal Speed.

Adolesan Dönem Boksörlerde 6 Haftalık Kuvvet ve Sürat Antrenmanlarının Fiziksel ve Fizyolojik Parametreler Üzerine Etkisi

Özet

Bu çalışmanın amacı, altı haftalık kuvvet ve sürat antrenman programının ergen boksörlerde fiziksel ve fizyolojik parametreler üzerindeki etkilerini belirlemektir. Çalışmaya 15-17 yaşlarında, en az dört yıllık antrenman deneyimine sahip yirmi dokuz sağlıklı erkek boksör gönüllü olarak katılmıştır. Katılımcılar maksimal kuvvet (n: 10), maksimal hız (n: 10, yaş) ve kontrol grubu (n: 9) olmak üzere üç gruba ayrılmıştır. Deney gruplarındaki boksörler altı haftalık antrenman süresi boyunca haftada üç gün boks antrenmanına ek olarak sırasıyla kuvvet ve sürat antrenmanı yapmışlardır. Verilerin istatistiksel analizinde SPSS programı kullanılmıştır. Maksimal kuvvet grubu için antrenman dönemi öncesi ve sonrası grup içi değerler karşılaştırıldığında, sağ el kavrama, sol el kavrama ve sırt kuvveti için son test sonuçları lehine anlamlı farklılıklar bulunurken ($p < .05$), diğer parametreler için anlamlı farklılıklar gözlenmemiştir ($p > .05$). Maksimal hız grubunda, hem sağ hem de sol el için görsel reaksiyon sürelerinde, sol el kavrama kuvvetinde ve 20 m mekik koşusunda son test sonuçları lehine anlamlı farklılıklar bulunurken ($p < .05$), diğer parametrelerde anlamlı farklılıklar oluşmamıştır ($p > .05$). Kontrol grubunda, sağ el için görsel reaksiyon süresinde anlamlı bir fark tespit edilirken ($p < .05$), diğer parametrelerde anlamlı bir fark bulunmamıştır ($p > .05$). Sonuç olarak, ergen erkek boksörlerin altı haftalık maksimal kuvvet ve maksimal sürat antrenmanlarının belirli fiziksel ve fizyolojik parametreler üzerinde olumlu bir etkisi olmuştur.

Anahtar Kelimeler: Adolesan, Boks, Maksimal Kuvvet, Maksimal Hız.

[1]This study was produced from the doctoral thesis titled "The effect of 6- week strenght and speed training on some physical and physiological parameters in adolescent boxers" published in 2023.

Introduction

Training consists of activities aimed at improving athletic performance; for example, resisting weights at certain time intervals yields changes to the athlete's body in terms of strength. Scientific advances have identified critical principles in physical training such as strength, speed, intervals, endurance, and periodization training (based on cycles of varying lengths). Furthermore, the application of other disciplines to physical training, including biomechanics, nutrition, and psychology, has led to improved performance (Hausswirth and Mujika, 2013). In addition to these factors, concepts such as psychological training or orientation toward training (motivation, etc.) play a major role in preparing for competition, and as such have been studied and discussed by researchers throughout the world (Sevim, 2010).

Physical activity is well understood to affect the human body. Since various types of sports exist, the basic energy sources used, as well as their duration and frequency, constitute frequent topics of research in sports science. Athletic performance may vary according to numerous factors, not only as a result of the physical condition of the athlete or the sport in question. Therefore, athletic coaches need to determine the physical and physiological capacities of their athletes and should be able to improve their performance in competitions by employing special training programs tailored to the athlete (Ozan, 2018).

Boxing, one of the oldest combat sports in human history, is considered the most bellicose sport in the world (Türker and Kahraman, 2020). In contrast to kickboxing and similar combat sports, it involves striking the opponent with only one's fists, without kicking or otherwise using the feet (El-Ashker and Nasr, 2012; Chaabène et al., 2015). In this respect, boxing is a combat sport requiring a high level of performance in terms of strength and effort due to its complex static and dynamic characteristics (Mitchell, 1994). The goal of boxing is to deliver direct and accurate strikes to the opponent's upper torso with solid technical punches. At the same time, the boxer must defend himself against the opponent's punches (Zorba, 1999; Öztürk, 2006). In order to score points and not cede points to the opponent, the boxer must enhance his technical and tactical skills. In addition, while executing such technical and tactical skills, the boxer's overall performance must be optimized so that his energy is not exhausted. Academic studies have shown that the anaerobic thresholds of boxers performing at a high level and their substantial aerobic capacity are important criteria for achieving success. In boxing, punching takes place with a very short and dynamic contraction; the execution of this movement involves significant muscle power. Lower and upper extremity forces, which should be connected in boxers, are the major factors yielding improved performance in the sport (Piorkowski et al., 2011), and strength is necessary to deliver an effective and technical punch (Pierce et al., 2006).

The period of puberty undoubtedly results in an increase in muscle strength for both men and women. Activities that provide a high level of strength stimulation performed correctly on a regular basis during adolescence contribute to increased myelin (covering the nerve axons with fatty sheaths and accelerating nerve impulse transmissions), improved skills, sustainable muscle strength development, and increased heart rate volume due to the growth of the heart and development in VO_{2max} (Murray and Kenney, 2019). In addition to the study of anaerobic endurance, speed-based research should also be conducted. The point to consider regarding endurance training during adolescence is that anaerobic loads should not be applied systematically since an enzymatic and hormonal system has not been established (Günay et al., 2018).

In view of this information, the objective of the present study was to determine the effects of a six-week strength and speed training program on selected physical and physiological parameters in adolescent boxers.

Materıals And Methods

Participants

A total of 29 adolescent boxers aged 15-17 years voluntarily with a minimum of four years of athletic experience participated in this study. The boxers were selected from the Provincial Directorate of Youth Services and Sports Boxing Club in the province of Ağrı, Turkey. The necessary permission for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of Selcuk University Faculty of Sports Sciences (25.01.2022/05). Prior to the start of the study, each of the subjects was given a voluntary consent form containing detailed information such as the risks and discomforts that may be experienced in the course of the study. The form in question was then read and signed by each participant. In addition, the families of the participants signed a parental consent form.

Participant Criteria

- Healthy
- Aged between 15-17 years
- Male
- Able to participate in six weeks of training without interruption
- Volunteer for the study

Grouping of Participants

Based on the performance measurements of the study participants, the latter were divided into two different experimental groups and one control group, such that the mean values of each group's

performance parameters were similar. The 29 healthy male boxers aged 15-17 who volunteered to participate in this study were separated into groups by the stratified randomization method. The three groups were comprised of a maximal strength group (n=10), a maximal speed group (n=10) and a control group (n =9). However, since one boxer from the control group discontinued his participation, the study proceeded with only nine boxers in that group. The subjects were instructed not to participate in any other exercise programs during the training period.

Training Protocol

In this study, training protocols lasting six weeks were assigned to three groups (the maximal strength training group, the maximal speed training group, and the control group) consisting of 29 individuals in total. The participants underwent initial testing (height, body weight, skinfold fat percentage, anaerobic-aerobic power, visual reaction speed, grip strength, back strength, and heart rate) three days prior to the start of the training. The groups were formed by gathering together participants with similar performance measurements. Boxers in all three groups continued their routine boxing training for the duration of the training protocols implemented in the study. In addition to their routine boxing workouts, the training groups also received conditioning targeting either strength or speed. The initial training sessions began three days following the testing and continued three days per week for six weeks. The maximal strength and maximal speed groups combined boxing with strength and speed training, respectively, while the control group trained only in boxing. The participants were re-tested three days after the last day of training.

Training Period

Studies have reported that 6-12 weeks of training at least three days per week are decisive for strength development (Hudelmaier et al., 2010). For this reason, in the present study, in addition to the routine boxing training, the training periods for maximal strength and maximal speed lasted six weeks, with the exercises performed three days per week.

Maximal Strength Training

Participants in the maximal strength training group underwent maximal strength training three days per week in addition to boxing training. For maximal strength training, the bench press and shoulder press exercises were performed. The pyramidal system was used during maximal strength training, such that weight loads were increased following each set, with full rest between sets and five minutes of rest between stations. The load intensities were 80% of the maximum in the first set, then increased by 5% for each set while the number of repetitions decreased by one until the maximal load intensity was reached.

Table 1

Training Program of the Maximal Strength Group

Monday	**Wednesday**	**Friday**
Bench Press	**Bench Press**	**Bench Press**
80% (5 reps)	80% (5 reps)	80% (5 reps)
85% (4 reps)	85% (4 reps)	85% (4 reps)
90% (3 reps)	90% (3 reps)	90% (3 reps)
95% (2 reps)	95% (2 reps)	95% (2 reps)
100% (1 rep)	100% (1 rep)	100% (1 rep)
Shoulder Press	**Shoulder Press**	**Shoulder Press**
80% (5 reps)	80% (5 reps)	80% (5 reps)
85% (4 reps)	85% (4 reps)	85% (4 reps)
90% (3 reps)	90% (3 reps)	90% (3 reps)
95% (2 reps)	95% (2 reps)	95% (2 reps)
100% (1 rep)	100% (1 rep)	100% (1 rep)

Training sessions were performed at the intensity and frequency specified in Table 1.

Maximal Speed Training

The participants in the maximal speed training group received speed conditioning in addition to boxing training three days per week. For maximal speed training, the participants performed the following exercises: punching bag interval training, rope interval training, and punchball interval training. Each exercise was performed for 15 seconds, with 30 seconds of rest between each of the six repetitions and a rest period of five minutes between stations.

Table 2

Training Program of Maximal Speed Group

Monday	**Wednesday**	**Friday**
Punching Bag	**Punching Bag**	**Punching Bag**
15 seconds x 6 repetitions	15 seconds x 6 repetitions	15 seconds x 6 repetitions
Rope	**Rope**	**Rope**
15 seconds x 6 repetitions	15 seconds x 6 repetitions	15 seconds x 6 repetitions
Punchball	**Punchball**	**Punchball**
15 seconds x 6 repetitions	15 seconds x 6 repetitions	15 seconds x 6 repetitions

Anthropometric Measurements

Height Measurement

The subjects stood in an anatomical position with bare feet, heels touching, and heads in the frontal plane. After placing the headboard to touch the vertex point, the subjects held their breath, and the height measurement was obtained in cm using a stadiometer (Holtain Ltd., UK) with a precision of ±1 mm (Tatlıcı, 2017).

Body Weight Measurement

Body weight was measured in kg using a Tanita 401 A scale (Japan) with a precision of ±100 g while the participants were barefoot, dressed only in shorts, and standing in an anatomical position (Tatlıcı, 2017).

Body Fat Measurement

For body fat percentage measurements, skinfolds at the spina iliaca, scapula, triceps, and biceps were measured three times each using the Holtain Skinfold Caliper. The formulas presented in Siri (1956) were used to calculate the values for body fat percentage.

Performance Measurements

Visual Reaction Speed Measurements

Visual reaction times were obtained using the FitLight™ device (Fitlight Sports Corp., Canada). The visual-motor reaction time consists of a simple reaction lasting 10 seconds to visual stimuli that appear on six wireless illuminated discs.

The discs were placed on a table in the shape of a half-moon. The participants placed their hands in the middle of the half-moon. The midpoint of each disc was positioned at a distance of 40 cm from the center of the half-moon, and the discs were arranged at a distance of 25 cm from each other. Before the start of the test, the participants brought their hands to the starting point, i.e., to the center. The participants put out the light by extending their hands toward the burning light, then brought their hands back to the center point before quickly putting out the next light. After 10 seconds, the test ended automatically. The fit-light device gave the average reaction speed of each participant for the 10-second period (Örs et al., 2019).

Vertical Jump Measurements (cm)

A Takai brand jump meter was used to measure the vertical jump height of the participants. In the jump test, which measures the explosive strength of the legs, a property dependent on the maximal

strength of the legs, the jump meter was adjusted according to the participants. Care was taken that both feet were positioned at an equal distance from the rope. The subjects performed an upward jump with the hands at the waist and the knees in the bent squat position at 90° flexion. After each measurement, the subjects were given two minutes to rest between jumps (Günay et al., 2019). The participants were allowed three attempts, with their best results recorded in centimeters.

Hand Grip Strength Measurements

Measurements of the participants' hand grip strength were obtained using a hand dynamometer (Bravomed 12-0286), which measures to within ±10 g. The hand dynamometer was adjusted according to the age of the subject before starting the test. The participants were then instructed to squeeze the dynamometer, separately twice with each hand, and the results appearing on the digital screen were noted. The best results for each hand were recorded (Günay et al., 2019).

Back Strength Measurements

In order to determine back strength, the participants stood with their feet placed on the dynamometer, with legs and backs straight and arms outstretched. The hand grip of the dynamometer was adjusted to the knee level of the subject who then pulled using maximum strength with hands at hip level. The subjects were allowed two attempts, and the highest value obtained was recorded (Günay et al., 2019).

Aerobic Power Measurements (20 m Shuttle Run)

A space with a 20 m long lane was created as the testing area. Colored adhesive strips were placed for the lane and turn lines, with the lines clearly visible with cones and dots. Running speed was monitored using a cassette player that signaled at regular intervals. A level tracking form was employed in the test to assess each athlete. Every time the 20 m line was crossed, a mark was checked on the form. At the end of the test, the signals received by the athlete were calculated and the maximum VO_2 levels of the subjects were estimated (in ml/kg/min) by consulting the evaluation table (Yılmaz, 2012).

Heart Rate (HR) Measurements

The participants' heart rates (HR) were determined using a heart rate monitor (Polar M 400 Polar-Elektro, made in Finland), which can be recorded at intervals of five seconds. Polar heart rate monitors, worn by the participants during the test, recorded resting heart rates before the test and fatigue following the test (Aktaş, 2019).

Statistical Analysis

The SPSS (Statistical Package for the Social Sciences) program was employed in the statistical analysis of the data. The Shapiro-Wilk test was conducted to determine the normality of the data obtained in the study. For the normally distributed data, a paired sample t-test was used for binary dependent variables while a one-way analysis of variance (one-way ANOVA) was performed to compare three or more dependent groups. In order to determine which groups the differences originated from, the Tukey HSD (honestly significant difference) test, a post hoc test, was employed. For the present study, a value of $p < .05$ was accepted as the level of statistical significance.

Findings

The comparison of the characteristics of the participants is given in Table 3.

Table 3

ANOVA Test Results for the General Characteristics of the Participants

Parameter	***Group***	***N***	***Mean***	***Std. Dev.***	***F***	***p***	***Tukey HSD***
Age (years)	*Maximal Force Group*[1]	10	15.20	0.42	3.106	.062	$p > .05$
	Maximal Speed Group[2]	10	15.70	0.95			
	Control Group[3]	9	16.11	0.93			
Height (cm)	*Maximal Force Group*[1]	10	172.60	5.46	1.205	.316	$p > .05$
	Maximal Speed Group[2]	10	169.70	7.89			
	Control Group[3]	9	174.44	6.64			
Body Weight (kg)	*Maximal Force Group*[1]	10	62.71	14.65	1.515	.239	$p > .05$
	Maximal Speed Group[2]	10	58.05	8.45			
	Control Group[3]	9	67.09	9.73			

According to Table 3, there were no significant differences between the groups in terms of age, height, and body weight parameters ($p > .05$ for all). These results indicate that the athletes in all three groups were similar with regard to their general characteristics.

The Anova test results for comparing the pre-test values of the participants' visual reaction, vertical jump and strength parameters are shown in Table 4.

Table 4

ANOVA Test Results Comparing Participants' Pre-Test Values For Visual Reaction, Vertical Jump, and Strength Parameters

Parameter	*Group*	*N*	*Mean*	*Std. Dev.*	*F*	*p*	*Tukey HSD*
Visual Reaction Right Pre-Test (sec)	*Maximal Force Group[1]*	10	0.56	0.06	.587	.563	$p > .05$
	Maximal Speed Group[2]	10	0.56	0.05			
	Control Group[3]	9	0.58	0.05			
Visual Reaction Left Pre-Test (sec)	*Maximal Force Group[1]*	10	0.59	0.05	.383	.686	$p > .05$
	Maximal Speed Group[2]	10	0.57	0.06			
	Control Group[3]	9	0.58	0.06			
Vertical Jump Pre-Test (cm)	*Maximal Force Group[1]*	10	28.63	4.16	3.946	**.032***	**2>1**
	Maximal Speed Group[2]	10	33.97	4.30			
	Control Group[3]	9	32.78	4.91			
Grip - Right Hand Pre-Test (kg)	*Maximal Force Group[1]*	10	38.15	5.00	3.055	.064	$p > .05$
	Maximal Speed Group[2]	10	39.38	6.35			
	Control Group[3]	9	44.14	5.11			
Grip - Left Hand Pre-Test (kg)	*Maximal Force Group[1]*	10	35.16	6.52	3.336	.051	$p > .05$
	Maximal Speed Group[2]	10	35.67	8.22			
	Control Group[3]	9	42.72	6.19			
Back Strength Pre-Test (kg)	*Maximal Force Group[1]*	10	107.90	19.28	3.810	**.035***	**3>1**
	Maximal Speed Group[2]	10	113.60	22.24			
	Control Group[3]	9	135.28	26.22			

*$p < .05$

The Anova test results for comparing the pre-test values of the participants' for body fat percentage, aerobic capacity, and heart rate (HR) parameters are shown in Table 5.

Table 5

ANOVA Test Results Comparing the Participants' Pre-Test Values For Body Fat Percentage, Aerobic Capacity, and Heart Rate (HR) Parameters

Parameter	*Group*	*N*	*Mean*	*Std. Dev.*	*F*	*p*	*Tukey HSD*
Body Fat Percentage Pre-Test (%)	*Maximal Force Group[1]*	10	25.41	5.72	1.710	.201	$p > .05$
	Maximal Speed Group[2]	10	22.24	1.81			
	Control Group[3]	9	25.60	5.06			
20 m Shuttle Run Pre-Test (number)	*Maximal Force Group[1]*	10	64.20	25.71	1.854	.177	$p > .05$
	Maximal Speed Group[2]	10	84.60	15.01			
	Control Group[3]	9	76.56	29.19			
Max VO_2	*Maximal Force Group[1]*	10	40.23	8.49	1.959	.161	$p > .05$

Pre-Test (ml/kg/min)	*Maximal Speed Group*[2]	10	47.05	4.34			
	Control Group[3]	9	44.07	9.57			
Resting HR Pre-Test (bpm)	*Maximal Force Group*[1]	10	67.30	4.95			
	Maximal Speed Group[2]	10	67.40	13.40	.619	.546	$p > .05$
	Control Group[3]	9	71.33	5.41			
Fatigue HR Pre-Test (bpm)	*Maximal Force Group*[1]	10	181.80	18.15			
	Maximal Speed Group[2]	10	188.80	11.38	.773	.472	$p > .05$
	Control Group[3]	9	187.67	8.47			

*$p < .05$

In Tables 4 and 5, the results of the comparisons of the pre-test values of the three groups are presented. There were no statistically significant differences detected between the groups in visual reaction right, visual reaction left, right-hand grip, left-hand grip, body fat percentage, 20 m shuttle run, maximum VO_2, resting HR, or fatigue HR ($p > .05$). Significant differences were observed between the groups for vertical jump and back strength measurements ($p < .05$). The vertical jumping skills of the boxers in the maximal speed group were superior to those in the maximal strength group, while the back strength of the boxers in the control group was greater than those in the maximal strength group.

Paired sample t test results for comparing the pre-test and post-test values of the visual reaction, vertical jump and strength parameters of the maximal strength group are shown in Table 6.

Table 6

Paired Sample T-Test Results for Comparison of the Pre-Test And Post-Test Values of the Maximal Strength Group for Visual Reaction, Vertical Jump, and Strength Parameters

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Visual Reaction Right (sec)	*Pre-Test*	10	0.56	0.06	0.929	.377
	Post-Test	10	0.54	0.02		
Visual Reaction Left (sec)	*Pre-Test*	10	0.59	0.05	1.696	.124
	Post-Test	10	0.57	0.04		
Vertical Leap (cm)	*Pre-Test*	10	28.63	4.16	-0.966	.359
	Post-Test	10	29.25	5.59		
Grip - Right Hand (kg)	*Pre-Test*	10	38.15	5.00	-3.376	**.008***
	Post-Test	10	40.57	5.06		
Grip - Left Hand (kg)	*Pre-Test*	10	35.16	6.52	-2.753	**.022***
	Post-Test	10	37.63	5.59		
Back Strength (kg)	*Pre-Test*	10	107.90	19.28	-2.284	**.048***

	Post-Test	10	121.70	13.41

*$p < .05$

As shown in Table 6, comparing the pre-test and post-test values of the boxers in the maximal strength group, there were no significant differences between the values for the visual reaction right and visual reaction left parameters ($p > .05$ for both). Regarding the pre-test and post-test values of the vertical jump and strength parameters of the boxers in this group, there was no significant difference between the values for vertical jump ($p > .05$), while a significant difference was observed between both right-hand and left-hand grip strength as well as back strength, in favor of the post-test results ($p < .05$ for all).

Paired sample t test results for the comparison of pre-test-post-test values of the maximal strength group's body fat percentage, aerobic capacity, and heart rate (HR) are shown in Table 7.

Table 7

Paired Sample T-Test Results for Comparison of the Pre-Test and Post-Test Values of the Maximal Strength Group For Body Fat Percentage, Aerobic Capacity, and Heart Rate (HR)

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Body Fat Percentage (%)	*Pre-Test*	10	25.41	5.72	-.612	.555
	Post-Test	10	25.67	5.14		
20 m Shuttle Run (number)	*Pre-Test*	10	64.20	25.71	-1.427	.187
	Post-Test	10	66.90	24.58		
Max VO_2 (ml/kg/min)	*Pre-Test*	10	40.23	8.49	-1.521	.163
	Post-Test	10	41.28	7.89		
Resting HR (bpm)	*Pre-Test*	10	67.30	4.95	0.111	.914
	Post-Test	10	67.00	5.01		
Fatigue HR (bpm)	*Pre-Test*	10	181.80	18.15	-1.822	.102
	Post-Test	10	192.00	9.99		

Significant difference *$p < .05$

As per Table 7, no significant differences were detected between the pre-test and post-test values of the maximal strength groups for the parameters of body fat percentage, 20 m shuttle run, maximum VO_2, and resting and fatigue heart rates ($p > .05$ for all).

Paired sample t-test results for comparison of the pre-test and post-test values of the maximal speed group for visual reaction, vertical jump, and strength parameters are shown in Table 8.

Table 8

Paired Sample T-Test Results for Comparison of the Pre-Test and Post-Test Values of the Maximal Speed Group For Visual Reaction, Vertical Jump, and Strength Parameters

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Visual Reaction Right (sec)	*Pre-Test*	10	0.56	0.05	4.657	**.001***
	Post-Test	10	0.52	0.04		
Visual Reaction Left (sec)	*Pre-Test*	10	0.57	0.06	2.952	**.016***
	Post-Test	10	0.53	0.04		
Vertical Jump (cm)	*Pre-Test*	10	33.97	4.30	0.085	.934
	Post-Test	10	33.88	5.63		
Grip - Right Hand (kg)	*Pre-Test*	10	39.38	6.35	-.512	.621
	Post-Test	10	39.90	7.95		
Grip - Left Hand (kg)	*Pre-Test*	10	35.67	8.22	-4.870	**.001***
	Post-Test	10	38.35	8.28		
Back Strength (kg)	*Pre-Test*	10	113.60	22.24	1.794	.106
	Post-Test	10	109.00	19.06		

Significant difference *$p < .05$

In Table 8 which presents the comparisons of the pre-test and post-test values of the boxers in the maximal speed group, a significant difference was detected between the values for visual reaction, both right and left, in favor of the post-test results ($p < .05$). While there were no significant differences between the values for vertical jump, right-hand grip, and back strength ($p > .05$ for), a significant difference was observed between the values for left-hand grip strength, also in favor of the post-test results ($p < .05$).

Paired sample t-test results for comparison of the pre-test and post-test values of the maximal speed group for body fat percentage, aerobic capacity, and heart rate (HR) are shown in Table 9.

Table 9

Paired Sample T-Test Results for Comparison of the Pre-Test and Post-Test Values of the Maximal Speed Group For Body Fat Percentage, Aerobic Capacity, and Heart Rate (HR)

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Body Fat Percentage (%)	*Pre-Test*	10	22.24	1.81	.347	.737
	Post-Test	10	22.15	1.78		
20 m Shuttle Run (number)	*Pre-Test*	10	84.60	15.01	-3.371	**.008***
	Post-Test	10	91.00	13.64		

Max VO_2 (ml/kg/min)	*Pre-Test*	10	47.05	4.34	-.913	.385
	Post-Test	10	47.92	4.40		
Resting HR (bpm)	*Pre-Test*	10	67.40	13.40	0.745	.475
	Post-Test	10	64.40	4.70		
Fatigue HR (bpm)	*Pre-Test*	10	188.80	11.38	-.639	.539
	Post-Test	10	191.40	7.62		

Significant difference *$p < .05$

According to Table 9, no significant differences existed between the pre-test and post-test values of the boxers in the maximal speed group with respect to body fat percentage, maximum VO_2, and resting and fatigue heart rates ($p > .05$ for all), while a significant difference was found in favor of the post-test results for the 20 m shuttle run ($p < .05$).

Paired sample t-test results for comparison of the pre-test and post-test values of the control group for visual reaction, vertical jump, and strength parameters are shown in Table 10.

Table 10

Paired Sample T-Test Results for Comparison of the Pre-Test and Post-Test Values of the Control Group for Visual Reaction, Vertical Jump, and Strength Parameters

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Visual Reaction Right (sec)	*Pre-Test*	9	0.58	0.05	3.657	**.006***
	Post-Test	9	0.52	0.03		
Visual Reaction Left (sec)	*Pre-Test*	9	0.58	0.06	1.538	.163
	Post-Test	9	0.55	0.04		
Vertical Jump (cm)	*Pre-Test*	9	32.78	4.91	1.886	.096
	Post-Test	9	31.31	5.75		
Grip - Right Hand (kg)	*Pre-Test*	9	44.14	5.11	-.239	.817
	Post-Test	9	44.42	5.78		
Grip - Left Hand (kg)	*Pre-Test*	9	42.72	6.19	-1.314	.225
	Post-Test	9	43.79	7.09		
Back Strength (kg)	*Pre-Test*	9	135.28	26.22	-.848	.421
	Post-Test	9	137.89	28.20		

Significant difference *$p < .05$

As seen in Table 10, which displays the results of the comparisons of the pre-test and post-test values of the boxers in the control group, while there were no significant differences between the visual reaction left-hand values ($p > .05$), a significant difference was determined in favor of the post-test results for the visual reaction right-hand parameter ($p < .05$). The pre-test and post-test values of

the vertical jump and strength parameters of the boxers in this group showed no significant differences in terms of vertical jump, right-hand grip, left-hand grip, and back strength ($p > .05$ for all).

Paired sample t-test results for comparison of the pre-test and post-test values of the control group for body fat percentage, aerobic capacity, and heart rate (HR) are shown in Table 11.

Table 11

Paired Sample T-Test Results For Comparison of the Pre-Test and Post-Test Values of the Control Group for Body Fat Percentage, Aerobic Capacity, and Heart Rate (HR)

Parameter	***Test***	***N***	***Mean***	***Std. Dev.***	***t***	***p***
Body Fat Percentage (%)	*Pre-Test*	9	25.60	5.06	-.692	.509
	Post-Test	9	27.00	6.88		
20 m Shuttle Run (number)	*Pre-Test*	9	76,56	29.19	-.328	.752
	Post-Test	9	77.33	26.27		
Max VO_2 (ml/kg/min)	*Pre-Test*	9	44.07	9.57	-.437	.674
	Post-Test	9	44.41	8.43		
Resting HR (bpm)	*Pre-Test*	9	71.33	5.41	1.629	.142
	Post-Test	9	67.33	6.63		
Fatigue HR (bpm)	*Pre-Test*	9	187.67	8.47	-.704	.502
	Post-Test	9	189.44	10.06		

Significant difference *$p < .05$

As shown by the data presented in Table 11, there were no significant differences between the pre-test and post-test values for the parameters of body fat percentage, 20 m shuttle run, aerobic capacity, or heart rate for the boxers in the control group ($p > .05$ for all).

Discussion

In the present study, no statistically significant differences were observed in the visual reaction times of the maximal strength group between the pre-test and post-test tests for both the right and left hands ($p > .05$). Contrary to our study results, Çelikel et al. (2020) reported statistically significant differences between auditory, right and left-hand visual reaction accuracy scores in favor of the post-test results following an eight-week program of strength exercises performed by male archers. This discrepancy may be due to differences in the intensity of the training and the population undergoing the training. The current study, which determined that there were no significant differences between the pre-test and post-test values for vertical jump and strength parameters of the boxers in the maximal strength group ($p > .05$ for all), found significant differences between the right and left-hand grip as well as back strength measurements in favor of the post-test results ($p < .05$ for all). In a study

examining the effects of a 6-week maximal strength training program on young men aged 17-22 years, a statistically significant difference was observed between the vertical jump pre-test and post-test values of the experimental group in favor of the post-test results (Gürbüz 2013). The vertical jump is affected by the velocity of the explosive force generated during the execution of the jump (Kızılca and Okut, 2024). The fact that the vertical jump results do not exhibit any similarity with the results obtained in similar studies may be explained by the fact that the vertical jump force is related to the explosive force of the legs and a maximal strength training program for legs was not implemented in this study. In a study examining the effects of a twelve-week training program on elite boxers, a statistically significant difference in grip strength was observed between the pre-training and post-training results, in favor of the latter (Çakmakçı et al, 2005). In his study on the effects of weight training, in which two of the four groups underwent strength training, Çınar (2012) reported statistically significant differences between the pre-test and post-test results for back strength in both groups in favor of the post-test values. Evaluating the outcomes of these studies, we can conclude that research not aimed at strength training does not lead to increased back strength.

In our study comparing the pre-test and post-test values of the maximal strength group, there were no significant differences between the values for body fat percentage, 20 m sit-up run, aerobic capacity, and resting and fatigue heart rates for the boxers in this group ($p > .05$ for all). A study by Kerkeser (2016) reported a significant change in body fat percentage following a six-week submaximal strength training program. Okut et al. (2023) found that four weeks of pre-competition training undergone by elite boxers did not result in a change in body fat percentage, but did increase muscle mass. In another study, comparing the results of the pre-test and post-test results of resistance exercises, the number of repetitions of which varied weekly, with the intensity increasing from 70% to 90% over six weeks, body fat percentages decreased significantly, while no change was observed in body mass (Ormsbee et al. 2012). The fact that our findings do not coincide with those of other studies in the literature may result from strength training contributing only to the development of strength while physical characteristics do not have much effect on changes. In our study, there were no statistically significant differences between the pre-test and post-test results of the maximum VO_2 values of the participants in the maximal strength group ($p > .05$). Bell et al. (2000) observed that strength exercises combined with aerobic exercises led to a significant increase in maximum VO_2 levels in 45 individuals, both men and women, after 12 weeks. Another study found that strength training combined with aerobic exercises was more effective in increasing maximum VO_2 (Pierson et al., 2001). In the present study, no significant differences were detected between the pre-test and post-test values for resting HR and fatigue HR for the boxers in the maximal strength group ($p > .05$). Gürbüz (2013) reported no differences ($p > .05$) in resting HR pulses in both the experimental group and the control group after six weeks of maximal strength training, a finding similar to ours. Another

study supporting our results found that after resistance exercises with a load intensity of 70-90% were performed three days per week for six weeks, there were no significant differences when comparing pre-test and post-test results (Ormsbee et al. 2012). Reviewing the studies on various strength training methods in the literature, we found studies reporting results that conflict with ours.

In our study, the pre-test and post-test visual reaction times of the boxers in the maximal speed group were compared, resulting in a significant difference between the values for both the right and left parameters in favor of the post-test results ($p < .05$). Okut and Kızılca (2024) determined that closed kinetic chain exercises had positive effects on visual reaction values in young male boxers. Karadağ et al. (2006), in their study on the effects of long-term training on the visual and auditory reaction times of football players, which compared results for dominant and non-dominant feet, the group that regularly underwent training only in football had statistically significantly shorter sight and sound reaction times than the group that trained in any branch of sport as physical activity. Upon review of the literature, we encountered results that support those of our study for the maximal speed group. Regarding the comparison of the pre-test and post-test values of the vertical jump and strength parameters for the boxers in the maximal speed group, although there were no significant differences in terms of vertical jump, right-hand grip, and back strength ($p > .05$ for all), a significant difference was found between the pre-test and post-test values for left-hand grip strength in favor of the latter ($p < .05$). Pala et al. (2011) observed a statistically significant difference between the pre-test and post-test values in favor of the post-test results for vertical jump strength after the national boxing team participated in an eight-week training camp. After elite female boxers underwent eight weeks of a high-intensity training program during preparation for the Turkish Individual Boxing Championship, a statistically significant difference was detected in favor of the post-test in the vertical jump values (Söyler et al., 2022). In the study conducted by Çınar et al. (2018) on adolescent boxers aged 14-15, there were no statistically significant differences between the pre-test and post-test results for hand grip strength. Although results both consistent and inconsistent with our own can be found in the literature, previous research generally supports our findings. Similar to the results of our study, following an eight-week training camp for boxers aged 13-14 years, Kılıç (2012) reported no significant difference between the pre-test and post-test back strength values of the participants ($p > .05$). Uzun et al. (2021) observed no significant differences between the pre-test and post-test back strength values for both the experimental and control groups in their study investigating the effect of plyometric training on certain motor characteristics in adolescent male badminton players aged 14-17 years ($p > .05$). Our results are similar to those of other studies that we have examined, leading to the conclusion that speed-based training programs do not increase back strength.

In our study, there were no significant differences between the pre-test and post-test values for the parameters of body fat percentage, maximum VO_2, and resting and fatigue HR of the boxers in the maximal speed group ($p > .05$ for all). However, a significant difference was found in favor of the post-test results for the 20 m shuttle run ($p < .05$). Kılıç (2012) examining the effects of an eight-week training camp on boxers aged 13-14, observed a statistically significant difference between the pre-test and post-test body fat percentages in favor of the post-test results. Pala et al. (2011) failed to detect any statistically significant difference between the pre-test and post-test results for the body fat percentages of boxers on the Turkish national team before the European Championship. The body fat percentages of the maximal speed group in the present study were consistent with the results of some studies, although not in alignment with those of other studies. This may be due to variations in the workouts and/or diets of the participating boxers. Korkmaz (2017), in his study on the effects of Tabata high-intensity interval training (HIIT) on anaerobic and aerobic performance in different environments, observed improved performance values in favor of the post-test results when conducted on normal ground, but found no statistically significant difference in maximum VO_2 values. Kılıç (2012) reported no statistically significant differences between the pre-test and post-test values for resting and fatigue heart rates in boxers aged 13-14 years following an eight-week training camp. Kahraman (2023) found that eight weeks of a repetitive sprint exercise performed by futsal players had positive effects on vertical jumping, speed, and lower extremity strength development. In a study by Rakobowchuk et al. (2008), there was a statistically significant difference between pre-test and post-test resting heart rate in a group that underwent sprint interval training during six weeks of endurance and sprint training. Comparing the results of previous studies with our findings on resting and fatigue heart rates in our maximal speed group, some have reported similar results while others did not. In general, these discrepancies may attributed to the athletes' different training levels, ages, and training program durations.

5. Conclusion

In this study, we examined the effects of six weeks of maximal strength and maximal speed training on selected physical and physiological parameters of adolescent boxers. In addition to maximal strength and maximal speed training, the effect of routine boxing training was also evaluated. As a result, the six-week programs of maximal strength and maximal speed training undertaken by adolescent male boxers were both found to positively affect certain physical and physiological parameters.

In line with the results of our research, we suggest the following:

- In order to improve strength and speed performance in boxers, the employment of maximal loading methods may yield more effective results.
- As a result of our findings, considering the improvement in the visual reaction times of the boxers in the maximal speed group, speed training may be effective in the development of skills such as defense, attack, etc. in athletes.
- If this training method is implemented close to the competition period, noteworthy developments may be observed in boxers' technical and tactical prowess during competition.
- In this study, the exercise program was limited to a period of six weeks and did not lead to improvements in some values (body fat percentage, maximum VO_2, resting and fatigue heart rates). Similar studies conducted over a longer period of time and thus having a greater effect on certain parameters may be more fruitful.
- The training method used in the present study can also be employed by athletes in different branches of sport.
- In order to ensure group homogeneity in similar studies carried out in the future, groups with similar characteristics should be created following initial testing.

Ethics Committee Approval Information

Ethics Committee: Selçuk Faculty of Sports Sciences Non-Interventional Critical Research Committee

Date of Ethics Approval: 25/01/2022

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Authors' Contribution Statement

Both authors contributed equally to all stages of the research.

Conflict of Interest Statement

The author(s) declare no conflict of interest related to this research.

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