Effects of strength vs. endurance training and their combination on physical performance characteristics in female horseback riders

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ABSTRACT

BACKGROUND: The purpose of this study was to investigate effects of strength (S), endurance (E) and concurrent strength and endurance (SE) training on neuromuscular and cardiorespiratory characteristics during the 12-week volume-equated protocols in female horseback riders.

METHODS: Subjects (N=44) (29.4±8.9 yrs) were assigned to S (n=11), E (n=11), SE (n=13) and control (C) (n=9) groups. Training consisted of progressive S, E or SE training 3x/week and riding exercise 4-6x/week. The measurements included maximal isometric bilateral leg press force (MVC_{LP}) and EMG of VL and BF muscles, rapid isometric force production (0-500ms), maximal force of trunk extensor/flexors (MVC_E/MVC_F), countermovement-jump (CMJ), maximal oxygen uptake (VO_2max), cycling-time ($Time_{max}$), blood lactate (L) and heart rate (HR) in the bicycle-ergometer test.

RESULTS: Only group S showed significant increases of 9% in MVC_{LP} ($p<0.01$) and 3% in MVC_E ($p<0.05$) forces. None of the groups showed significant increases in CMJ, rapid isometric force production or EMG. $Time_{max}$ in the ergometer test increased significantly in S ($p<0.05$), SE ($p<0.05$) and E ($p<0.01$) with significant increases in VO_2max in E ($p<0.05$) and SE ($p<0.01$).

CONCLUSIONS: The present strength-training program led to the significant gain in maximal strength in S but not in SE, maybe due to some interference effects produced by the actual endurance training and riding related endurance training. All groups increased significantly $Time_{max}$ but VO_2max increased only in E and SE. It would be useful for female horseback riders to perform combined SE training and to perform S training periodically to insure gains in strength, when needed.

Keywords: Equestrian sports, horseback riding, strength training, endurance training, combined strength and endurance training

TEXT

Introduction

Over the centuries, equestrian sport has evolved into a wide range of hobby and competitive sports. This sport is a seamless collaboration between human and horse, which requires both riding skills and physical fitness of a rider and horse. Horseback riding is a popular, growing sport for both amateur and competitive sports in Europe[1]. The following forms of horseback riding competition are recognized worldwide; dressage riding is a highly skilled exhibition form of riding competitions, where horse and rider perform highly skilled series of predetermined movements[2]. Show jumping, the most popular sport of horseback riding, is the competitive riding event where the purpose of horse and rider is to overcome obstacles on the course within a given time[3]. Eventing is a combination that competitors must take part in each of several contests, dressage, showjumping and cross-country, where the immovable cross-country obstacles are crossed in a natural environment[4]. The technical requirements of equestrian competitions are increasing with the transition to the more modern horseback riding style and horses. Increased demands of horseback riding requires better physical and technical performance by the rider. The type and level of horseback riding specify the content of the physical fitness levels of the rider.

The rider has to be on the saddle in a balanced position, allowing the hips to open so that the legs lie gently around the horse. The upper body must be balanced and remain straight or slightly forward on a light seated position and keeping the whole body tight but flexible[5]. Riding in different speeds and horses create demands for muscle endurance and body strength of a rider. Endurance capabilities are needed during the horseback riding exercise to enable the rider to perform tasks in a focused and accurate manner[6].

Early studies have reported that equestrian sports is one of the only sports that physical training has focused exclusively on sports equipment, i.e. horse, but not so much the rider[7,8,9,10,11]. It has been even suggested that there would be no relationship between the fitness level and success in intercollegiate equestrian athletes[12]. It is, however, known that a physically and technically skilled rider can ride more economically by lower energy consumption and heart rate [11].

Since the actions of the rider affect the communication with the horse[5,13], he/she should have an optimal level of strength, power and mobility in all riding situations[13]. A limited number of studies available have come to the conclusions that strength and power capacity of a horseback rider is mostly at the same level as in physically active non-riding females of the same age[6],[9,11,14,15]. However, one study did report greater isokinetic concentric and eccentric thigh strength levels in female riders compared to control subjects[16]. With regards to endurance performance, it is known that oxygen uptake and heart rate of the rider increase relative to speed of the horseback riding [11,14,17,18,19,20]. As demands of horseback riding increases, energy consumption increases [21,22,23]. Maximal oxygen uptake (VO_2max) values in international level of horseback riders are higher than those of novice level riders ranging from 48 to 34 ml/kg/min[9,11,14,17]. Thus, novice level horseback riders are mostly at about the same level as physically active non-riding females at the same age [6,9,14,15]. In general, high level in physical performance is one of the components of riding skills that supports the safety of riding performance[8].

Horseback riding as such seems to be endurance type of loading with repeated submaximal muscle contractions during different gaits of a horse and, on the other hand, a rider needs maximal and explosive strength to communicate optimally with the horse. Horseback riding is a time-consuming sport, and it is important to design physical training of the rider properly so that training is easy to implement and support the riding skills. It is unclear which type of training would be optimal for a rider to meet the requirements of both strength and endurance capacity. Only two studies have analyzed the effects of either an endurance or strength training intervention without a horse on the rider[6,23]. However, no scientific reports have been published on combined strength and/or endurance training in horseback riders.

A number of studies in young healthy women or men have shown that combined strength and endurance training has led to positive increases both in endurance and strength levels, even at a relatively low training frequency 2-3 x / week, when the training period is about two months or longer [24,25,26,27]. However, if the total volume of combined training becomes very high and/or the duration of combined training period is very long, endurance training may interfere with the development of maximal and explosive strength [24,28,29]. Previously untrained subjects may increase maximal strength in early stages of their training through combined strength and endurance training and during pure strength training mostly due to neural mechanisms with only minor increases in muscle mass[24,30].

As horseback riding requirements increase, more information is needed about both strength and endurance training, and especially about combined strength and endurance training on physical fitness profile in horseback riders. The purpose of the present study was to investigate effects of strength (S) training, endurance (E) training, and concurrent strength and endurance (SE) training on neuromuscular and cardiorespiratory characteristics using the 12-week volume-equated training protocols in female show jumping and eventing horseback riders.

Materials and methods

Participants

Forty-four female show jumping and eventing horseback riders (age 29.4 ± 8.9 yrs, height 168.0 ± 6.1 cm, BMI 23.9 ± 3.5 kg/m^2) volunteered to participate in the study. They were divided into four groups, strength (S) (n=11), endurance (E) (n=11), combined strength and endurance (SE) (n=13) and control (C) (n=9) (Table I). Participants rode a minimum of four times / week their own or rented horse with the jumping level of minimum 1.06 ± 0.11 m. The riders had practiced mainly horseback riding before participating in this study. The riding skills of participants were from the national to the international level. Riding experience of all participants was 23.2 ± 7.3 years and competition experience 14.3 ± 7.5 years (Table II). The participants were free of acute and chronic illnesses. In addition, a cardiologist analyzed health questionnaires and ECG of each subject. Subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Parental or guardian signed consent was obtained under the age of 18 years. This study was conducted in accordance with the ethical standards of complied with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Jyväskylä.

Experimental design

Intervention: The training program consisted of three different types of training programs in three different groups, strength (S), endurance (E) and combined strength and endurance (SE). Subject groups performed either strength training or endurance training 3 times a week and combined strength and endurance training 1.5 + 1.5 times a week. Strength training was performed in progressive four-week cycles; week 1: light 60-80 %, week 2: moderate 80-90 %, week 3: hard 80-100 % and week 4: recovery 70-75 % of 1RM. Endurance training were performed also in progressive four-week cycles; week 1: light 70-80 %, week 2: moderate 80-90 %, week 3: hard 80-100 % and week 4: recovery 60-70 % of measured maximal heart rate. Duration of one training session in S, E and SE was 30 - 60 min over 12 weeks. The training programs was carried out in each experimental group independently, although the first training session was supervised. Training diaries were used to analyse the frequency and content of training exercises.

In more detailed, ***strength training*** consisted of 10 exercises for muscle-endurance and maximal strength targeted at the muscle groups essential to horseback riders[6]. Muscle endurance training included 7 different exercises (pushup, pelvic tilt, side blank, sit up and knee tuck by gymnastic ball as well as arm and leg lift and static v-sit) performed by progressive circuit weight training (CWT) for the whole body. The first round of CWT was a low intensity warm-up round followed by 2 - 5 actual rounds. One exercise was performed 40 s work / 30 s recovery. Maximal strength training was performed after CWT including bilateral knee extension and flexion and leg press exercises. The loads ranged from 60 - 100 % of 1 RM for 3 - 12 reps per set and the number of sets ranged from 2 - 6 set for each exercise.

Endurance training included both interval and long-lasting low-intensity endurance exercises by running two times / week and biking one time / week. All interval sessions included warm-up of 6 minutes by walking or biking (60 % of measured maximal heart rate) and 3 - 4 interval sets of four minutes at the intensity of 70 - 90 % of maximal heart rate. In addition, 1 - 2 sets of 3 - 4 x one minute intervals of 80 - 100 % were performed every second week. Long lasting (35 - 45 minutes) low intensity (about 70 % of maximal heart rate) were performed every 4th week for 3 times a week. Training diary and the heart rate monitor (percentage of measured maximal heart rate) controlled training.

Combined Strength and Endurance training **consisted** of **strength training** 1.5 x / week and endurance training 1.5 x / week above on different days. In addition, all experimental groups executed ***riding exercises*** 4 - 6 x / week, approximately 60 min / horseback riding session. One horseback riding session included either basic dressage, show jumping, cross country training or flat work. ***The control group*** executed only riding exercises 4 - 6 x / week approximately 60 min / horseback riding session. The present horseback riders were at a high level of riding.

Force and endurance performance measurements: The force measurements were maximal isometric bilateral leg press force (MVC_{LP}) and rapid force production (0 - 500 ms) including electromyography (EMG) measurements. In addition, dynamic countermovement jump (CMJ) and maximal isometric force of the trunk extensor and flexor muscles (MVC_E, MVC_F) performances were measured. Endurance performance was measured by the cycle ergometer test including maximal oxygen uptake (VO_2max), cycling-time ($Time_{max}$), heart rate (HR) and blood lactate levels (L). The experimental groups were measured identically before and after the intervention. The control group was also tested twice. A familiarization session was carried out before the actual strength and endurance measurements. All measurements were performed in the same testing session in the order described below.

Bilateral isometric leg press force (MVC_{LP}): Maximal bilateral isometric force (N) was measured using a horizontal dynamometer (designed and manufactured by the Department of Biology of Physical Activity, University of Jyväskylä, Finland) at the knee angle of 107° (180° = knee fully extended)[30]. Participants were instructed to produce maximum force as rapidly as possible against the force plate for a duration of 2 - 4 s. Participants were verbally encouraged to perform their maximal. A minimum of three up to five trials were used to determine the maximal isometric leg extension force with one-minute break separating the trials. Isometric force signals were passed in real-time to the analog-to-digital (AD) converter (Micro 1401, Cambridge Electronic Design, UK). The trial with the highest peak force was selected for further analysis. Force signals were sampled at 2000 Hz and low-pass filtered (20 Hz).

Electromyography: Surface Electromyography (sEMG) was used to measure activity of the vastus lateralis (VL) and biceps femoris (BF) muscles of the right and left leg during the MVC_{LP} by two bipolar electrodes / measured muscle. During the familiarization session, the positions of the electrodes of the right and left leg muscles were measured according to Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines. These positions were marked with indelible ink tattoos to ensure electrode position was similar throughout the 12-week period[31].

The raw sEMG signals were amplified by 1000 and sampled at 3000 Hz. The signals were passed from a portable transmitter, worn around the subjects' waist to a receiver box (Telemyo 2400R, Noraxon, Scottsdale, AZ, USA). The signal was relayed to a desktop computer via an AD converter (Micro 1401, Cambridge Electronic Design, UK). Analysis of the isometric sEMG was performed using a customized script (Signal 2.16, Cambridge Electronic Design, UK) and converted to integrated sEMG (iEMG). Maximum iEMG was determined from the 1500 - 2500 ms time of contractions representing the peak force phase for isometric bilateral leg press. The iEMG analyzed also for the first 500 ms of the contraction (0 - 500 ms), to assess rapid muscle activation.

Counter movement jump (CMJ): In the starting position of CMJ, the feet were parallel at a distance equal to the width of the shoulders in a balanced upright position, keeping the trunk as vertical as possible and the hands on the hips throughout the test and the knee angle at 180 degrees. Thereafter, the subjects bent her knees down to about 90 degrees and rebounded herself immediately up as fast and hard as possible trying to jump as high as possible. The contact platform (ErgoJump Bosco System) was used to record the height of the jumps[32]. A minimum of three maximal CMJ performances were recorded and the best result of trials was selected for further analysis. This device was a conductor carpet (dimensions L -175 x W - 70 cm) connected to the electronic timing system. The timer switches on automatically when a subject takes off and switches off at the time when the feet make contact with the plate again. Microprocessors (Psion

Organizer II © Datapak 32 k) were used to record the data collected from the platform through an external connection and ErgoJump Bosco System software©.

Maximal isometric force of the trunk extensor and flexor muscles (MVC_E, MVC_F) were measured using the trunk dynamometer (designed and manufactured by the Department of Biology of Physical Activity, University of Jyväskylä, Finland). The participants were secured to a standing position in the trunk extension and flexion device with the safety belt in the hip area. The correct position was ensured by the adjustable chest (flexion) or shoulder (extension) and hip support. The upper extremities were kept relaxed near to the body. Participants were instructed to produce maximal force against the chest or shoulder pad and maintain it for 2-4 sec. A minimum of three up to five trails were used to determine maximal isometric trunk extension and flexion forces with a one-minute resting period separating the trials. The trial with the highest peak force was used in the statistical analyses.

Maximal oxygen uptake (VO_2max): Subjects underwent the continuous, incremental test to volitional exhaustion on the Monark cycle ergometer (Ergomedic 839E, Monark Exercise AB, Vansbro, Sweden) according to the test protocol of the University of Jyväskylä. The measurement was terminated when subjects could no longer keep the rpm at 60. The test was initiated at an initial power output of 50 W. After a 3 min warm-up period, the increments of 25 W were made every 3 min until exhaustion. The blood lactate levels (L) was measured at the end of each load, including warm up and 3 x 3 min recovery of 50 W. Heart Rate (HR) was measured at the end and beginning of each load using Polar H1 Heart Rate monitors (HRM, Polar Electro OY, Kempele, Finland). Maximal oxygen uptake was measured by the Oxycon Mobile® (OM) (Jäger, Würzburg, Germany). OM is the portable spirometric device consisting of a transducer holder with a turbine inside attached to a facemask. The rotation of this turbine is detected optoelectrically and allows the determination of minute ventilation. OM measures the oxygen concentration through an electrochemical sensor and data are transmitted telemetrically and recorded on a personal computer. During exercise, the battery-operated OM can be strapped to the back of the subject and it allows continuous data sampling[33,34].

Statistical analysis

Data is presented as means ± standard deviations (SD). The IBM SPSS Statistics software (v. 20-24, IBM Corporation, Armonk, New York, USA) and the Microsoft Excel Program (Version Plus 2016, Microsoft Corporation, Redmond, WA, USA) were used for statistical analyzes. The normality of the data was checked using the Shapiro-Wilk and Kolmogorov-Smirnov test. One-way analysis of variance (ANOVA) was used for normally distributed data and Tamhane for not-normally distributed data. The one-way multivariate analysis of variance (one-way MANOVA) is used to determine whether there are any differences between independent groups on more than one continuous dependent variable. Bonferroni and Tukey post-hoc procedures were applied when appropriate. Changes during the experimental groups from week 0 and to 12 were analyzed with absolute values for within-group changes and values relative to pre for between-group differences. Paired sampled Student´s t-tests were utilized for comparisons of the experimental within-group changes. Pearson correlation coefficients were calculated. The statistical significance was accepted when $p<0.05$. A trend was accepted at $p<0.10$.

Results

No significant differences were observed at baseline in physical characteristics (Table I) and riding background (riding and competition years and level of riding) (Table II) of the present four groups of female horseback riders. No significant changes took place in body mass or BMI after the training intervention in any of the groups.

Maximal isometric bilateral leg press force increased significantly (9.0 ± 8.0 %) after the 12 -week training period in the S group ($p<0.01$) (Table III and Figure 1) with no significant changes in the other groups. No significant changes were found in rapid isometric force (average force 0 - 500 ms) in any of the experimental groups (Table III). CMJ decreased slightly in the E, SE ($p<0.05$) and C groups but was maintained the same in the S group (Table III). No significant chances took place in maximal isometric force of the trunk flexors in any of the groups (Table III). Maximal isometric force of the trunk extensor muscles increased significantly only in the S group ($p<0.05$) with no significant changes in the other groups (Table III).

No statistically significant increases in maximal iEMG of VL of right or left leg were observed during the maximal bilateral isometric leg press action in any of the experimental groups (Table IV). No significant chances took place in Biceps Femoris EMG coactivation (%) during maximal bilateral leg press after the training intervention in any of the groups (Table IV).

$Time_{max}$ in the cycle ergometer test increased significantly in all three experimental groups ($p<0.05$ - 0.01) after the intervention (Figure 2 and Table V). Significant increases were found in VO_2max in the E ($p<0.05$) and SE ($p<0.01$) groups. Blood lactate levels after the cycle ergometer test (maximal lactate after exhaustion – recovery lactate 9 min after exhaustion) decreased after the training period significantly ($p<0.05$) in the S group (6.5 ± 8.3 %), but there were no significant changes in any of the other experimental groups (Table V). Maximal HR levels during the cycle ergometer test before the intervention in S, E, SE and C groups were 184.9 ± 7.8, 179.9 ± 9.4, 184.0 ± 7.8 and 189.2 ± 7.6 bpm, respectively. There were no significant changes in maximal heart rate levels during the cycle ergometer test in the experimental groups after week 12.

The frequency of training in the S group was 78.5 ± 23.1 %, in E 77.5 ± 18.7 % and in SE 75.8 ± 21.0 % of the planned 3 times a week. The evaluation of criteria was that the exercise session was done both quantitatively and qualitatively according to the present training protocol.

Discussion

The present results showed that a significant ($p<0.01$) increase of 9 % took place in maximal bilateral leg press force during the 12-week volume equated training period in the S, but no significant changes were noted in the E or SE groups of the present female horseback riders. None of the groups showed significant increases in maximal EMG of trained muscles during maximal isometric force production, CMJ or rapid isometric force production (0 - 500 ms). In addition, a significant ($p<0.05$) increase was found in isometric force of the trunk extensors of the present female horseback riders in S. No significant changes were found in strength levels of MVC_E or MVC_F in other experimental groups. Cycling time in the cycle ergometer test increased in all three experimental groups ($p<0.05$-0.01). However, VO_2max increased significantly in E ($p<0.05$) and SE ($p<0.01$).

The training of the experimental groups was planned to take place three times a week for 12 weeks. Approximately 77 % of the training program in the overall total group was completed. The actual amount of strength training was enough to lead to the significant increase in the strength level in MVC_{LP} in the S group. There was no significant change in MVC_{LP} in the SE group, maybe due to the lower volume and/or frequency of actual strength training and/or possibly due to some interference effects in the SE group[24,35]. Interference effects in strength gain has been detected, when the overall volume of training is high[24]. The SE training program included 50 % of strength and another 50 % of endurance training and, in addition, horseback riding training approximately 60 minutes in each training session at the minimum of four times a week. It is possible that the training stimulus for strength training might have been too low, including also endurance type of effects of actual horseback riding training and thus, some interference might have taken place in the present SE group.

Rapid isometric force production (0 - 500 ms) did not increase in any of the experimental groups. The present results are in line with previous findings that have shown interference in rapid force production, especially during combined strength and endurance training[24]. In addition, the present strength training program of this study focused mainly on the development of maximal force, and to develop rapid isometric force, the training program should have included exercises and lower load levels used for explosive strength training. Muscle hypertrophy was not measured in the present study, but it is unlikely that muscle cross-sectional area of leg extensors would have increased. The E group did not increase its strength simply due to the fact that the training program of E did not include strength training.

Maximal EMG during the isometric leg press actions did not increase significantly in any of the experimental groups. The present 12-week volume equated strength training seemed to lead only to minor increases of 7 - 8 % in EMG during the isometric bilateral leg press but large individual differences took place and no significant increase was noted. It may be that the total number of training sessions emphasized more endurance type of training, due to horseback riding training, leading to no systematical increases in maximal muscle activation in the trained muscles measured by surface EMG. The finding that no significant decreases took place in biceps femoris coactivation % during leg press further suggests that the volume of strength training was probably too low compared to the overall volume of endurance training .

MVC_E and MVC_F muscles were trained by circuit weight training using only the body as a load. Only the S group increased significantly the strength level of trunk extensors but there were no significant changes in any other experimental groups. It could be assumed that the strength exercises (e.g. leg press) with additional load may have also indirectly affected the strength levels of trunk extensors together with horseback training in the S group. Because the magnitude of the increase in trunk extensor strength was very small, specific trunk exercises with additional load should be used for strength gains also for this muscle group.

CMJ in the S group remained unaltered, while some minor decreases occurred in all other groups. It is possible, that in addition to lack of explosive dynamic strength training in the present training program, possible interference problems due to endurance and combined strength and endurance training might have affected the results in CMJ and rapid isometric force production[24]**.** When strength training includes also lower-load explosive type of dynamic strength training, increases in CMJ have taken place also during low volume/frequency combined strength and endurance training in women[27]**.** It is possible that horseback riding training in the present study might have had some negative effects on dynamic speed and explosive strength, as riding as such can be expected to develop more endurance than force production characteristics.

Cycling time in the cycle ergometer test increased significantly in S ($p<0.05$) and SE ($p<0.05$) and in E ($p<0.01$). Although the present horseback riders were at a high level of riding, their physical performance levels were approximately only at about the same level compared to women at about the same age[9,11,15,16,17]. Consequently, it could be assumed that the present training programs together with the riding training have increased muscle endurance in each group.

Maximal oxygen uptake increased significantly in the E ($p<0.05$) and SE groups ($p<0.01$). Respiratory, cardiovascular and peripheral circulatory factors including skeletal muscle metabolism are physiological limiting factors of oxygen uptake[36]. Based on the data by Shvartz & Reibold maximal oxygen uptake levels of the present female horseback riders are at about the average level compared to women of the same age[37]. It can be assumed that the present E and concurrent SE training programs of this study contained sufficient endurance stimuli together with actual horseback riding leading thus to the increases in VO_2max, although only 1 - 2 actual endurance training sessions per week were performed.

Maximal blood lactate level was measured instantly after exhaustion and 9 minutes after exhaustion during the active recovery of the maximal cycle ergometer test. Blood lactate levels of the present horseback riders decreased significantly only in the S group. There were no significant changes in blood lactate levels in two other experimental groups. This finding is interesting and needs further investigations, and whether this would take place also after intensive horseback riding. Faster recovery might be useful for the actual riding in competitions, where many classes are ridden, possibly with several horses, creating a need for faster recovery.

The actual average number of training sessions performed by the present subjects was 77 % of the total number of the training plan. This participation can be consisted of quite high, since the subjects trained independently in several places all over Finland and it is not typical for a rider to have a specific training program included in the total horseback training process. According to the survey of the horseback riders of this study, reasons of riders prevented from carrying out the training program 3 times a week, as planned, were, for example, caring for a horse before and after horseback riding, competitions, participation in coaching, long distances, family life, studying, work, etc.

Conclusions

According of this study, training “only” two times a week can improve maximal strength during strength training but endurance capacity both during endurance and combined strength and endurance training in female horseback riders. However, no increases took place in maximal strength during combined strength and endurance training. It is advisable to increase the training frequency up to three times weekly, and take into account the content and periodization of training. Furthermore, one good choice might be to schedule the strength and endurance training periods of horseback riders at the time, when the horseback riding training is at its least, i.e. during the post competitive season and partially during the competition season.

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NOTES

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TABLES

Table I. Physical characteristics (Mean ± SD) in female horseback riders in the present strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups.

Groups	**n**	**Age (yr)**	**Height (cm)**	**Body mass (kg)**		**BMI (kg/m^2)**	
				Wk 0	Wk 12	Wk 0	Wk 12
S	11	27.1 ± 7.6	168.5 ± 8.1	65.5 ± 11.3	65.8 ± 11.1	23.0 ± 3.0	23.1 ± 3.0
E	11	35.2 ± 5.3	169.4 ± 6.2	74.0 ± 8.0	73.5 ± 8.3	25.8 ± 3.1	25.6 ± 2.8
SE	13	27.2 ± 10.3	166.9 ± 7.3	62.5 ± 7.9	63.3 ± 7.8	22.4 ± 2.4	22.7 ± 2.5
C	9	30.7 ± 7.5	168.7 ± 9.1	62.8 ± 12.0	63.1 ± 12.2	21.9 ± 2.9	22.0 ± 2.9

BMI = Body Mass Index

Table II. Riding background (Mean ± SD) in female horseback riders in the present strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups.

Groups	**n**	**Riding years**	**Competition years**	**Level of show-jumping after intervention (cm)**
S	11	22.7 ± 5.7	15.5 ± 8.0	116.0 ± 12.6
E	11	27.2 ± 6.3	13.9 ± 7.4	118.3 ± 5.0
SE	13	20.7 ± 10.0	14.2 ± 8.8	116.9 ± 9.5
C	9	22.1 ± 7.3	13.5 ± 5.8	116.0 ± 5.2

Table III**.** Maximal force and rapid force production in bilateral maximal isometric leg press and CMJ (Mean ± SD) before and after training intervention in female horseback riders in the present strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups.

Groups		**Leg press bilateral maximal force (N)**		**Average force 0-500 ms (N)**			
	n	Wk 0	Wk 12	Wk 0		Wk 12	
S	11	1934 ± 436	2100 ± 462**	1320 ± 255		1422 ± 314	
E	11	2114 ± 492	2160 ± 485	1334 ± 321		1385 ± 204	
SE	13	1757 ± 364	1734 ± 315	1166 ± 264		1121 ± 278	
C	9	1854 ± 506	1927 ± 559	1292 ± 316		1279 ± 279	
Groups		**CMJ (cm)**		**Trunk muscles maximal force (kg)**			
	n	Wk 0	Wk 12	Wk 0		Wk 12	
				Extensors	Flexors	Extensors	Flexors
S	11	19.7 ± 4.0	19.9 ± 3.0	61.6 ± 7.6	50.1 ± 13.7	63.2 ± 6.8*	49.4 ± 12.4
E	11	18.1 ± 3.9	17.6 ± 3.0	61.9 ± 10.7	48.6 ± 11.8	62.4 ± 13.0	49.9 ± 11.1
SE	13	19.6 ± 4.5	18.6 ± 3.9*	57.1 ± 10.0	49.7 ± 11.7	59.7 ± 9.3	49.9 ± 8.4
C	9	20.1 ± 3.5	18.5 ± 4.4	59.2 ± 12.2	49.5 ± 14.5	61.6 ± 9.9	51.2 ± 13.2

Table IV. Maximal integrated EMG (during 1500-2500 ms) of Vastus Lateralis (VL) of the right and left leg during the isometric bilateral leg press and left biceps femoris (BF) EMG coactivation % (in relative to maximal agonist values for BF) during leg press in the four groups at week 0 and 12.

Groups		**VL right (µV/s)**			**VL left (µV/s)**			**Left BF EMG coactivation (%) during leg press**	
	n	Wk 0	Wk 12	Δ %	Wk 0	Wk 12	Δ %	Wk 0	Wk 12
S	11	166±69	178±90	7.8±24.5	152±43	162±61	6.6±26.3	24.3±8.6	23.5±9.9
E	11	152±25	[#]134±50	-7.5±25.5	160±52	144±52	-12.0±24.1	18.6±13.0	14.2±4.8
SE	12	174±39	178±46	3.4±19.6	166±47	[#]158±41	-3.1±9.8	21.6±8.3	22.8±6.0
C	9	149±61	[##]166±57	15.6±17.4	156±64	162±61	8.3±25.1	17.2±9.8	19.3±8.5

n=10, ## n=8

Table V. Mean characteristics (Mean ± SD) during the intervention in the maximal cycle ergometer test in female horseback riders in the present strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups.

Groups		**VO_2max (ml/kg/min)**		**Time to exhaustion (min)**	
	n	Wk 0	Wk 12	Wk 0	Wk 12
S	10	32.6 ± 3.8	32.2 ± 3.9	18.28 ± 2.20	19.19 ± 1.59*
E	10	28.7 ± 4.2	30.5 ± 4.0*	19.14 ± 2.43	20.11 ± 2.27**
SE	12	32.0 ± 5.1	34.2 ± 3.7**	19.15 ± 3.21	20.17 ± 3.14*
C	9	34.3 ± 3.3	32.5 ± 4.3	18.11 ± 2.53	18.24 ± 2.40
Groups		**Max lactate after exhaustion (mmol/l)**		**Blood lactate at recovery (9 min) (Δ % from maximal value)**	
	n	Wk 0	Wk 12	Wk 0	Wk 12
S	10	10.4 ± 2.0	11.7 ± 2.4	25.7 ± 12.2	32.4 ± 12.8*
E	10	10.2 ± 1.5	10.6 ± 1.7	26.8 ± 13.7	23.4 ± 29.8
SE	12	10.9 ± 3.0	11.7 ± 2.3	27.2 ± 18.3	30.6 ± 21.1
C	9	9.3 ± 1.6	10.1 ± 2.0	20.0 ± 19.9	23.7 ± 9.6

*<0.05 **<0.01

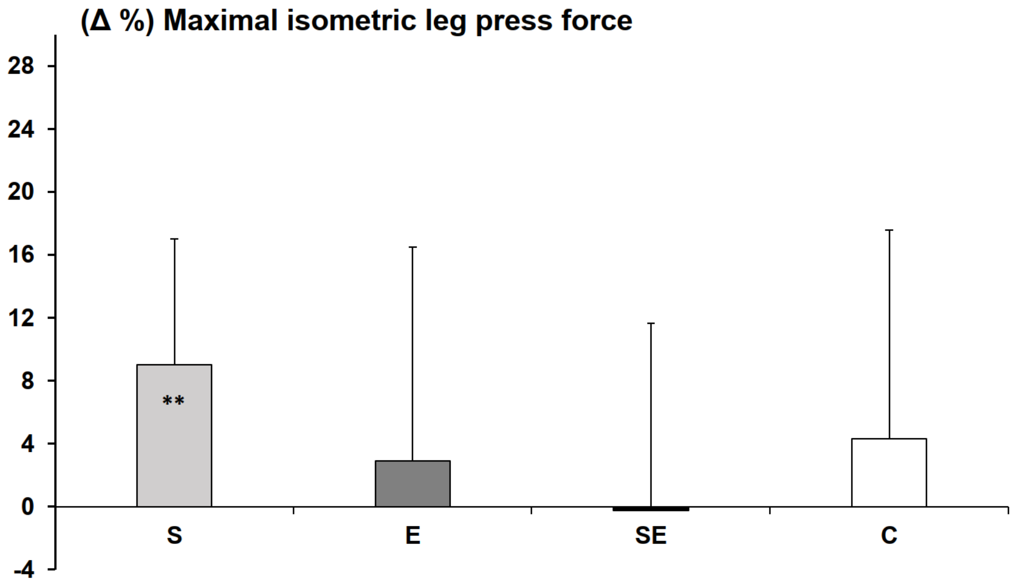

Figure 1. Relative changes (Δ %) in maximal isometric bilateral leg press force after the 12-week intervention in female horseback riders in the strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups (**$p<0.01$).

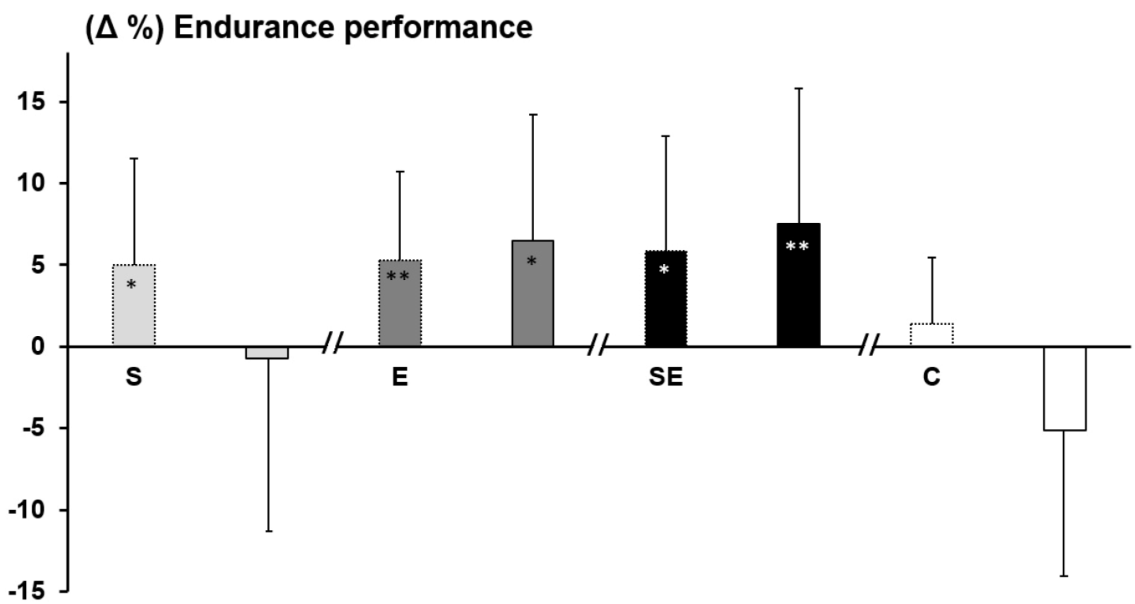

Figure 2. Relative changes (Δ %) in endurance performance of $Time_{max}$ (left columns) and VO_2max (right columns) after the 12-week intervention in female horseback riders in the strength (S), endurance (E), combined strength and endurance (SE) and control (C) groups (*$p<0.05$, **$p<0.01$).