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The Effect of 12-Week Traditional Resistance Training Applied to Elite Curling Athletes on Muscular Endurance

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ORIGINAL ARTICLE

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Abstract

The purpose of this study was to compare effects of 12-weeks tradinational resistance training (TRT) on total work (TW), relative peak work (RPW) and peak power (PP) in elite national curlers. Twenty-four participants were included in the study. Subjects were separated into two gorup, resistance training group (RES) and control group (CON). While RES performed 12-week TRT in addiction to curling training, CON just performed curling training. All twenty-four national elite curling athletes performed a body composition test and isokinetic strength test at 240^{-1}/ms angular speed pre and post TRT. TW and PP values were directly obtained from isokinetic dynamometer and RPW was calculated by dividing the peak work values by the body weight of the person. The differences between RES/CON and pre-post in TW, RPW and PP variables were determined using an analysis of variance with Independent T Test. The data obtained from the research were shown as mean and standard deviation. Higher TW, RPW, and PP outputs were generated in the RES in comparison with the CON exercise ($p<0.05$); but, flexion phases of TW and PP output were not significantly different in RES and CON groups at pre and post tests ($p>0.05$).

Keywords: Strength, athlete, curling, muscle

Elit Curling Sporcularına Uygulanan 12 Haftalık Direnç Antrenmanının Kassal Dayanıklılık Üzerine Etkisi

Öz

Bu çalışmanın amacı, 12 haftalık geleneksel direnç antrenmanı elit curling sporcularında total iş, relatif zirve iş ve zirve güç üzerindeki etkilerini karşılaştırmaktır. Araştırmanın katılımcı grubunu yirmi dört curling sporcusu oluşturmuştur. Katılımcılar, direnç antrenman grubu ve kontrol grubu olmak üzere iki gruba ayrıldı. Direnç antrenman grubu curling antrenmanlarına ek olarak haftada üç gün 12 hafta direnç antrenmanı yaparken, kontrol grubu sadece curling antrenmanlarına devam etmiştir. Tüm katılımcılar direnç antrenmanın öncesinde ve sonrasında sporcusunun 240^{-1}/ms açısal hızda izokinetik ve vücut kompozisyonu testine alındı. Total iş ve zirve güç değerleri doğrudan izokinetik dinamometreden elde edildi ve relative zirve iş değerleri zirve iş değerleri vücut ağırlığına bölünerek hesaplandı. Total iş, relativ zirve iş ve zirve güç değişkenlerinde direnç antrenman grubu ile kontrol grubu arasındaki farklar, Bağımsız t testi kullanılarak belirlendi. Araştırmadan elde edilen veriler ortalama ve standart sapma olarak gösterildi. Direnç antrenman grubu kontrol grubuna göre anlamlı düzeyde daha yüksek total iş, zirve güç ve relatif zirve iş değerleri elde etti ($p < 0.05$); ancak fleksiyon fazlarında total iş ve zirve güç çıktısı her iki gruptada ilk ve son testler arasında herhangi bir anlamlı farklılık göstermedi ($p>0,05$).

Anahtar kelimeler: Kuvvet, sporcu, curling, kas

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Introduction

Curling is a game played by teams consisting of four players (World Curling Federation, 2023). The playing positions at game are generally known as Lead, Second, Third and Fourth (Kim et al., 2021; World Curling Federation, 2023). Curling is played on a very long strip of specially prepared ice called a Sheet (44.5x4.75m) (Reeser and Berg, 2004; World Curling Federation, 2023). Every sheet has a end. There are two circles which called target, known as houses. Houses consists of four rings. This rings help define which stones are closest to the centre. A game of curling is played over ten ends, however in some formats and competitions this may be reduced to eight ends (Yanagi et al., 2013). The main purpose of curling is to position the stones, almost 20 kilos each, close to the center in the area called the house, located at the opposite end of the ice (World Curling Federation, 2023; Yanagi et al., 2013). At a game played ten ends, curlers throw eighty stones. Seventy-five percent of the eighty stones could be asked to be swept by the lead and second players (Bradley, 2009). A player could theoretically sweep for up to 1.7km and 20 min (20 sec intervally) per game. To reach stones to house, curlers often delivery accurately and sweep strongly the ice in order to change the speed or the trajectory of the stone thrown in the games of curling (Yanagi et al., 2013). A curling game almost lasts up to three hours (approximately 73min) (Buckingham et al., 2006).

Curling consist of two motor skills which is stone delivering and ice sweeping (Reeser and Berg, 2004). Delivery ve Sweep performances determine whether stones reach the target or not (Lee et al., 2019; Yoo et al., 2012). Two performance parameters need to develop high game performance. Curling is mostly considered as a strategy-based game. However, curling also consist of different physiological, physical and motor parameters such as strength, endurance, balance (Turriff, 2016; Weeks, 2020). When the literature is examined, studies on curling seem to focus mostly on engineering, biomechanics, psychology, and behavioral science (Collins and Durand-Bush, 2014; Hattori et al., 2016; Kim et al., 2021; Kraemer, 2009; Marmo et al., 2006; Song et al., 2022; Westlund, 2012). On the other hand, it is seen that studies examining in term of physiological and physical characteristics are limited (Bostancı and Yılmaz, 2021; Flueck, 2020; Sam et al., 2021). Considering the number of shots, the number of sweeps and the duration of the match in a curling match, many physiological and physical parameter become important for curlers (Bostancı and Yılmaz, 2021; Turriff, 2016). One of the most important of these parameters is muscular endurance (Weeks, 2020). Muscular endurance allows both fatigue to occur too late and motor skills to be performed with the desired performance (Porcari et al., 2015). Looking at the literature, Auld and Kivi (2010) reported that up to 94% of the heart rate reserve was reached during the sweep, in their study on the recovery of curlers. At the same time, it has been reported that athletes have rest periods of 30-180 seconds after sweeping and it was reported that good strength was required for sweeping. In a study on training planning in curling, curling was defined as a sport that requires a high level of aerobic capacity, considering the time and the skills it contains (Shank and Lajoie, 2013). At the same time, fatigue has been shown to be an important factor for performance (Behm, 2007). It also suggested that curling is a sport in which balance, muscular endurance, trunk strength, aerobic capacity, and flexibility are factors which influence performance and should be incorporated into a training program (Behm, 2007). Reeser and Berg (2004) studied the injuries of curling athletes in 2004 and stated that curlers frequently encounter knee, waist and shoulder pains. Similarly, Berry et al. (2013) investigated the injury types and rates of elite curlers, and found that injuries were more common in regions similar to the results of Reeser and Back (2004). In the same study, it was stated that injuries were more common during sliding and sweeping. In another study, in which the physical fitness assessment of the athletes who do the sitting in Paralympic winter sports was done, it was stated that curling athletes had lower aerobic capacity compared to other sports types (Bernardi et al. 2012). There are studies on physical and physiological issues such as disability levels, aerobic capacities, fatigue, heart rate of curling athletes. However, the lack of studies on the muscle strength of curling athletes is seen as a deficiency in the literature. This study may be the first study to question the development of curling athletes with the strength program. At the same time, it is thought that it will be an important evidence for training plans. Therefore, an important parameter that determines the performance of curling athletes is conditioning training.

The purpose of the present study is to examine the effect of 12-week traditional resistance training applied to elite curling athletes on muscular endurance.

Method

Subjects

Twenty-four elite curling athletes (twelve men & twelve women) participated voluntarily this study. All of them met following inclusion criteria: being a national team athlete and doing regular curling training. Exclusion criteria were the following: contraindications to all-out effort testing, having any orthopedic injury, taking supplementation, and undergoing medical treatment. Participants were informed about the possible risks and benefits of the study and provided informed written consent. Detailed information about the participants is shown in table 1. Tests were conducted according to the principles expressed in the Declaration of Helsinki and the ethics committee of the Atatürk University (No:50 Date: 25.04.2023) approved the entire study design. Participants were instructed to maintain their regular diet and not to perform strenuous exercise during the this entire study period.

Table 1

Descriptive Characteristics of Participants

				PRE	Post
	Parameter	Gender	N	X̄ ± SD	X̄ ± SD
RESISTANCE GROUP	Age	Women	6	26,50±4,13	26,78±4,25
		Men	6	24,83±1,16	25,02±1,30
	Height	Women	6	164,16±3,18	164,16±3,18
		Men	6	178,66±8,52	178,66±8,52
	Weight	Women	6	55,66±5,68	52,20±4,86
		Men	6	79,00±8,64	74,15±6,40
CONTROL GROUP	Age	Women	6	24,16±1,72	24,76±1,85
		Men	6	24,83±1,83	25,10±1,80
	Height	Women	6	165,80±4,05	165,80±4,05
		Men	6	177,20±6,60	177,20±6,60
	Weight	Women	6	56,83±4,07	55,52±4,85
		Men	6	78,66±5,46	77,02±6,32

Experimental Approach to the Problem

Twenty-four athletes were evaluated with tests pre and post twelve-weeks of tradinational resistance training (3d_wk-1). Twelve subjects applied traditional resistance training in addiction to curling training predominately used resistance machines or free weight and body weight. Twelve subjects applied just curling training. Pre and post training measures included body composition tests and isokinetic strength tests of knee, hip and elbow joints.

This study utilized two group, repeated measures design, where participants were doing same resistance training program for 12-weeks. Athletes visited the laboratory on two occasions, pre and post 12-week controled resistance-training program. Before laboratory visits, participants were instruted to almost 12-hours and refrain from training, caffeine intake for the pre-24 hours and no eat for the pre-3 hours from tests. All subject were firstly measured before and after the 12-week resistance training program was body composition (fat-free mass, fat mass, and body fat percentage). Secondly tests included isokinetic strength of knee, hip and elbow joints.

Instruments

1. Leg strength and Leg endurance were assessed by an isokinetic dynamometer (IsoMed 2000, D&R Ferstl, Hemnau, Germany). The dynamometer was calibrated according to the manufacturer's protocol before data collection (IsoMed Applications/Operations, IsoMed Software 4.0).

2. Body composition was assessed with BODPOD estimating body fat percentage using air displacement plethysmography (Life Measurement Instruments, Concord, CA). BodPod device was calibrated according to the user manual.

3. Height was assessed by using a wall-mounted stadiometer.

Procedures

We used randomly a controlled procedure. Subjects were assigned two group called resistance training group (RES) and control group (CON). RES was applied a full-body resistance training which consisting of machine exercises and body & free weight as well as regular curling training. Control group was doing just regular curling training. Tradinational resistance training program was designed to work all major muscle groups. Subjects performed 2 sets of 12 repetitions for each exercise with 2-minute rest between each set for first and second weeks. After two weeks were completed, subjects performed 3 sets of 15 repetitons for each exercise with 1.5 min rest between each set on third and fourth weeks. On fifth and eighth weeks, subjects performed 3 sets of 20 repetitions for exercise with 1 min rest. On the last four weeks, subjects performed 4 set of 20 repitition for each exercise with 1 min. rest. The training intensity was planned to be in the range of 50-75% of maximal strength (Alcaraz et al., 2011). Resistance training group trained for 1 hour per session, 3.wk-1 for 12 weeks (i.e., day 1—lower body; day 2—upper body; day 3—lower body; the next day, they would start with a upper body workout). After subjects were applied to warm up for 5–15 minutes on a bike or a treadmill, they started the workout.

All subject asked any questions or concerns to researcher with the phone or face-to-face about program, training progressions.

Before subjects started resistance training program, they joined an orientaton session of exercises and were insructed on suitable techique and ritm for selected exercises. After subjects finished this process, they determined a starting resistance (10 reps maximum) and performed successfully ten repetitions of a certain weight. Subjects applied three familiarization sessions before training program. After familiarzation sessions completed. Firstly, height was evaluated by using a wall-mounted stadiometer. Body composition and isokinetic strength measures were tested by pre-exercise (week 1). Then, subjects performed 12-weeks resistance training. 12-weeks resistance training programs were completed and subjects were tested for post-exercise (after week 12) to examine whether any differences in performance between RES and CON. All tests were performed by the researchers certified as a Doctoral degree in Exercise Kinesiology.

Training Programme

Subjects began an 12-week resistance-training program after maximal strength testing for each exercise. Maximal strength was decided with 1 RM test. Thirty-six training seasons were scheduled to be finished over 12-week period, with three workouts per week. Subjects were denied participation in only 15% of thirty-six training sessions. Resistance training program was started with lower limb exercises. Next week program was started with upper body exercises and this was regularly continued. In this way, The number of upper and lower body training programs was balanced.

Exercise	***Weeks***	***Warm-up***	***Set***	***Rep.***	***Rest***	***Cooldown***
✓ Leg Extensions, ✓ Leg Curls, ✓ Leg Presses, ✓ Squats, ✓ Deadlifts, ✓ Hip Thrust ✓ Overhead Press, ✓ Barbel Rows, ✓ Lat Pull Down, ✓ Bench Presses, ✓ Biceps Curls, ✓ Triceps Extensions, In addition, the subjects chose two exercise themselves.	1-2	15 min.	2	12	2 min.	5-10 min.
	3-4	15 min.	3	15	1.5 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.
	4-12	15 min.	4	20	1 min.	5-10 min.

- Participant ratio of approximately 1:6.
- During exercise session, subjects drank 150 ml of the water every 15-20 min.
- Cooldown: jogging, walking, stretching or cycling.

Statistical Analyses

The data were analyzed using the Statistical Package for the Social Sciences version 25.0 (IBM Corp, Chicago, IL, USA). Shapiro Wilk tests were used for normality and the skewness and kurtosis values of the data ranged from -2 to +2 (George, 2011). As a result of normality tests, it was determined that the data showed normal distribution ($p>0.05$). Outliers were determined using boxplots. Indepentent T Test was used pair comparisons in term of time (PRE and POST-training), group (RES and CON group). Descriptive statistics include mean (M) and SDs. Differences were considered significant at the $p<0.05$ level.

Results

This section shows the statistical analysis results of the results obtained from the participants.

Table 2

Comparison of the relative Peak Work Values of the Participants in Terms of Group and Measurement Time

Joint	Parameter (joule/kg)	Group	X̄ *Pre/SD*	X̄ *Post/SD*	p
ELBOW	Peak Work Flex R BW	***CON***	3,04±1,81	3,47±2,05	***0,043****
		RES	3,06±1,89	4,17±1,99†	
	Peak Work Flex L BW	***CON***	2,81±1,78	3,25±1,72	***0,044****
		RES	2,76±1,76	3,55±1,67†	
	Peak Work Ex R BW	***CON***	7,89±2,34	8,73±2,32	***0,029****
		RES	7,88±2,36	10,17±1,86†	
	Peak Work Ex L BW	***CON***	8,41±1,29	9,10±1,30	***0,019****
		RES	8,61±1,17	9,70±1,18†	
HIP	Peak Work Flex R BW	***CON***	9,15±2,16	9,94±2,00$^{\alpha}$	***0,007****
		RES	9,23±2,18	12,00±1,94†	
	Peak Work Flex L BW	***CON***	9,25±1,86	10,48±1,49$^{\alpha}$	***0,010****
		RES	9,24±1,99	12,75±1,64†	
	Peak Work Ex R BW	***CON***	25,21±4,68	27,86±4,39$^{\alpha}$	***0,009****
		RES	25,69±5,03	36,10±3,24†	
	Peak Work Ex L BW	***CON***	23,90±4,45	25,26±4,54$^{\alpha}$	***0,030****
		RES	24,35±4,84	32,70±3,45†	
KNEE	Peak Work Flex R BW	***CON***	11,30±2,07	12,50±2,05$^{\alpha}$	***0,022****
		RES	11,52±2,55	15,38±2,27†	
	Peak Work Flex L BW	***CON***	11,16±1,66	12,23±1,68$^{\alpha}$	***0,021****
		RES	11,54±2,17	14,18±1,72†	
	Peak Work Ex R BW	***CON***	10,13±1,93	11,20±1,87$^{\alpha}$	***0,000****
		RES	10,26±1,28	12,93±1,37†	
	Peak Work Ex L BW	***CON***	9,46±1,33	10,64±1,10$^{\alpha}$	***0,011****
		RES	9,53±1,54	12,62±1,60†	

Table 3

Comparison of the Total Work Values of the Participants in Terms of Group and Measurement Time

Joint	Parameter (joule)	Group	X̄ *Pre/SD*	X̄ *Post/SD*	p
ELBOW	Total Work Flex R	***CON***	309,00±248,18	342,83±263,21	0,506
		RES	310,00±247,85	375,66±262,94	
	Total Work Flex L	***CON***	283,66±234,05	312,08±251,99	0,589
		RES	281,58±233,93	332,66±264,16	
	Total Work Ex R	***CON***	798,08±319,28	923,83±343,20$^{\alpha}$	***0,041****
		RES	811,91±334,79	1081,00±318,94†	
	Total Work Ex L	***CON***	922,50±279,92	1023,16±300,70$^{\alpha}$	***0,036****
		RES	936,16±298,26	1242,00±350,29†	
HIP	Total Work Flex R	***CON***	973,08±401,01	1047,83±411,13	0,310
		RES	952,41±389,14	1120,08±431,87	
	Total Work Flex L	***CON***	914,41±335,98	988,66±325,04	0,075
		RES	931,66±349,24	1220,41±366,52	
	Total Work Ex R	***CON***	2672,75±689,55	2847,66±721,93$^{\alpha}$	***0,022****
		RES	2632,08±676,98	3551,25±925,49†	
	Total Work Ex L	***CON***	2505,66±831,97	2646,16±845,11$^{\alpha}$	***0,040****
		RES	2445,83±816,70	3185,75±845,20†	
KNE	Total Work Flex R	***CON***	1215,83±461,11	1335,75±490,66	0,111
		RES	1230,66±468,04	1567,91±526,36	

	Total Work Flex L	***CON***	1204,50±403,53	1307,16±421,76	0,194
		RES	1235,33±415,17	1453,25±442,46	
	Total Work Ex R	***CON***	1022,50±273,58	1134,08±298,63$^{\alpha}$	***0,038****
		RES	1042,50±294,63	1320,58±391,97†	
	Total Work Ex L	***CON***	1000,41±313,16	1114,91±310,19$^{\alpha}$	***0,041****
		RES	1003,66±340,43	1288,33±393,01†	

Table 1

Comparison of the Peak Power Values of the Participants in Terms of Group and Measurement Time

Joint	Parameter (watt)	Group	X̄ *Pre/SD*	X̄ *Post/SD*	p
ELBOW	Peak Power Flex R	***CON***	31,00±26,05	33,33±26,52	0,519
		RES	30,75±26,03	38,50±28,74	
	Peak Power Flex L	***CON***	26,25±22,68	28,50±22,80	0,448
		RES	26,08±21,89	34,33±27,33	
	Peak Power Ex R	***CON***	72,75±30,93	73,00±27,96$^{\alpha}$	***0,040****
		RES	72,91±31,65	87,08±29,90†	
	Peak Power Ex L	***CON***	76,75±28,77	78,66±27,66$^{\alpha}$	***0,044****
		RES	78,08±28,89	94,91±31,45†	
HIP	Peak Power Flex R	***CON***	134,08±52,91	140,00±53,35	0,357
		RES	134,08±53,77	157,16±55,63	
	Peak Power Flex L	***CON***	132,75±50,03	137,83±50,49	0,196
		RES	134,85±49,94	168,16±52,46	
	Peak Power Ex R	***CON***	355,83±93,28	372,50±96,53$^{\alpha}$	***0,025****
		RES	359,00±98,70	478,83±140,32†	
	Peak Power Ex L	***CON***	346,50±108,35	369,75±118,96$^{\alpha}$	***0,039****
		RES	349,00±115,55	461,10±124,88†	
KNEE	Peak Power Flex R	***CON***	180,91±78,99	187,41±81,31	0,389
		RES	181,25±79,34	214,83±79,43	
	Peak Power Flex L	***CON***	174,41±65,28	180,25±67,40	0,479
		RES	175,66±66,92	196,00±63,92	
	Peak Power Ex R	***CON***	163,50±49,26	168,66±50,44$^{\alpha}$	***0,034****
		RES	162,60±51,60	205,15±62,60†	
	Peak Power Ex L	***CON***	152,05±48,60	157,66±52,31$^{\alpha}$	***0,033****
		RES	149,08±50,60	199,83±68,81†	

Discussion and Conclusion

The isokinetic muscle strength characteristics of the elbow, hip and knee muscles of elite curlers with same training levels were significantly affected with tradinational resistance training. 12-weeks tradinational resistance training improved to elbow, hip and knee muscles of elite curlers. In curling games, the hip and knee joints are thought to play an important role during delivering. During delivering, they provide stabilization of body and take a role in delivering movement. The hip and knee joint also affect speed of starting speed. On the other hand, elbow joint acts as a link between the stone and the body. This joint also provide stabilization of arm. So, each of them is important for delivering movement in curling.

Resistance training is important to gain size, strength, power and local muscle endurance for all athletes, because many sports need to improve strength for the performance (Bartolomei et al., 2014). Strength, one of the five biomotor feature, is improved by athletes for appling motor movement (Behringer et al., 2011; Issurin, 2010). So, the elite curlers improve strength for using both delivering and sweeping. The result of our study showed that tradinational resistance training (TRT) in addiction to curling training improve elbow, hip and knee muscles' strength. Relative Peak Work (RPW) values of resistance training group (RES) are significantly different control group (CON). RPW values of all joints are also significantly improved by tradinational resistance training program at RES group. When Total Work (TW) values of RES group evaluated, it appeared that TRT has effect more extensor muscles than flexor muscles. TW values of extension phases are significantly different from TW values of flexion phase in RES group. CON group is not have any different between flexor and extensor muscles in TW values. And finally, When Peak Power (PP) values of RES and CON groups evaluated, it appeared that RES group PP values are significantly different from CON group. PP values of extensor muscles are more than PP values of flexor muscles. We can say that TRT protocol is effect on relative peak work of extensor-flexor muscles, peak power of extensor muscles and total work of extensor muscles at all joints.

When the literature is examined, there are different studies on isokinetic strength assessment in different sports. However, no study has been found on the evaluation of strength on curling athletes. In different sports, studies generally showed that TRT protocol effect on gaining power, size, strength and muscular endurance. A study by Alcaraz et al. (2011) showed that the TRT protocol gave similar results to high-intensity circular strength training. At another study Campos et al. (2002) compared three resistance training method and they found that TRT increases muscular mass and strength in healthy men. TRT also contributed to physical performance (Alcaraz et al., 2008). Morris et al. (2022) reported that TRT protocol improves speed, power and strenght as others resistance exercise protocols. In another study, it stated that TRT improved peak power of muscles (Tomljanović et al., 2011). Winwood et al. (2015) compared strongman and TRT on a variety of body composition, muscular function, and performance measures and they found that both training strategy has effect on strength performance. Maté-Muñoz et al. (2014) reported that TRT has effect on strength performance and power in untrained men. It stated in a study compared plyometric, olympic powerlifting and TRT that TRT also improved isokinetic power (Chaouachi et al., 2014). In another study, the effects of TRT and suspension strength training in elderly individuals were compared and it was determined that TRT had a positive effect on maximal strength and muscle thickness (Soligon et al., 2020). Another study on healthy young by Moro et al. (2020) evaluated effects of 6 weeks-TRT on body composition, aerobic power and strenght and found that TRT had positive effects on strength but not body composition and power. Mcweeny et al. (2020) reported as previovus studies that TRT improved strength. TRT also improved exercise performance (Chang et al., 2022). Murton et al. (2021) reported that TRT improved lower limbs strength and power in their comparative study on elite rugby players. Zarezadeh-Mehrizi et al. (2013) reported at study carried out on soccer players that strength significantly increased in both groups but this increase was significantly higher in the TRT group compared to the cluster group. The performance adaptations in the TRT group were consistent with the known effect of resistance training on muscular strength and power (Hegedus et al., 2016). Likewise, TRT improves golfer's phyiscal performance. Montalvo-Pérez et al. (2021) founded that TRT led to significant improvements in all strength/power-related outcomes. MacDonald et al. (2012) compared to different three training methods and they found that TRT provides improvements in lower limb strength and antropometrics.

Strength can lead to an improvement in specific sport performance by the athlete. A wide variety of neuromuscular factors have been reported to contribute to high power production, including motor unit recruitment, rate coding, and synchronization. Strength training causes muscle hypertrophy (Schoenfeld, 2010; Zabaleta-Korta et al., 2020). Cross-sectional area growth (hypertrophy) in the muscles can increase muscle performance and efficiency. This can be shown as the main reason for the significant difference seen pre and post the training intervention. As a result, TRT generally improves strength and power in different groups. The reason for TRT effect may be the greather training volume compare to others. Muscular development also increases the basal metabolic rate. The increase in basal metabolic rate, especially due to the decrease in fat and the increase in muscle, cause significant changes in body composition. Depending on this situation, the relative strength parameters of the athletes are affected. This can be shown as the main reason for the increase in RPW in the results of our study.

TRT significantly increased the relative work capacity of the wrist, knee and hip joints of curling athletes both flexion and extension. However, a significant improvement was observed only in the extensor muscles of all joints in total work and peak power. In order to increase competition performance, TRT can be included in curling training programs. Trainers and athletes can use TRT in their training plans to improve the strength endurance. The effect of TRT training on TW and PP values is mostly on the extensor muscles. Here, the main reason why the extensor muscles develop more can be shown that curling athletes work more extensor muscles during ice training. The preference of extensor muscles for stabilization and balance, especially in the ascent and sweep phases, may have caused the TRT training to be more effective. This research using TRT on elite curlers population provides ground work for future studies to different resistance training methods. This study is first resistance training study to improve strength on elite curlers. Therefore, future studies in this area may include to different level curlers, resistance training methods, ages. Also, this resistance training, TRT, evaluated with different variables.

Declaration of interests

No potential conflict of interest was reported by the authors

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Ethics approval and informed consent

Tests were conducted according to the principles expressed in the Declaration of Helsinki and were approved the entire study design by the ethics committee of the Atatürk University Faculty of Sport Sciences (No:50 Date: 25.04.2023)

Authors Contributions Conclusion

Design of the Research: HHY, KS, GA

Data Collection: HHY, KS

Statistical Analysis: HHY, GA

Preparation of the Article: HHY, KS, GA

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