

Comparison of the Effects of Isoinertial Resistance Training with Different Setting Methods in Elite Female Handball Players

Elit Kadın Hentbolcularda Farklı Setleme Yöntemiyle Yapılan İzoinersiyal Direnç Antrenmanlarının Etkilerinin Karşılaştırılması

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Abstract

The present study aims to compare the effects of isoinertial leg curl training performed by elite female handball players with different setting methods during the season. 17 female handball players (22.3 ± 4.6 years of age) voluntarily participated in the study. The participants were assigned to control (CG), traditional set (TS), and rest-redistribution (RR) groups. The TS and RR groups performed a total of 16 sessions of isoinertial leg curl training for 8 weeks with repetitions and sets equalized for resting volume. All participants performed isokinetic knee joint strength, 20m sprint, Illinois agility, and active (AJ) and squat jump (SJ) tests as pre- and post-tests. One-way analysis of variance was used to evaluate inter-group differences, dependent groups t-test was used for intra-group differences, and repeated measures analysis of variance was used to compare isoinertial power outputs. As a result of the analyses, no significant intra- or inter-group differences were found in agility and sprint tests. In the RR group, a significant difference was obtained for the AJ and SJ tests in the intra-group analysis and a significant difference was obtained in favor of RR for the AJ and SJ tests in the inter-group analysis. In terms of isokinetic knee joint strength, a significant difference was obtained only in the $300^\circ \cdot \text{sec}^{-1}$ dominant leg flexion in the RR intra-group comparison. In conclusion, it is thought that the duration of the study may have been short and the volume of the training intervention may have been insufficient for this level of athletes. Despite this, it was concluded that the RR method can be used in isoinertial training for the development of jump performance.

Keywords: Isoinertial, handball, strength, power, jump

Özet

Bu araştırmada elit seviyedeki kadın hentbolcularda sezon içinde farklı setleme yöntemleriyle uygulanan izoinersiyal leg curl antrenmanlarının etkilerini karşılaştırmak amaçlanmıştır. Çalışmaya 17 kadın hentbolcu (yaş, 22.3 ± 4.6 yıl) gönüllü olarak katılmıştır. Katılımcılar kontrol (KG), geleneksel setleme (GS), dinlenmeyi yeniden yapılandırma (DYY) gruplarına atanmıştır. GS ve DYY dinlenme hacmi eşitlenmiş tekrar ve set sayılarıyla 8 hafta boyunca toplam 16 seans izoinersiyal leg curl antrenmanları yapmışlardır. Tüm katılımcılar ön ve son test olarak izokinetik diz ekleme kuvveti testi, 20 m sprint testi, illinois çeviklik testi, aktif (AS) ve squat sıçrama (SS) testlerini gerçekleştirmişlerdir. Gruplar arasındaki farkları değerlendirmek için tek yönlü varyans analizi; grup içi farklar için bağımlı gruplarda T-Test, izoinersiyal güç çıktıların karşılaştırılmasında ise tekrarlı ölçümler Varyans Analizi kullanılmıştır. Analizler sonucunda çeviklik ve sprint testlerinde grup içi veya gruplar arası anlamlı farka rastlanmamıştır. DYY grubunda grup içi analizde AS ve SS testleri için anlamlı fark elde edilirken gruplar arası analizde de AS ve SS testleri için DYY lehine anlamlı fark elde edilmiştir. İzokinetik diz ekleme kuvvetinde sadece DYY grup içi karşılaştırmasında $300^\circ \cdot \text{sn}^{-1}$ baskın bacak fleksiyonunda anlamlı fark elde edilmiştir. Sonuç olarak bu seviye sporcular için çalışmanın süresinin kısa, antrenman müdahalesi hacminin yetersiz kalmış olabileceği düşünülmektedir. Buna rağmen sıçrama performansının gelişimi için DYY yönteminin izoinersiyal antrenmanlarda kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: İzoinersiyal, hentbol, kuvvet, güç, sıçrama

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1. INTRODUCTION

Handball is a physically demanding team sport. During the 60-minute match duration, handball players simultaneously perform different types of movements and technical match activities that require intense effort with short time intervals (Michalsik, Madsen, & Aagard, 2015). The increasing number of national and international tournaments in handball, along with the increasing number of matches, has resulted in a long competition period of 9-10 months per year. Therefore, the physical condition of elite handball players has a significant impact on game performance not only in every match during the entire regular season, but particularly in various tournaments where multiple matches are played in a short period of time (Michalsik & Aagard, 2015). In handball, increases were observed in the performance of athletes through strength training (Hermassi et al., 2010; Madruga-Parera et al., 2020; Maroto-Izquierdo et al., 2020; Sabido et al., 2017). Performance-defining movements common to most sports (sprint, jump, agility, etc.) have been shown to be associated with the maximum strength of athletes (McBride et al., 2009; Peterson et al., 2006; Swinton et al., 2014).

On the other hand, measuring the strength of athletes can help to identify the risk of an injury in advance (Beam & Adams, 2013, p. 55). For example, low hamstring muscle strength in contrast to the strength of the quadriceps muscle group may cause an imbalance in strength and lead to lower extremity injuries (Beam & Adams, 2013, p. 63). It has also been observed that strengthening the hamstring muscle group of athletes increases important performance parameters such as sprinting, jumping and agility (Clark et al., 2005; de Hoyo et al., 2016; Güllü & Doğan, 2021). One of the training methods that has gained popularity in hamstring strength development is the isoinertial training method (O' Brien et al., 2022; Tous-Fajardo et al., 2006). The isoinertial method is based on the application of eccentric overload generated by a device that utilizes the inertia of rotating cogs during the athlete's movement (Fiorilli et al., 2020; Tous-Fajardo et al., 2006). Simulating the mechanism of a YoYo toy (Tesch et al., 2017), this method provides eccentric resistance proportional to the athlete's effort in the concentric phase (Fiorilli et al., 2020). In this device, the concentric phase of the movement is desired to be performed as fast as possible. At the end of the concentric phase, the wheel starts to rewind and the eccentric phase of the movement begins. In this eccentric phase, it is aimed to delay the motion as much as possible, that is, to slow down this rewinding in order to create an overload (de Hoyo et al., 2016). In general, it is known that methods that emphasize the eccentric phase achieve more gains with less metabolic expenditure compared to methods where the concentric phase is dominant (Franchi et al., 2017; Salci, 2008).

In the review conducted by Tesch et al. (2017), it was stated that the studies cited in the paper applied the isoinertial method with protocols consisting of 4 sets of 7 repetitions, usually two or three days a week. Sabido et al. (2017) stated that applying only one session of isoinertial half squat and lunge exercise consisting of 4 sets of 8 repetitions to the weekly training program in handball players had a positive effect on functional performance parameters and emphasized the usefulness of this low-volume and high-intensity method in improving dynamic athletic performance. Similarly, in other studies comparing the isoinertial method and traditional training methods, it was reported that the isoinertial method provided greater gains (Coratella et al., 2019; Madruga-Parera et al., 2020; Norrbrand, Pozzo, & Tesch, 2010). In the meta-analysis conducted by Beato and Dello Iacono (2020), it was stated that there are studies in which isoinertial exercise was shown to chronically improve athletic performance, but the number of studies on elite athletes (particularly female elite athletes), is limited. It was reported that more precise evidence and recommendations could be provided by changing the type of exercise, the number of sets and repetitions of exercises, rest intervals and the place of isoinertial exercise in the general training program in future studies.

Munoz-Lopez, Pozzo, and Floria (2021) conducted a crossover analysis by dividing each set into clusters of five repetitions and one cluster. As a result of the analysis, the values in the first set were found to be more positive than the other sets in almost all variables, and likewise, the first cluster of the first set (the first five repetitions) was found to be more positive than all other clusters. It is suggested that such studies that provide real-time measurements can guide the decision on the appropriate training volume (i.e.: sets and repetitions). One of the most well-known aspects of applying diversity in training volume is to divide the repetitions in a set into clusters and complete the set by giving short rests (i.e: dividing the number of repetitions in a set into 2-6 clusters and completing the set by applying 10-60 seconds of rest between the clusters), which is called the cluster set (CS) method (Tufano, 2016; Dello Iacono, Martone, & Hayes 2020). Tufano, Brown, and Haff (2017) referred to the CS structure with total rest periods equal to

the traditional set(TS) as the rest-redistribution (RR) method. Due to the limited number of studies in isoinertial resistance training, which has increased in popularity in recent years, sufficient application suggestions have not yet been developed. In the literature review performed, no study was found comparing the RR method, in which rests are distributed into sets, with the TS method in studies performed on the isoinertial training device. Considering this gap in the literature, the present study aims to compare isokinetic knee joint strength, agility, sprint and jumping skills at various angular velocities in elite female handball athletes by applying two different leg curl exercises for 8 weeks during the competitive season and to compare whether there is a difference between the control (CG), TS and RR groups and to present the effects to sports scientists and practitioners.

2. METHOD

2.1. Study Group

17 female handball players from the Anadolu University Handball team, competing in the Turkish Women's Handball Super League in the 2020-2021 season, who are over the age of 18 and who have not had any serious health and injury problems in the last 6 months, voluntarily participated in the study. The handball players (n=17) playing in the same team were divided into 3 groups [control group (CG) n=6, traditional set group (TS) n=5, rest-redistribution group (RR) n=6] by simple randomisation. Table 1. shows the descriptive statistics of the handball players. Ethics committee approval was obtained from Eskişehir Technical University, Science and Engineering Sciences, Scientific Research and Publication Ethics Committee. Before the tests and isoinertial training protocols, the subjects were informed about the applications and a voluntary consent form was approved in writing.

Table 1. Descriptive statistics of the subjects

Handball players (n=17)	CG (n=6)		TS (n=5)		RR (n=6)		p
	Mean	Sd.	Mean	Sd.	Mean	Sd.	
Age (year)	22.8	5.6	21.4	2.7	22.6	5.3	.874
Height (cm)	172.5	7.5	170	5.9	169.5	7.1	.736
Weight (kg)	69.1	13.8	65.5	10	63.6	8.1	.686
Body fat percentage (%)	23.6	4.9	20	4.9	18.9	4.4	.238

2.2. Study Design

Table 2. Study Design and Experimental Procedure

Pre- and Post-tests	Day 1	Anthropometric measurements Warm-up on bicycle ergometer (5 min.) Stretching exercises (5 min.) Active and squat jump tests (3 repetitions each) Isokinetic knee joint strength measurement					
	Day 2	Static and dynamic warm-up (10 min.) Illinois Agility Test (3 repetitions) 20 m sprint test (3 repetitions)					
Isoinertial Exercise and Training Days	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Strength isoinertial standing leg curl	Technical tactics	Strength isoinertial prone leg curl	Technical tactics	Technical tactics	League match	Rest

2.3. Data Collection

On the first day, 5 minutes of bicycle ergometer (Monark, Cardio Care 827 E), and 5 minutes of static and dynamic stretching exercises were performed as a warm-up protocol before the tests performed in the laboratory. On the second day, 10 minutes of static stretching and dynamic warm-up were applied as a warm-up protocol before the tests applied in the gym. The jump test measurements of the subjects were recorded using the My Jump 2 mobile application. MyJump app provides reliable intersession and intrasession data, as well as valid measurements for maximal jump height during fast and slow stretch-shortening cycle muscle actions, and during concentric-only explosive muscle actions. (Gallardo-Fuentes, F. et al., 2016).

Following the protocol of the mobile application, before the tests, the vertical distance between the protrusion at the front of the iliac bone and the ground was measured in the squat position with a knee joint angle of 90° and the distance between the protrusion at the front of the iliac bone and the toe tip with the foot in the full plantar flexion position in the supine position. The results were recorded in the mobile application for each athlete. In the jumping tests, 3 repetitions were performed for both tests and the highest values in active and squat jumping were recorded. Isokinetic muscle strength values of the subjects were measured with an isokinetic dynamometer (Humac Norm Testing & Rehabilitation System, USA) eccentrically/concentrically for the dominant and non-dominant joint at angular velocities of 60°.sec⁻¹, 180°.sec⁻¹ and 300°.sec⁻¹ in the knee joint extension and flexion movements. The subjects performed 3 trial repetitions and 5 maximal repetitions and the highest value was taken as the peak torque value. The dynamometer and seat settings related to the device were adjusted on the test day as specified in the manufacturer's user manual. Verbal encouragement was provided to the subjects during the tests.

For the agility test, a 5m-wide, 10m-long area was placed in the handball court with 4 funnels placed at the corners. In the center of the area, 4 funnels with a distance of 3.3m between each one were arranged on a straight line and a track was prepared. The test track consisted of a 40 m straight run with 180° turns every 10 m at the edges and a 20 m slalom run between the funnels with 180° and 360° turns in the middle section. Photocells were placed at the start and end points of the Illinois agility test course. Before the Illinois agility test, the test was introduced in a practical way. Prior to the test measurements, the subjects were asked to perform 2 repetitions at a light pace. Afterwards, each subject was tested 3 times with maximum effort. Verbal encouragement was provided to the subjects throughout the test administration. The subjects rested for at least 3 minutes between repetitions. The best performance of each subject was evaluated. Figure 1 shows the schematic of the test.

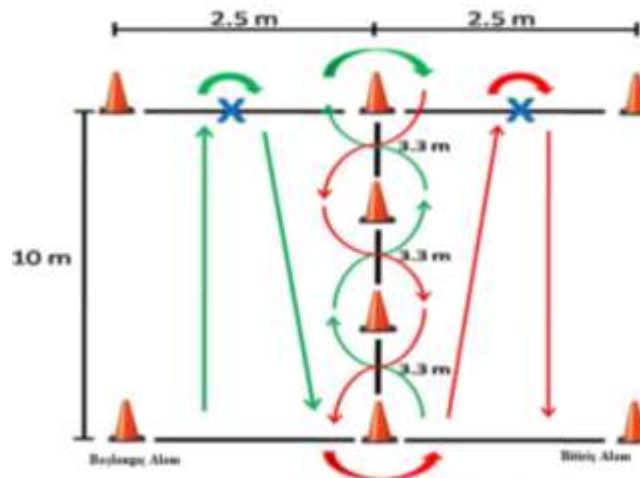


Figure 1. Illinois Agility Test (Raya et al., 2013)

The 20 m sprint test was used to evaluate the speed performance of the subjects. The 20 m sprint track was set up in the handball court with photocells at the beginning and end of the track. The 20 m sprint test was performed 3 times. Between 3 repetitions, at least 3 minutes of rest was given for each subject. The best time of each subject was evaluated.

Before the isoinertial strength training, 2 familiarization sessions were performed in order to adapt to the isoinertial training method. The CG continued their in-season team training during the 8-week training intervention but did not participate in isoinertial strength training. A total of 2 sessions of leg curl isoinertial strength training per week, one session standing and one prone, were added to the normal training schedule for the TS and RR groups. Isoinertial leg curl training was performed unilaterally for the right and left leg. Standing leg curl exercise for the right and left leg was performed on Monday and lying leg curl exercise for the right and left leg was performed on Wednesday. The TS group performed a total of 27 repetitions of isoinertial strength training with 3 sets of 9 repetitions and 60 seconds of rest between the sets. The RR group performed 9 sets of 3 repetitions with 15 seconds of rest between the sets for a total of 27 repetitions of isoinertial strength training. Total rest periods and total number of repetitions were kept equal for the two groups practicing isoinertial strength training. After each repetition performed by the subjects, the power outputs and set values of the repetitions were monitored instantaneously from the tablet connected to the device. After each athlete completed a session, the training was recorded in the Desmotec app for Android (Dsoft). Since the isoinertial training method requires at least one repetition to initiate the rotation of the belt attached to the wheel, the TS group performed 3 repetitions before each set (i.e., 9 repetitions in total) and the RR group performed 1 repetition before each set (i.e., 9 repetitions in total). Trial repetitions were not taken into account in power output calculations. The subjects performed the trial repetition at a light pace and then performed the other repetitions with maximum effort. Since the operating practice of the isoinertial training device is to maintain the speed applied in the concentric phase in the eccentric phase, the subjects were asked to exert maximum effort in the concentric phase, resist the movement in the eccentric phase and restart the concentric phase in the last 1/3 of the eccentric range of motion. The same inertial load was used throughout the study (Desmotec, large inertial load disk = 0.02 kg-m², Italy).



Image 1. Prone isoinertial leg curl exercise



Image 2. Standing isoinertial leg curl exercise

2.4. Statistical Analysis of Data

The performance data obtained as a result of the tests applied to the handball players were analyzed with the SPSS 22.0 statistical package program. All values were given as mean and standard deviation. Normality of the data was determined by examining the results of the Shapiro Wilk test, skewness and kurtosis values and histogram graphs. Skewness and kurtosis values were taken as ± 3 (Tabachnick & Fidel, 2013). One-way analysis of variance (Anova test) was used to evaluate the inter-group differences and Paired T-test was used to determine the intra-group differences. Repeated measures ANOVA with 2x3 (group and time) was used to compare isoinertial training outcomes in the TS and RR groups.

3. FINDINGS

In this section, as a result of the 8-week isoinertial leg curl training with different setting methods, the differences between the groups in terms of dynamic athletic performance and isokinetic knee joint strength in the pre-test and post-test data are presented in tables.

3.1. Comparisons of Inter-Group Pre-Test Values

Table 3. Table of dynamic athletic performance pre-test values between the groups

Tests	CG (n=6)		TS (n=5)		RR (n=6)		F	p
	Mean	SD	Mean	SD	Mean	SD		
20 m Sprint (sec.)	3.51	.264	3.37	.212	3.41	.155	.709	.509
SJT (cm)	22.42	4.331	25.29	4.26	22.14	4.482	.846	.450
AJT (cm)	23.60	3.626	26.11	4.012	24.44	4.738	.504	.615
Agility (sec.)	17.66	1.418	16.66	1.092	16.95	.639	1.230	.322

Not. $**p<0.001$; $*p<0.05$. SJT=Squat jump test; AJT=Active jump test; CG= Control Group (n=6); TS= Traditional Set (n=5); RR= Rest Redistribution(n=6); SD = Standard Deviation

When the statistical procedures are evaluated, it is observed that there is no statistically significant difference in any value between the dynamic athletic performance pre-test data of the groups. When the results are evaluated, it is seen that the groups have similar characteristics.

Table 4. Table of isokinetic knee joint force peak torque pre-test values between the groups

Tests	CG (n=6)		TS (n=5)		RR (n=6)		F	p
	Mean	SD	Mean	SD	Mean	SD		
60°.sec-1 dominant leg extensor (N·m)	143.66	20.69	167.2	39.93	149.5	18.81	1.09	.363
60°.sec-1 dominant leg flexor (N·m)	99.83	10.26	110.4	20.1	100.83	18.68	.648	.538
180°.sec-1 dominant leg extensor (N·m)	97.16	11.72	107.4	24.41	84.66	16.76	2.23	.144
180°.sec-1 dominant leg flexor (N·m)	73.0	11.59	84.6	17.5	62.66	14.67	3.08	.077
300°.sec-1 dominant leg extensor (N·m)	69.33	8.93	78.2	16.6	68.66	10.59	1.01	.387

300°.sec-1 dominant leg flexor (N·m)	53.66	14.55	67.6	11.86	56.66	11.2	1.78	.204
60°.sec-1 non-dominant leg extensor (N·m)	139.83	19.09	153.8	36.01	144.5	15.51	.463	.639
60°.sec-1 non-dominant leg flexor (N·m)	100.16	7.3	103.6	23.49	99.16	13.4	.120	.888
180°.sec-1 non-dominant leg extensor (N·m)	97.5	16.82	105.0	18.78	90.66	12.45	1.08	.363
180°.sec-1 non-dominant leg flexor (N·m)	73.16	9.1	79.6	13.35	71.0	12.08	.804	.467
300°.sec-1 non-dominant leg extensor (N·m)	74.33	11.34	77.0	11.72	67.16	7.8	1.364	.288
300°.sec-1 non-dominant leg flexor (N·m)	55.16	9.32	62.0	12.4	55.0	11.02	.713	.507

Not. ** $p < 0.001$; * $p < 0.05$. CG= Control Group (n=6); TS= Traditional Set (n=5); RR= Rest Redistribution(n=6); SD = Standard Deviation

3.2. Comparison of the Test Results of the Groups

Table 5. Intra-group differences obtained by subtracting the post-test data of the groups from the pre-test data

Tests	CG (n=6)		TS (n=5)		RR (n=6)		F	p
	Mean	SD	Mean	SD	Mean	SD		
20 m Sprint (sec.)	0.010	.050	-0.040	.068	-0.021	.053	1.083	.365
SJT (cm)	1.026	1.374	-0.262	1.173	3.566*	1.602	10.691	.002*
AJT (cm)	-0.003	1.20	0.754	1.189	2.793*	1.382	7.779	.005*
Agility (sec.)	-0.050	0.212	-0.142	0.208	-0.110	.158	.324	.729

Not. ** $p < 0.001$; * $p < 0.05$. SJT=Squat jump test; AJT=Active jump test; CG= Control Group (n=6); TS= Traditional Set (n=5); RR= Rest Redistribution(n=6); SD = Standard Deviation

In terms of the statistical procedures, when the pre-test and post-test differences were compared between the 3 setting method groups, it was seen that there was no difference in dynamic athletic performance data between the CG and TS groups, while there was no difference in the sprint and agility tests in the RR group, and the pre-test and post-test differences of the RR group showed significant differences (SJT ($p=0.02^*$), AJT ($p=.005^*$)) compared to the CG and TS groups. When the differences obtained from the dynamic athletic performance post-test pre-test results between the groups were evaluated, a significant difference was observed only in the jumping tests of the RR group compared to the other groups.

Table 6. Differences of isokinetic knee joint force peak torque post-test pre-test results of the groups

Tests	CG (n=6)		TS (n=5)		RR (n=6)		F	p
	Mean	SD	Mean	SD	Mean	SD		
60°.sec-1 dominant leg extensor (N·m)	3.50	8.80	-3.40	12.32	0.83	11.12	.567	.580
60°.sec-1 dominant leg flexor (N·m)	0.50	4.08	-2.60	5.77	-2.33	10.13	.327	.727
180°.sec-1 dominant leg extensor (N·m)	3.50	8.89	2.60	8.53	-0.16	8.70	.285	.756
180°.sec-1 dominant leg flexor (N·m)	2.66	4.13	-0.40	11.52	4.16	8.44	.418	.666
300°.sec-1 dominant leg extensor (N·m)	-0.33	11.09	4.20	8.84	1.66	6.08	.352	.709
300°.sec-1 dominant leg flexor (N·m)	0	10.21	-2.60	4.27	4.33	3.14	1.483	.261
60°.sec-1 non-dominant leg extensor (N·m)	7.16	7.35	2.20	7.39	2.50	14.29	.416	.668
60°.sec-1 non-dominant leg flexor (N·m)	0	4.28	-0.60	0.89	-0.33	7.42	.019	.981
180°.sec-1 non-dominant leg extensor (N·m)	2.33	8.61	3.40	12.66	-0.50	9.48	.220	.806
180°.sec-1 non-dominant leg flexor (N·m)	5.66	5.27	4.80	11.69	4.33	8.04	.038	.963
300°.sec-1 non-dominant leg extensor (N·m)	-3.50	16.59	1.20	10.35	0.33	6.88	.245	.786
300°.sec-1 non-dominant leg flexor (N·m)	4.00	6.75	3.20	8.10	1.83	9.28	.109	.897

Not. ** $p < 0.001$; * $p < 0.05$. CG= Control Group (n=6); TS= Traditional Set (n=5); RR= Rest Redistribution(n=6); SD = Standard Deviation

When the post-test and pre-test differences in isokinetic knee joint strength were compared between the groups, it was observed that there was no significant difference in any angular velocity between the groups. It is observed that practicing a total of 16 sessions of isoinertial leg curl training in 8 weeks during the season in a women's handball team at the topflight will not provide a significant improvement in isokinetic knee joint (concentric/concentric) strength.

4. DISCUSSION

When the pre-test and post-test values of the subjects were compared, a significant difference was found in the jumping tests in the RR group. There was no significant difference in other dynamic athletic performance test data in the 3 groups. Additionally, in the isokinetic knee joint strength tests applied to all 3 groups, a significant difference ($p=0.20^*$) was found between the pre-test and post-test values of $300^\circ\text{.sec}^{-1}$ dominant leg flexor only in the RR group. Another comparison in this study was to compare the isoinertial concentric and eccentric power outputs (W) of the two setting groups at the beginning (week 1), middle (week 4) and end (week 8) of the training period. In the evaluations, although an increase in isoinertial power output was obtained during the training process, no significant difference was found between the two groups except for the dominant leg standing leg curl eccentric power output ($p=0.035^*$).

Time-motion analysis shows that handball players spend less time in running speeds defined as sprinting. This may be due to the small effective playing field in handball, which does not allow players to reach maximum speed. In the present study, 20 m sprint test, which is the length at which athletes can usually cover distance at high speeds, was used, considering that the field players cannot enter the 6-meter-long defensive areas of the two teams in the 40 m-long playing field of handball. When the 20 m sprint performance pre-test and post-test data were evaluated, it was seen that there was a regression for the CG (from 3.518 ± 0.264 sec to 3.528 ± 0.288 sec) and this result did not create a statistically significant difference ($p=0.651$, $p>0.05$). When the test data were evaluated in the 20 m sprint performance for the TS group, an improvement was observed (from 3.37 ± 0.212 sec to 3.33 ± 0.241 sec). However, when statistical procedures were evaluated, this improvement did not create a statistically significant difference ($p=0.264$, $p>0.05$). When the test data were evaluated for the RR group, an improvement was observed (from 3.41 ± 0.155 sec to 3.39 ± 0.151 sec), but when the statistical procedures were evaluated, this improvement did not constitute a significant difference ($p=0.361$, $p>0.05$). According to these results, there was no significant difference in the differential statistics between the 3 groups ($p=0.365$, $p>0.05$).

When other studies in which sprint performance was evaluated with the isoinertial method were examined, it was observed that Nunez et al. (2018) divided male athletes into two groups and performed unilateral lunge exercise or bilateral squat exercise with the Isoinertial method for 6 weeks, 2 sessions per week. The researchers used the 10 m sprint test and found no significant difference between the pre-test and post-test data in terms of development in both groups. Sabido et al. (2017) applied half squats and unilateral lunges to male handball athletes for 4 sets of half squats and unilateral lunges, 7 repetitions per set, consisting of one session per week for 7 weeks, and compared the pre-test and post-test results by equalizing the training volumes of the control group and the isoinertial experimental group. For the 20 m sprint performance, there was no significant difference between the pre-test and post-test results, although an improvement was obtained in both groups. When the data in the present study are evaluated, it is seen that two different setting methods do not create a significant difference in 20 m sprint performance compared to the control group, but the fact that there is a small amount of regression in the control group and a small amount of improvement in both training groups suggests that increasing the number of subjects and sessions in such a study or increasing the duration of the study may give more significant results in sprint performance.

One of the parameters frequently used in the defense and attack phase in handball is jump (Michalsik, Madsen, & Aagard, 2015). In the present study, the active jump test (AJT) and squat jump test (SJT) were compared as jump tests. When the differences between the pre-test and post-test results for AJT were evaluated, it was seen that the results of the two tests were very close to each other in the CG (pre-test: 23.608 ± 3.62 cm, post-test: 23.605 ± 3.39 cm) and there was no significant difference ($p=0.995$, $p>0.05$). In the TS group (pre-test: 26.112 ± 4.01 cm, post-test: 26.866 ± 3.97 cm), there was an improvement in the post-test compared to the pre-test, but this was not significant ($p=0.229$, $p>0.05$). There was a significant difference ($p=0.004$, $p<0.05$) in the RR group (pre-test: 24.400 ± 4.73 cm, post-test: 27.233 ± 4.88 cm). In the comparison of the difference between the post-test and pre-test differences between the groups, it is seen that this change in the RR group creates a significant difference ($p=0.005$, $p<0.05$). When the differences between the pre-test and post-test results for SJT were evaluated, it was seen that there was an increase in the CG group (pre-test: 22.425 ± 4.33 cm, post-test: 23.451 ± 3.35 cm), but this did not create a significant difference ($p=0.005$, $p<0.05$). For the TS group (pre-test: 25.298 ± 4.26 cm, post-test: 25.036 ± 3.19 cm), although there was a slight decrease, the results of the two tests gave similar results and this did not create a significant difference ($p=0.664$, $p>0.05$). For the RR group (pre-test: 22.146 ± 4.48 cm, post-test: 25.713 ± 4.51 cm), there was a significant difference ($p=0.003$, $p<0.05$). In the comparison of the difference between the post-test and pre-test differences between the groups, it is seen that this change in the RR group is a significant difference ($p=0.002$, $p<0.05$). When the results are analyzed, it is seen that similar results were obtained in the two jump tests (SJT and AJT) and a significant difference was observed only in the RR group. To the best of our knowledge, the most important finding in the present study, which is the first study in which the isoinertial and cluster setting methods were applied, is that while no significant difference was obtained in jump performance with the TS method, it should be underlined that the RR method provides significant improvement and creates a significant difference. When the effect of other studies conducted with the isoinertial method on jump performance is examined, in the study conducted by Sabido et al. (2017) in which 4 sets of half squats and unilateral lunges for 7 repetitions per set consisting

of one session per week for 7 weeks was applied to male handball athletes, a small improvement was found in AJT performance in the same extent as the control group and it was stated that there was no significant difference between the groups. Sagelv et al. (2020) evaluated the effects of isoinertial squats and barbell squats with 85% 1TM for 6 weeks using AJT for jump performance. When the pre-test and post-test results were evaluated, the researchers stated that there was a significant difference in both training groups and that squatting with the isoinertial method had a positive effect on jump performance. Maroto-Izquierdo, Garcia Lopez, and De Paz (2017) applied 4 sets of 7 repetitions of isoinertial leg press and 7 TM 4 sets of traditional leg press for 6 weeks (15 sessions) to male handball athletes and compared dynamic athletic performance data according to pre-test and post-test results. The researchers, who used both AJT and JT, stated that there was a more significant difference in both jump tests in the isoinertial leg press training group compared to the traditional leg press group, while AJT performance showed more improvement than JT performance. In the study conducted by Coratella et al. (2019) in which semi-professional soccer players practiced isoinertial squats (inertial load = 0.11 kg·m⁻²) and traditional squats (80% - 1 TM) for 8 weeks, 1 session per week during the season, both AJT and JT were used. The researchers found a significant difference between the pre-test and post-test results in the jump tests in both training groups and stated that the effect size in the isoinertial method was moderate and the effect size in the traditional method was small.

In the present study, there was no significant difference in jump performance in both jump tests in the control and TS groups, while a significant difference was found in both jump tests in the RR group. When the findings are evaluated, it is expected to find a significant difference in the jump tests in which the tensile-shortening cycle occurs in an eccentric-based training method, while it seems to be a remarkable result that there is a significant difference between the two sets of isoinertial training groups. In the isoinertial method, it is emphasized and expected from the athlete to perform the concentric initiation movement at maximum speed in the first repetition of the exercise after the trial repetitions, which may have led to this finding as more initiation movements were performed in the RR group. However, the small number of subjects, which is one of the most important limitations of this study, and the fact that the study constitutes the first setting study conducted in such a method arouses curiosity about what results can be yielded by a similar study with a larger number of subjects or a longer training period.

In handball, agility performance is taken into consideration to understand the abilities and physical levels of players (Popowczak et al., 2021). The ability to accelerate, stop quickly, change direction, and accelerate again is an important part of a handball player's skills (Bayraktar, 2017; Esfahankalati & Venkatesh, 2013). The Illinois agility test, which includes all of these criteria, was used to evaluate agility performance in this study. When the differences between the pre-test and post-test results for the Illinois agility test are evaluated, although there is a very small amount of improvement in the CG (pre-test: 17.665 ± 1.418 sec, post-test: 17.615 ± 1.519 sec), the results of the tests are almost the same. This resulted in no significant difference between the pre-test and post-test measurements of agility performance in the CG ($p=0.590$, $p>0.05$). In the TS group (pre-test: 16.668 ± 1.092 sec, post-test: 16.526 ± 0.911 sec), despite a small amount of improvement, there was no significant difference between the pre-test and post-test results ($p=0.203$, $p>0.05$). There was also an improvement in the RR group (pre-test: 16.955 ± 0.639 sec, post-test: 16.845 ± 0.721 sec), but this improvement was not significantly different ($p=0.150$, $p>0.05$). Although there were more positive results in the difference of post-test and pre-test differences for both of the training groups compared to the control group (CG: -0.050 ± 0.212; TS: -0.142 ± 0.208; RR: -0.110 ± 0.158), no significant difference was found in the comparison of the differences of the 3 groups ($p=0.729$, $p>0.05$).

When the impact of other studies conducted with the isoinertial method on agility performance is examined, it was observed that Fiorilli et al. (2020) compared the pre-test and post-test results of dynamic athletic performance in young male football players by applying specific football exercises with the isoinertial and plyometric methods for 6 weeks. Using the Illinois agility test to evaluate agility performance, the researchers found a significant difference between the pre-test and post-test results in the isoinertial training group, while the improvement in the plyometric training group did not make a significant difference. Coratella et al. (2019) had semi-professional football players perform isoinertial squats (inertial load=0.11 kg·m⁻²) and traditional squats (80% - 1 TM) for 8 weeks, 1 session per week during the season and used the T-test to measure agility. The authors compared the pre-test and post-test results and found a significant difference in the isoinertial group in the T-test, while there was no significant difference

in the control group. Madruga-Parera et al. (2020) compared the development of motor skills by applying isoinertial training and cable training methods with handball-specific exercises for 8 weeks and evaluated the change of direction performance with COD180 and RCOD tests. In the COD180 test, subjects performed two 180° direction changes for both dominant and non-dominant leg using the same leg in each trial. The first change of direction was performed 7.5 m after the start and the second one was performed 5 m after the first change of direction. The RCOD test involved eight continuous repetitions of a 10-meter sprint requiring a 180° direction change halfway through each 10-meter sprint (5 m). When the results were examined, the authors did not find a significant difference between the two training groups in the COD180 test, but in the RCOD test, they reported a significant difference in favor of the isoinertial training group, especially for the dominant leg. However, the training volume of the study was much higher than the present study. The researchers implemented 3 different functional movements, 3 sets of 12 repetitions per set, as a training intervention and performed 2 sessions per week.

Although it is thought that an eccentric-based training can improve performance in an agility test involving change of direction by causing better deceleration and acceleration (Fiorilli et al., 2020), the reason why no significant difference was obtained in highly trained female athletes in the present study may be that the duration of the study was short for this level and the athletes were already at a high level in their pre-test performance (Agility pre-test results: CG: 17.66; TS: 16.68; RR: 16.95). According to the Illinois Agility Test norm values reported by Brown and Khamoui (2012), agility times below 17.0 seconds for female athletes are considered "excellent," and those between 17.0 and 17.9 seconds are considered "good." Therefore, the pre-test results of the participants indicate that they were already performing within these high-performance ranges before the intervention, which may have limited the potential for further improvement.

In the present study, in addition to evaluating the effect of isoinertial hamstring training on dynamic athletic performance, the effect of isokinetic muscle strength, which is commonly used to assess injury risk in athletes, was also examined. When the results were analyzed, a significant difference ($p = 0.02$, $p < 0.05$) was observed between the pre-test and post-test results in the dominant leg flexion movement at $300^{\circ}\cdot s^{-1}$ only in the RR group, while no significant differences were found in other isokinetic test parameters.

When other studies in the literature involving the isoinertial method and isokinetic strength tests were examined, it was seen that Maroto-Ízquierdo et al. (2020) compared the pneumatic training method, which provides a constant force production with a pressurized air, with the isoinertial training method in elite male handball athletes. Unlike the present study, the authors used upper extremity exercises and tested shoulder joint strength at angular velocities of 60, 180 and $240^{\circ}\cdot sec^{-1}$ in pre-test and post-tests by training two separate groups with these methods for 6 weeks. When the results of the study were analyzed, the authors stated that there was a significant improvement in all angular velocities for both groups and that the improvement was more significant for the isoinertial group, especially in peak torques at angular velocities of 60 and $240^{\circ}\cdot sec^{-1}$ in internal rotation. Monajati et al. (2018) equalized the groups they used in terms of the number of male and female subjects and applied 6 similar lower extremity movements in the isoinertial and traditional training methods for 6 weeks among recreational-level volleyball players and used $60^{\circ}\cdot sec^{-1}$ hamstring eccentric peak torque, $60^{\circ}\cdot sec^{-1}$ hamstring concentric peak torque and $60^{\circ}\cdot sec^{-1}$ quadriceps peak torque as isokinetic test evaluation. As a result of the study, the researchers reported a significant difference compared to the pre-test with significant improvement for the $60^{\circ}\cdot sec^{-1}$ hamstring concentric peak torque, which was also tested in the present study. In the study conducted by Coratella et al. (2019), hamstring and quadriceps strength in semi-professional football players was evaluated with an isokinetic dynamometer as the subjects performed isoinertial squats (inertial load=0.11 kg-m-2) and traditional squats (80% - 1 TM) for 8 weeks, 1 session per week during the season. The researchers reported significant improvement in quadriceps and hamstring peak torques of both groups in the post-test measurements. When acute studies in which the isokinetic test and isoinertial training method were combined, Beato et al, (2019) examined the PAP effect to evaluate acute power gain after performing 3 sets of isoinertial half squats with 6 repetitions per set in males who actively participated in sports, and reported that acute power gain was obtained in quadriceps concentric peak torque, hamstring concentric peak torque and hamstring eccentric peak torque after isoinertial half squat exercise (3-9 min). Beato et al. (2020) examined the PAP effect after isoinertial squat and deadlift exercises in amateur male university athletes and concluded that both exercises would acutely contribute to isokinetic hamstring eccentric peak torque. In general, when the studies in the literature are evaluated, it is seen that they were performed with male athletes and athletes with less overall training volume

compared to the sample group used in the present study. There is no study performing isokinetic evaluation by combining the setting methods used in this study with the isoinertial method.

According to the findings of the present study, a significant difference was obtained only in the RR group in the dominant leg flexion movement at an angular velocity of $300^{\circ}.\text{sec}^{-1}$ in the pre-test and post-test comparisons, while no significant difference was found in any angular velocity in the comparison of the groups with each other. The reason for this may be that athletes training at a high level constituted the sample group and the study was conducted in the middle of the second half of the season when the athletes had reached a certain strength level. Moreover, in the isoinertial training protocol, the inertial load (large inertial load disk = $0.02 \text{ kg}\cdot\text{m}^2$) was kept constant throughout the 8-week training period to assess isoinertial strength gains. Since the speed of movement can change according to the force applied by the athlete in this device, all athletes trained at different speeds, which made it difficult to evaluate the development of the groups with an isokinetic dynamometer that gives constant angular velocity. The fact that more significant improvement was obtained at an angular velocity of $300^{\circ}.\text{sec}^{-1}$ in the RR group can be attributed to this interpretation. As stated by Beato and Iacono (2020), who conducted a review study under the title "Implementing flywheel (isoinertial) exercise in strength training: current evidence, practical recommendations, and future directions", having athletes work with individual inertial load in the isoinertial method for scientific studies appears to be an approach that is still not employed for this method.

Suggestions

For the literature, the present study serves as the first to compare the difference according to the number of sets and repetitions in the isoinertial method as well as being a unique study conducted with the isoinertial method in high-level female athletes. In this study, despite the continuous increase in isoinertial power output, the effect on dynamic athletic performance appeared to be small. However, the main finding of the study for setting methods is that more significant improvement in jump performance can be achieved using the RR method. Conducting a similar study with different sample groups or high-level athlete groups in a different period of the season or with a longer training intervention period may reveal different results. It should also be noted that the sample size in this study is small the study included only one handball team. The application of a similar study to a larger sample group can make a significant contribution to the literature. Another notable point is that the high standard deviation in the group averages may have been affected by the training interventions of the athletes at different levels. Conducting future studies with individualized training loads for the isoinertial method can make a significant contribution to the literature.

Conflict of Interest

There are no conflicts of interest between the author(s) and any individual, institution, or organization that could have influenced the research process or its outcomes.

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