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Original Article

The effect of an interventional exercise program on the biomechanics of the shoulder girdle in the execution of ball transfer in high-level handball players

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Abstract
Handball athletes are subjected to high loads especially during the process of overhead throwing. Female and male athletes often complain of pain and report unexplained loss of speed and control of ball transfer. Shoulder blade dyskinesia and overuse syndrome have been identified as risk factors for injury among elite handball athletes. Understanding the dynamics of ball transfer and its kinematic phase is crucial for health professionals. In this study, the effect of an interventional exercise program was evaluated to investigate its effect on the range of motion and muscle activation of the shoulder girdle, elements that are major components of ball transfer in handball. The sample consisted of 20 high level handball athletes from Greece. The athletes were divided into two groups, 10 study 10 control group and were given the exercise program. Before and after the application of the program, the following measurements were performed: a) Angular external and internal rotation b)Isokinetic evaluation of shoulder at external and internal rotation in 90° abduction, at 60°/sec, 180°/sec and 300°/sec angular velocities. Statistically significant difference showed: a) in external rotation of 180°/sec, b) the deficit internal rotation of 300°/sec and c) in the deficit of external and internal rotator muscles, after inferential statistics was contacted. Statistically significant difference also showed in 300°/sec ratio of left shoulder, increasing the external towards the internal torque. In conclusion, from the angular evaluation, it appeared that the results in the range of motion were not as expected. The interventional program was not as beneficial as it would expect. This contradicts the results in the deficits and ratio in both the internal and external rotation of both shoulders, in witch was sufficiently beneficial. The results of the study suggest training guidelines giving important information to the health professionals involved, while providing feedback to the handball athletes.
Key words: handball; goniometry; isokinetic dynamometry; shoulder girdle; biomechanics; scapular dyskinesia.

Introduction

The shoulder is perhaps the most complex joint of the human body, with an elaborate anatomy and complex biomechanics (Gull, Bai, & Bak, 2020; Cicchella, 2020). There are stabilizing mechanisms in the shoulder region, such as the geometry of the region, ligaments, muscles as well as the cavity compression effect (Funk, 2023). Understanding the biomechanics of the shoulder plays a very important role in its proper and smooth functioning (Fritch, Labbe, Courseault & Savoie, 2021; Berthold, Dyrna, & Beitzel, 2021). The pathologies affecting the shoulder in handball players are equally complex. Handball athletes continue, training and participating in competitions, while experiencing pain, instability and reduced strength rates,(Cools, et al 2021; Fontánez, De Jesus, Frontera, & Micheo, 2023 ; Myklebust, Hasslan, Bahr & Steffen, 2013). These adaptations occur not only in the glenohumeral joint but also in other parts of the kinetic chain. As a result of these changes in the loads on the shoulder gridle, we have a change in biomechanics as well as in the technique during ball transfer (Mayes, Salesky, & Lansdown, 2022; Cools, et al 2016; Borsa, Laudner & Sauers, 2008). Adjustments created by repetitive activity in overhead throwing athletes, leading to shoulder pain as well as a decrease in strength levels, range of motion, poor and increasing the risk of injury. Such adaptations include changes in glenohumeral joint trajectory range, imbalance in muscle strength of the shoulder rotator muscles, scapular dyskinesia, instability of the lumbar spine, and changes in hip muscle length and strength (Kibler et al 2022).We know from literature that the dominant upper extremity differs in terms of position with the secondary extremity and is not identical. It has been observed in overhead throwing athletes that the position of the dominant scapula differs from the secondary scapula, is in a lower downward position, greater abduction, outward rotation, and greater upward rotation (Tagliarini, et al 2023; Bullock et al 2021; Burkhart, S., Morgan., & Kibler, 2003). It appears that neuromuscular dysfunction of the shoulder girdle is due to weakness of the rotator cuff muscles of the scapula and may lead to limited stability of the joint against the thoracic wall. In addition, the muscle weakness in the area limits the range of motion, particularly upward rotation, leading to overloading of the anterior surface of the glenohumeral joint, synovial bursa, and an increase in the likelihood of subacromial

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impingement (Kirschner, Gulotta, & Thomas, 2021;.Paine & Voight, 2013). Many studies have analyzed the throwing in baseball. This gives us a lot of data on this type of throwing (Escamilla, et al 2001; Stodden,et al 2001). There are some commonalities between the different types of arm throwing, with each sport having different requirements. Particularly in handball, as the kinematic analysis of throwing in handball is not well documented (Burger et al 2023).

Furthermore, the few studies that have examined throwing in handball have focused on one part of the throw (mainly the shot), but have not provided a thorough and comprehensive view of ball transfer (Pueo, Tortosa-Martínez, Chirosa-Rios, & Manchado, 2022; Fradet, Kulpa, Multon & Delamarche, 2016). Early identification and treatment of these problems are essential requirements for improving sports performance and limiting the occurrence of injuries. From the above it seems that there is a gap in the research literature regarding the biomechanics of the shoulder zone and more specifically during ball transfer in handball. This led to the purpose of the present study which was to evaluate the effect of an interventional exercise program on shoulder girdle biomechanics in order to investigate its effect on the range of motion and muscle activation of the shoulder joint muscles that are major components and elements in ball transfer in the sport of handball.

Material and Methods

Participants: The study was conducted among adult men and women top division A1 handball athletes in Greece. Female and male athletes who reported pain or dyskinesia of the scapula participated in the study. The investigation of the evaluation and the impact of the program involved muscle activation of both shoulders.

Criteria for inclusion in this study: all questionnaire participants who reported that they had some kind of history of shoulder pain in the last 6 months.

Exclusion criteria in this study: All questionnaire participants who reported a shoulder dislocation, fracture or shoulder surgery in the past year; 2) endovascular shoulder injections in the past 3 months; 3) a history of neck or upper extremity injury within the past month; 4) cervical spine disease or neurological disorder that may affect shoulder movement; 5) scoliosis or excessive kyphosis; and 6) pain during the measurement procedure that may prevent it from being performed.

Procedure: during the preparation period of the teams, a questionnaire was given to top division teams of the A1 men's and A1 women's league. The purpose was to collect data for the selection of male and female athletes who would meet the inclusion criteria of the study. A total of 198 male and female athletes responded to the questionnaire. A random selection was then made of 20 individuals who met the inclusion criteria. All of them showed evidence of scapular dyskinesia. They were divided into two groups of 10 subjects. In group A, the control group, each athlete followed the usual team training program. In group B. the study group, each athlete followed an interventional training program (exercise program 3 times a week for 3 months), in addition to the usual team training program. The same measurements were taken for all the subjects.

Description of measurements:

Angular measurement: The angular measurements taken were, at standing position, external and internal shoulder rotation. The measurement was conducted with a Myrin goniometer/clinometer (item no. 711432, Balsta, Sweden). The purpose of the goniometry was to record the range of motion of both shoulders.

Isokinetic dynamometry: The purpose of the isokinetic assessment was to measure the strength of the shoulder muscles during the concentric phase of muscle activation. Three angular velocities were selected: low (60°/s), intermediate (180°/s) and high (300°/s). Measurements were made on the Humac Norm 770 CSMi isokinetic dynamometer (Stoughton, MA, USA). Internal and external rotation of the shoulder joint was performed for both shoulders. Differences in force level in n/m, deficit, between flexor and extensor muscles, and the flexor and extensor muscle ratio of both shoulders in %, expressed in Mean (M) and Standard Deviation (SD), were recorded and evaluated.

Study team intervention program: The study group had to perform the exercise program 3 times a week for 3 months. Each workout started with a range of motion warm-up followed by strength training. Exercises involving one arm were performed only on the affected side. If both shoulder blades were affected, then the entire exercise program was applied to both sides. Strengthening exercises focused on the general area of the scapula, specifically the transverse and lower trapezoid fossa and serratus anterior, while the stretches focused on the upper trapezoid, thoracic muscles and posterior glenohumeral joint bursa. The program included the following exercises. Extension exercises: 1) cobra stretch, with the palms next to the chest and the legs extended, lifting the torso with full extension at the elbows in forward flexion; and 2) cross body stretch with arm adduction in lateral flexion. Strengthening exercises: 1) push-up plus external rotation with shoulder abduction; 2) supine punch; 3) arm flexion ≥ 135° in lateral decubitus; 4) side-lying forward flexion up to 135°; 5) side-lying external rotation; 6) prone extension. The exercise program was designed to improve muscle activation, for muscular endurance and strength. In each exercise, each participant performed one training set using 50% resistance of perceived 1-RM. The strength training consisted of 3 sets / 15 repetitions of each exercise.

Statistical Analysis: Results were analyzed both descriptively and inductively. Descriptively, the mean (M) and standard deviation (SD) were used, as well as the frequency of values and their corresponding percentage. Inductively, the Independent Samples t-test was used for analysis of variance between the study group and the control group, separately, first at baseline and then at final measurement. In addition, after each group was isolated, a Paired Samples t-test analysis of variance was performed to find differences between the initial and final measurement. IBM SPSS 22 was used to perform the statistical analysis and the significance level was set at 0.05.

Results

Angular measurements of the shoulders

This is the goniometry done before the interventional program was given to the study group. a) First measurement of external shoulder rotation with elbow in 90° extension flexion in study and control group: The M. of external rotation at the right shoulder in the first measurement in the study group was 52.50° with S.D. ± 12.15°, while 54.5, ±7.12 it was in the control group. In the study group on the left shoulder was 48.8 ± 11.62° and in the control group 53.7° ± 6.48°. From the data analysis, there did not appear to be a statistically significant difference between the two groups (p > 0.05). b) First measurement of internal shoulder rotation with the elbow in 90° extension flexion in study and control group: In the first measurement of internal rotation in the right shoulder in the study group, M. was 34.5° with SD ± 8.47°, while in the control group it was 36.8° ± 10.28°. While in the same measurement on the left shoulder in the study group it was 41.0° ± 8.52° and in the control group it was 36.20° ± 12.94°. No statistically significant difference was seen between the two groups (p 0.05) when we performed the data analysis

The M. of internal rotation in the right shoulder at the first measurement in the study group was 34.5° with S.D. ±8.47°, while in the control group was 36.8° ±10.28°. In the left shoulder in the study group it was 41.0° ± 8.52° and in the control group it was 36.20° ± 12.94°. From the data analysis, there did not appear to be a statistically significant difference between the two groups (p > 0.05).

In the next section, the data on the goniometry performed after the intervention program took place in the study group and were recorded. c) Second measurement in the study group and control group of external shoulder rotation with the elbow in 90° extension flexion: the M. in the study group of external rotation of the right shoulder was 52.6° with SD ± 9.66°, while in the control group it was 51.8° ± 8.81°. In the left shoulder at the study group it was 49.60° ±11.57° and in the control group it was 54.80° ± 10.21°. Data analysis showed that there was no statistically significant difference in the angular measurements of the second measurement between the two groups (p 0.05). (d) Second measurement of internal shoulder rotation with the elbow in 90° extension flexion in study and control groups: The M. in the second measurement of the study group in internal rotation of the right shoulder was 33.2° with SD ± 9.39°, while in the control group it was 31.5° ± 7.20°. In the study group on the left shoulder it was 37.20° ± 7.84° and in the control group it was 31.5° ± 7.20°. Data analysis showed that there was no statistically significant difference in the angular measurements of the second measurement between the two groups (p 0.05). Also in the study group, between the first and second measurement, there seemed to be no statistically significant difference in any pair by performing Paired Samples t-test.

Isokinetic evaluation of the shoulders

Force assessment with the isokinetic dynamometer at the shoulder joint was performed at three angular velocities, 60°/sec, 180°/sec and 300°/sec. Internal and external rotation of the shoulder was tested at 90° abduction. This is the dynamometry done before the interventional program was given to the study group. Table 1 below is a simple data recording to determine the level of shoulder strength that existed before in both study groups. From the analysis of the data using Independent Samples t-test, it was found that no significant statistical difference (p>0.05) was found between the study group and the control group. Table 1 records the results of the first measurement in the study group in the isokinetic assessment. More precisely, the results of the muscles of both shoulders are presented, regarding the deficit between the external and internal rotator, as well as the ratio between the external and internal rotator cuff muscle. From the analysis of the data with Independent Samples t-test, it was shown that there was only one statistically significant difference in the 60°/sec deficit in the outside pivot.

Table 1: Differences of internal & external rotation of shoulder muscles in the study group in the first measurement

Angular velocities	Deficit of Internal Rotators	Sig. (2 tailed)	Deficit of External Rotators	Sig. (2 tailed)	Ratio Right	Sig. (2 tailed)	Ratio Left	Sig. (2 tailed)
Study	M & S.D.		M & S.D.		M & S.D.		M & S.D.	
60°/sec	18.2%,±9.8 %	0.123	8.3 %, ± 4.22 %	*0.005	97.3 %, ± 21.33 %	0.300	98.0 %, ± 34.56 %	0.979
180°/sec	14.0 %,±14.38 %	0.546	9.8 %, ±6.99 %	0.277	99.9 %, ± 34.6 %	0.398	94.9 %, ± 41.49%	0.576
300°/sec	18.8 %,±15.79 %	0.793	9.5 %, ±5.19 %	0.453	109.3 %,± 41.06 %	0.807	89.0 %, ±29.06 %	0.242

Table 2 shows the deficit differences of the right and left external and internal rotators before the intervention program was given to the control group. More precisely, the results of both shoulders are presented in terms of deficit, as well as the ratio between the external and internal rotator cuff muscles. The results showed that there was a statistically significant difference in external rotation in the control group between the external and internal rotator muscles at 60°/sec.

Table 2: Differences of internal and external shoulder muscle rotators in control group in the first measurement

Angular velocities	Deficit of Internal Rotators	Sig. (2 tailed)	Deficit of External Rotators	Sig. (2 tailed)	Ratio Right	Sig. (2 tailed)	Ratio Left	Sig. (2 tailed)
Control	M & S.D.		M & S.D.		M & S.D.		M & S.D.	
60°/sec	11.1 %, ±9.79 %	0.123	17.1 %,±7.65 %	*0.07	109.2 %,±28.09 %	0.301	98.5 %, ± 47.61 %	0.979
180°/sec	10.5 %,±10.77 %	0.546	14.1 %,± 9.9 %	0.278	113.6 %,± 36.17 %	0.398	103.6 %,± 24.76 %	0.578
300°/sec	17.1 %,±12.61 %	0.793	12.0 %, ± 8.9 %	0.455	105.6 %,± 23.18 %	0.808	105.7 %, ± 32.57 %	0.242

Data were then recorded for the second measurement that took place after the interventional program took place in the study group. This was the dynamometry taken after three months and after the interventional program was given to the study group. Simple data recording was done and the level of shoulder strength obtained after the interventional program in both study groups was determined. Using the Independent Samples t-test in the data analysis, it was shown that there were no statistically significant differences (p 0.05) in both the study and control groups. Table3 presents the results in the study group between the external and internal rotator cuff muscles and both the shoulders in terms of deficit in the external rotation, analyzing the data with Independent Samples t-test. More specifically, M.O. 8.5 % T.A. ±7.98 % was recorded, p=0.032. Also statistically significant difference was also shown in the deficit of 300°/sec in the internal rotation. More specifically, an M.O. of 9.4 % T.A. ±5.5 % was recorded, p=0.043. Furthermore, a statistically significant difference was also recorded in the ratio at the right shoulder with a M. of 134.2 % S.D. ±22.93 %, p=0.013.

Table 3: Differences of internal and external shoulder muscle rotators in study group in the second measurement

Angular velocities	Deficit of Internal Rotators	Sig. (2 tailed)	Deficit of External Rotators	Sig. (2 tailed)	Ratio Right	Sig. (2 tailed)	Ratio Left	Sig. (2 tailed)
Study	M & S.D.		M & S.D.		M & S.D.		M & S.D.	
60°/sec	12.5 %, ±7.33 %	0.912	8.4 %, ± 7.38 %	0.482	117.7 %, ± 16.18 %	0.539	112.2 %, ± 23.96 %	0.967
180°/sec	16.8 %,±12.48 %	0.644	8.5 %, ±7.98 %	*0.032	121.3 %, ± 15.62%	0.106	118.5 %, ± 17.55%	0.543
300°/sec	9.4 %,±5.5 %	*0.043	12.2 %, ± 12.36 %	0.603	134.2 %, ± 22.93 %	*0.013	130.2 %, ±23.93 %	0.475

Table 4 presents the results in the control group, between the external and internal rotator cuff muscles of both shoulders in terms of deficit, as well as the ratio. There was a statistically significant difference in the 180°/sec ellipse in the external rotation. More precisely, an M.O. of 17.6 %, S.D. ± 9.47 %, p = 0.032 was recorded. In addition, a statistically significant difference was also observed in the ratio at the right shoulder with M.O. 112.8 %, T.A. ±9.16 %, p=0.018.

Table 4: Differences of internal and external shoulder muscle rotators in control group in the second measurement

Angular velocities	Deficit of Internal Rotators	Sig. (2 tailed)	Deficit of External Rotators	Sig. (2tailed)	Ratio Right	Sig. (2 tailed)	Ratio Left	Sig. (2 tailed)
Control	M & S.D.		M & S.D.		M & S.D.		M & S.D.	
60°/sec	13.0 %, ±12.09 %	0.912	10.8 %,±7.58 %	0.482	113.4 %,±14.48 %	0.539	111.8 %,±17.79%	0.967
180°/sec	21.1 %,± 26.14 %	0.647	17.6 %,±9.47 %	*0.032	111.0 %,± 11.7 %	0.108	113.9 %,± 15.6 %	0.543
300°/sec	21.7 %, ±17.01 %	0.053	15.1 %,± 12.11 %	0.603	112.8 %,± 9.16 %	*0.018	122.1 %,± 25.65 %	0.475

Subsequently, by conducting the Paired Samples t-test between the first and second measurement in the study group, it was found that there was no statistically significant difference (p 0.05). Table 5 records the results in the study group between the first and second isokinetic assessment, in terms of the ratio between the external and internal rotator cuff muscles of both shoulders. From the results of the analysis of variance, it appeared that there was a statistically significant difference in the 300°/sec ratio in the left shoulder. Table 5: Differences in the ratio between internal and external rotator cuff muscles

Table 5: Differences in ratio between internal and external rotators in the second measurement in the study group

Pair	*Angular Velocities*	*N*	*M*	*S.D.*	*Sig.(2tailed)*
Pair 1	*1^{η} 60°/sec Ratio right*	*10*	*97.3 %*	*± 21.33 %*	*0.82*
	2^{η} 60°/sec Ratio right	*10*	*117.7 %*	*± 16.19 %*	
Pair 2	*1^{η} 60°/sec Ratio left*	*10*	*98.0 %*	*± 34.56 %*	*0.373*
	2^{η} 60°/sec Ratio left	*10*	*112.2 %*	*± 23.96 %*	
Pair 3	*1^{η} 180°/sec Ratio right*	*10*	*99.9 %*	*± 34.6 %*	*0.145*
	2^{η} 180°/sec Ratio right	*10*	*121.3 %*	*± 15.62 %*	
Pair 4	*1^{η} 180°/sec Ratio left*	*10*	*94.9 %*	*± 41.49 %*	*0.144*
	2^{η} 180°/sec Ratio left	*10*	*118.5 %*	*± 17.55 %*	
Pair 5	*1^{η} 300°/sec Ratio right*	*10*	*109.3 %*	*± 41.06 %*	*0.187*
	2^{η} 300°/sec Ratio right	*10*	*134.2 %*	*± 22.93 %*	
Pair 6	*1^{η} 300°/sec Ratio left*	*10*	*89.0 %*	*± 29.06 %*	**0.014*
	2^{η} 300°/sec Ratio left	*10*	*130.2 %*	*± 23.93 %*	

Next, by performing a Paired Samples t-test analysis of variance between the first and second measurement in the control group, showed that there was no statistically significant difference (p 0.05) in the control group. The same seems to be true between deficit, external and internal rotators, and also between ratio, external and internal rotators.

Discussion

According to the evaluation of the two groups in terms of the angular measurements performed in the present study, and more precisely in external and internal shoulder rotation, it showed that there was no statistically significant difference in any of the variables. These results seem to be in agreement with a study by Jurgel et al. (2005), which was conducted in patients with frozen shoulder. Specifically in the previous study, it appeared that there were no significant changes at shoulder range of motion concretely in external and internal rotation. Changes at shoulder range of motion concretely in external and internal rotation.

The adaptations in this study are likely due to the fact that the intervention program given to the study group had only two stretching exercises, while it was more based on strengthening.

As it concerns the assessment of strength with the isokinetic dynamometer in internal and external shoulder rotation, this was done before the interventional program was given to the study group. Data was recorded to determine the level of shoulder strength that existed before in both study groups. Using Independent samples t-test in the data analysis, it was shown that there was no statistically significant difference between the study group and the control group. From the results of the data analysis of variance, the first measurement in the study group, using the Independent Samples t-test, in terms of deficit and ratio between the external and internal rotator cuff muscles of both shoulders, showed that there was only one statistically significant difference in the 60°/sec deficit in the external rotation. The recording of the random deficit, leads to the conclusion, that from before the study group had a power deficit, in reproducing the external rotation movement. This is probably due to the fact that the athletes with some kind of shoulder problem were neglected to strengthen this movement, due to discomfort or reduced range of motion or pain.

In addition, from the results of the data analysis of variance, the first measurement in the control group, in terms of deficit as well as the ratio between the external and internal rotator cuff muscles of both shoulders, it was shown that in the deficit at 60°/sec, there was a statistically significant difference in the external rotation. The recording of the random power deficit in the control group as well, leads to the conclusion, that from earlier, the control group also had a power deficit, in the reproduction of the external rotation movement. This is probably due to the same reason, namely that the athletes with some kind of shoulder problem, were neglected to strengthen this movement, due to discomfort or reduced range of motion or pain.

The second measurement, in the internal and external shoulder rotation at 90° abduction, was the one taken after three months and after the interventional program was given to the study group. Data was recorded to determine the level of shoulder strength that resulted after the interventional program in both study groups. Analysis of the data using Independent Samples t-test showed that there were no statistically significant differences in both the study and control groups

Using the Independent Samples t-test in the data analysis of variance on the isokinetic assessment at the second measurement in the study group, in terms of the deficit, and the ratio between the external and internal rotator cuff muscles, of both shoulders, it showed that there was a statistically significant difference in the 180°/sec deficit in the external rotation. Also, there was a statistically significant difference in the 300°/sec deficit in the internal rotation. In agreement with Jiří, Roman, Jiří, & Kateřina (2017) and Chandler, Kibler, Stracener, Ziegler, & Pace (1992) the strength of eccentrically activated external rotator cuff muscles does not increase analogically with the increase in strength of internal rotator cuff muscles. An imbalance of the shoulder rotator cuff muscle is caused due to different muscle adaptations (Wang & Cochrane, 2001).

In addition, by conducting Independent Samples t-test on the results of isokinetic assessment in the second measurement in the control group, in terms of the deficit, and the ratio between the external and internal rotator muscles of both shoulders, it was shown that there was a statistically significant difference in the 180°/sec deficit in external rotation. If the two 180°/sec deficits are compared with each other, we can see from the averages that the external rotation adaptations in the study group are better as they are reduced compared to the control group.

With this result, the positive impact of the program was demonstrated. The result that the muscle deficit of external rotation which the study group exhibited was statistically significantly reduced compared to the control group indicates that the strength training successfully targeted the external rotator cuff muscles. These findings appear to be in agreement with similar research by Niederbracht, et al (2008), with female tennis athletes and a 5-week strengthening program, which showed statistically significant gains in external rotation performed by the experimental group versus the control group. Subsequently, by performing a Paired Samples t-test analysis of variance it showed that there was no statistically significant difference between the first and second measurement in the study group.

Performing Paired Samples t-test on the isokinetic assessment data, it appeared that there was no statistically significant difference between the first and second measurement in the study group in terms of the deficit between the external and internal rotator cuff muscles of both shoulders. From the results of the analysis of variance, by conducting Paired Samples t-test, of the isokinetic evaluation, the first and second measurement in the study group, in terms of the ratio between the internal and external rotator cuff muscles of the two shoulders, it appeared that there was a statistically significant difference in the ratio of 300°/sec in the left shoulder. More specifically, M. 89.0%, S.D. ± 29.06% was recorded in the first measurement and M. 130.20%, S.D. ± 23.93% in the second measurement $p=0.014$. Comparing the results of the two measurements with each other we see that there was an increase in the ratio of external to internal torque. The muscles that contribute to external rotation, infraspinatus, teres minor and deltoid. Strengthening them with the combination of intensity, frequency and duration of the interventional program produced adaptations and increased their strength. According to Garber et al. (2011), in their research in the American College of Sports Medicine, less muscle antagonist activation is a physiological response to the functional changes that strength endurance training contributes to strength. The infraspinatus and teres minor stabilize the humeral head against internal rotation forces, helping to maintain alignment and stability of the head within the scapula (Lugo, Kung & Ma, 2008).

These results seem to be in agreement with Niederbracht, et al (2008) and Moncrief, Lau, Gale, & Scott (2002). However, they seem to disagree with Treiber, et al (1998) who, in a similar study with elite tennis players, reported that a greater imbalance in the external to internal rotation torque ratio occurred. However, these data should be interpreted with caution because they are difficult to compare with the findings of this study due to discrepancies in study methodology, measurement methods and sample selection. There are no similar measurement studies in the literature that could be related to the results of the current study. Most studies report measurements using isometric dynamometry and are based on handheld dynamometers. In addition, all available non-isokinetic studies based on isometric dynamometer evaluated concentric force only and failed to assess the effects of outside rotator cuff muscles on eccentric strength and the kind of muscle activation observed in the deceleration phase of the movement above head level.

Then by performing a Paired Samples t-test analysis of variance it showed that there was no statistically significant difference between the two measurements in the control group. By conducting Paired Samples t-test analysis of variance, it appeared that there was no statistically significant difference between the deficit, external and internal rotators of the first and second measurement in the control group. By conducting Paired Samples t-test analysis of variance, it was shown that there was no statistically significant difference between deficit, external and internal rotators of both measurements in the control group.

Although the present study contributes significantly to this issue, it should be said that the results should be taken into account in relation to some limitations of the research such as:
1) Only top handball athletes in the top two categories took part in the study.
2) Due to the corona virus pandemic, the research included participants mainly from Northern Greece. 3) Due to the corona virus pandemic, the period of the research lasted more than one season. 4) The study group included 10 left-handed and 10 right-handed athletes. 5) The research due to corona virus pandemic was conducted without full surveillance as to whether or not the athletes who made up the study group were adhering to the interventional program. However, at the end, all participants involved stated that they adhered to the program.
6) No additional tests or measurements of other variables were included in the study to evaluate the problem, due to the limited time of the athletes.

Conclusions

The investigation of whether and to what extent an interventional program of specialized training affected the range of motion and strength levels of handball players were the subject of this study. Whether and to what extent there were adjustments from the study group's program was the question. By evaluating the 20 male and female athletes who formed the sample of this study, it was found that the intervention program had a beneficial effect in some areas and to varying degrees, while in other areas there was no beneficial effect. From the results of the goniometry, the beneficial impact of the interventional program on range of motion was not demonstrated and it was shown that the interventional program should be increased with more stretching exercises. In isokinetic dynamometry we had variations in the ratio between the external and internal rotator cuff muscles of both shoulders. This is probably due to the fact that there is less activation of antagonist muscles as a physiological response to the functional changes that strength endurance training contributes to strength. In order to have better adaptations for the internal rotators as well, future research should add exercises that could further contribute to their strengthening. The observed differences between male and female handball athletes are important information for exercise professionals and can provide feedback to athletes. These results may also simultaneously indicate guidelines during training.

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