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Isokinetic evaluation of biomechanical parameters of the shoulder complex in handball players

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SUMMARY

Sport disciplines which require from players such activities as throwing over the head, enforce the large mobility in the shoulder joint, often forcing to achieve extreme values of achievable ranges of motion. In this kind of situation, the lack of coordination and cooperation of all components of the shoulder girdle, ranging from basic connectivity, ending with an imbalance of muscles will result in an abnormal mobility pattern. Pathological motor pattern, repeatedly reproduced, inevitably leads to fixation of pathological motor habits which may result in the injury within the musculoskeletal system. Currently, a great convenience for the medical team is to use modern equipment that allows the comprehensive assessment of the damage and also to use it for complex rehabilitation. One of the most interesting ways to conduct medical rehabilitation is the concept of diagnosis and isokinetic exercises. The aim of the study was to determine differences in isokinetic testing of selected parameters between dominant and non – dominant upper limbs among professionals practicing handball.

The study shows that the isokinetic values obtained in dominant traumatic limb in experimental group were higher than those achieved by non-dominant limb, which indicates the ability to trigger adaptive and compensation mechanisms.

Key words: shoulder girdle, isokinetic measurements, handball players

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INTRODUCTION

The function of the upper limb depends on good interaction between all of the structures which form the shoulder complex. The overriding aim of the whole mechanism is easy manipulation of the upper limb, starting with shoulder and ending with hand. Impaired functioning of a single element in the mechanism of the shoulder complex will result in a malfunction of the adjacent joints. Sports which require from players such activities as throwing over the head, which extort large mobility from the shoulder joint, often forcing to achieve not only extreme values of achievable ranges of motion but also to achieve values exceeding ranges of motion. In this kind of situation, the lack of coordination and cooperation of all components of the shoulder girdle, ranging from basic connectivity, ending with an imbalance of muscles will result in an abnormal mobility pattern. Pathological motor pattern, repeatedly reproduced, inevitably leads to fixation of pathological motor habits which may result in an injury within the musculoskeletal system. Examples of sport disciplines, in which this mechanism is important are handball or baseball. Excessive range of motion, which is necessary to throw the ball, is achieved through synchronous and coordinated movements in all joints of the shoulder girdle, mainly in the shoulder joint and between scapula and thoracic spine [1,2,3]. Until the boost movement is controlled within players compensatory – adaptive capacity it may be an advantage because it allows to generate greater torque force, which as a sport consequence may reflect in the quality of throwing.

Currently, a great convenience for the medical team is to use modern equipment that allows the comprehensive assessment of the damage and also to use it for complex rehabilitation. One of the most interesting ways to conduct medical rehabilitation is the concept of isokinetic diagnosis and isokinetic exercises. According to Thistle et al., isokinetic contraction is a dynamic contraction of the muscle, which takes place with constant angular velocity. The only variable parameter is the resistance which is adjusted to the force generated by a patient. This resistance is produced by isokinetic dynamometer. The equipment is connected to a computer on which desired values, including the angular velocity or limb position, can be set [4].

Until recently, computers allowed only to obtain basic information such as the total work or endurance of the tested limb. Currently, with the advancement of technology, it became possible to analyze other, more specific parameters, which include the opportunity to examine specific, isolated muscle group, possibility to choose the tested contraction between concentric and eccentric, and finally the ability to work in a closed or open kinematic chains.

Just like any other method, this one also has its opponents. Among their opinions the most popular are complaints about muscles working conditions and adaptive resistance – they suggest that such work is done in artificially created conditions, which is inconsistent with the physiological daily living human activity [4].

However, looking at research results in this field of study in recent years, we can conclude that this method has many benefits, both for diagnostic purposes, where the measured data provide a range of information about selected biomechanical muscles parameters and allows the graphic illustration of the measurements and for therapeutic purposes where it is possible to use the resistance adapted to the patients possibilities, what makes isokinetic exercises safe at all stages of rehabilitation [4,5,6].

OBJECTIVES

The aim of the study was to determine differences in isokinetic testing of selected parameters between dominant and non – dominant upper limbs among professionals practicing handball.

In order to precisely determine and investigate the problem, following research questions have been put:

1) Are there any differences between dominant traumatic and non – dominant upper limbs among chosen biomechanical parameters?
2) Whether the earlier trauma within the shoulder complex has an impact on the results?
3) Which of the angular velocities in isokinetic testing (180°/s and 300°/s) has a greater impact on achieved results?

MATERIAL AND METHODS

The study has been approved by the Bioethics Committee of the Medical University of Silesia in Katowice KNW/0022/KB1/65/12.

The study involved 20 professional handball players aged 19-27 years ($\bar{x}$ = 26,55 ± 4,05). All of the players were diagnosed with trauma within the shoulder joint and completed the process of treatment. Average BMI within the group was $\bar{x}$ =25,45 ± 1,43 the average length

Tab. 1. Characteristics of the study groups

	AGE (in years)	WEIGHT (kg)	HEIGHT (cm)	TRAINING EXPERIENCE (in years)	BMI
STUDY GROUP	26,55 ± 4,05	88,15 ± 11,74	1,86 ± 0,1	16,06 ± 4,95	25,45 ± 1,43

Tab. 2. Characteristics of the experimental group in terms of the occurrence of injuries

TYPE OF INJURY	
Damage to the rotator cuff	7 persons – 35%
Coracoclavicular ligament tearing	3 persons – 15%
Shoulder contusion	2 persons – 10%
Muscles tearing	2 persons – 10%
Slight instability	2 persons – 10%
Tearing of the muscles with the rotator cuff injury	2 persons – 10%
Tearing of the muscles with contusion of the shoulder girdle	2 persons – 10%

of training experience $\bar{x}$ =16,06 ± 4,95. The study was conducted at the Center of Physiotherapy „Fizjofit" in Gliwice, after prior written consent of the players. The entire research group represented the highest level of sport skills, representing the clubs from the premier league.

Participants were informed about the characteristics and purpose of the study, as well as about their full capability to interrupt the test at any time at the request of the subject.

The assessment of internal and external rotators in two upper limbs, in conditions of concentric isokinetic work, according to the standard protocol has been done in each athlete. Bilateral evaluation consisted of making 5 moves of the internal and external rotation with the angular velocity of 180°/s and 10 replicates at a speed of 300°/s. In addition, subjects were instructed to execute two trial repetitions of the test before each series, in order to familiarize them with the course of the test and with changing conditions of the study. According to the isokinetic protocol there always was a 60 – second pause to rest between each series.

The test was performed in a sitting position. The tested upper limb was set in 90° of abduction, 90° elbow flexion (with its support to stabilize the position) and 30° horizontal flexion which provided correct biomechanical relationship according to which the axis of rotation of the dynamometer was located in the axis of rotation of the shoulder joint in the plane of the blade. Hand stabilization in the tested limb was obtained by the handle holder in the distal portion of the lever arm of the dynamometer. Stabilization of the trunk and chest was provided by two lanes, oblique to each other. This kind of stabilization may help to avoid accompanying movements of the trunk and may isolate pure motion in the shoulder joint.

During the test numerous verbal commands were used in order to motivate respondents to intensive work, which is consistent with the methodology of isokinetic measurements [7,8].

Before testing athletes performed some warming – up exercises, which consisted of: 10 minutes ride on the cycloergometer or on the elliptical bike and 2 exercises on the Keiser Functional Trainer machine, one for internal rotation and second one for external rotation. Exercises were performed in two series with 12 repetitions for each rotation.

During the test three isokinetic parameters were measured: peak moment of the force (peak torque), average power and total work made by internal and external rotators of the shoulder joint.

The statistical analysis was done using Statistica 8.0 software. In order to compare determine the level of peak torque, total work and average power in each rotation of the angular velocity of 180°/s and 300 °/s for dominant traumtic and non-dominant limbs numerical characteristics: mean, standard deviation and 95% confidence interval were determined.

Before the analysis Kruskal – Wallis test was performed and it showed no normal distribution with a significance level of $p < 0.05$. This served to perform nonparametric statistical methods in statistical analysis.

To assess whether the level of peak torque, total work and average power differs significantly between damaged and healthy limbs in experimental population, Friedman ANOVA analysis for dependent variables was used.

To assess the prevalence of dependence or absence thereof between dominant and non – dominant limbs during peak torque, total work and average power in players in experimental group for each rotation Spearman correlations were calculated.

RESULTS

The results presented below are the results of isokinetic measurements conducted on Biodex System 3 device. The survey was conducted using a standard isokinetic protocol, maintaining appropriate methodology.

The level of isokinetic parameters in study group in external rotation at angular velocity of 180°/s was lower for non – dominant limb. Analysis of variance showed that the differences between all analyzed isokinetic parameters were statistically insignificant.

On the other hand, in the case of isokinetic analysis of the parameters in study group in internal rotation at angular velocity of 180°/s, the level of analyzed isokinetic parameters was also lower for the non – dominant limb. Analysis of variance showed that the differences between peak moment of force, total work and average power of both limbs were significant at $p = 0.002$.

The level of isokinetic parameters in study group in external rotation at angular velocity of 300°/s was lower for non – dominant limb. Analysis of variance showed that the differences between peak moment of force in study group were significant at $p = 0.03$. Analysis of

variance for total work and average power showed no statistical significance at p = 0.18.

On the other hand, in the case of analysis of isokinetic parameters in study group in internal rotation at angular velocity of 300°/s, the level of analyzed isokinetic parameters was also lower for the non – dominant limb, while the analysis of variance showed that the differences between peak moment of force, total work and average power of both limbs were statistically significant at p = 0.002.

The above data show that the level of peak moment of force was highly significantly correlated between dominant and non – dominant limb for each rotation at angular velocity of 180°/s. In study group correlations were higher for internal rotation R = 0.92 than for external rotation R = 0.68. . Correlation analysis showed that all of the relations between peak moment of muscular force were significant at p <0.001.

The level of total work was highly significantly correlated between dominant and non – dominant limb for each rotation at angular velocity of 180°/s. In study group, the correlation was higher for internal rotation, R = 0.97 than for external rotation R = 0.64. Correlation analysis showed that all of the relations between limbs total work were significant at p <0.003.

The average power was highly significantly correlated between dominant and non – dominant limb for each rotation at angular velocity of 180°/s. In study group, the correlation was higher for internal rotation R = 0.92 than for external rotation R = 0.60. Correlation analysis showed that all of the relations between limbs average power were significant at p <0.006.

The above data show that the level of peak moment of force was highly significantly correlated between dominant and non – dominant limb for each rotation at angular velocity of 300°/s. In study group correlations were higher for internal rotation R = 0.92 than for external rotation R = 0.84. Correlation analysis showed that all of the relations between limbs muscles in peak moment of force were significant at p <0.000004.

Tab. 3. Statistical analysis for individual isokinetic parameters at angular velocity of 180°/s in rotational movements – study group

EXTERNAL ROTATION 180°/S – STUDY GROUP												
	PEAK MOMENT OF FORCE (Nm)				TOTAL WORK (J)				AVERAGE POWER (W)			
	×±SD	CI		p	×±SD	CI		p	×±SD	CI		p
DTL	32,51±6,81	29,32	35,69	0,64	155,88±29,59	29,32	35,69	0,82	49,82±11,62	44,38	55,25	0,37
NDL	30.97±4,41	28,9	33,03		149,25±25,41	28,9	33,03		48,09±8,78	43,98	52,19	
INTERNAL ROTATION 180°/S – STUDY GROUP												
	×±SD	CI		p	×±SD	CI		p	×±SD	CI		p
DTL	64,83±14,54	58,02	71,63	0,002	378,43±83,94	339,14	417,71	0,002	378,43±83,94	339,14	417,71	0,002
NDL	55,91±10,29	51,09	60,73		321,64±63,99	291,69	351,59		321,64±63,99	291,69	351,59	

DTL – dominant traumatic limb, NDL – non – dominant limb, x±SD – mean ± standard deviation, CI – confidence interval significance, p – level of significance

Tab. 4. Statistical analysis for individual isokinetic parameters at angular velocity of 300°/s in rotational movements – study group

EXTERNAL ROTATION 300°/S – STUDY GROUP												
	PEAK MOMENT OF FORCE (Nm)				TOTAL WORK (J)				AVERAGE POWER (W)			
	×±SD	CI		p	×±SD	CI		p	×±SD	CI		p
DTL	24,37±5,83	21,64	27,09	0,03	188,45±59,44	160,63	216,26	0,18	41,78±14,61	34,94	48,62	0,18
NDL	23,16±4,83	20,9	25,42		177,37±50,55	153,71	201,02		38,94±11,64	33,49	44,39	
INTERNAL ROTATION 300°/S – STUDY GROUP												
	×±SD	CI		p	×±SD	CI		p	×±SD	CI		p
DTL	60,95±12,86	54,92	66,97	0,002	589,1±133,98	526,39	651,8	0,002	125,66±32,43	110,48	140,83	0,002
NDL	54,84±10,09	50,11	59,56		519,31±104,03	470,62	567,99		110,68±26,78	98,15	123,21	

DTL – dominant traumatic limb, NDL – non – dominant limb, x±SD – mean ± standard deviation, CI – confidence interval significance, p – level of significance

The level of total work was highly significantly correlated between dominant and non – dominant limb for each rotation at angular velocity of 300°/s. In study group correlations were higher for internal rotation R = 0.94 than for external rotation R = 0.82. Correlation analysis shows that all of the relations between limbs total work were significant at p <0.00002.

The average power was highly significantly correlated between the dominant and non – dominant limb for each rotation at angular velocity of 300°/s. In study group correlations were higher for internal rotation R = 0.88 than for external rotation R = 0.76. Correlation analysis showed that all of the relations between limbs average power were significant at p <0.0002.

DISCUSSION

Many biomechanical and electromyographic studies confirm the pivotal role of the rotator cuff during any activity of the shoulder joint (Speer 1995) [7]. Its main tasks include: dynamic stabilization of the humeral head in the acetabulum, as well as the acceleration and deceleration of the shoulder joint during such activities as throwing. Among players performing throws over their heads, upper limbs which are in abduction and in external rotation during the phase of swinging and preparing the ball to throw, it requires a dynamic, coordinated and synchronized cooperation of the muscular and nervous systems, to maintain the proper congruence of the humeral head in the shoulder joint [8-10].

Tab. 5. Correlations for internal and external rotation at angular velocity of 180°/s between non – dominant limb and dominant traumatic limb in study group for individual isokinetic parameters

EXTERNAL ROTATION 180°/s			
	PEAK MOMENT OF FORCE (Nm)	TOTAL WORK (J)	AVERAGE POWER (W)
	SG	SG	SG
R	0,68	0,64	0,60
p	0,00099	0,0026	0,005
t(N-2)	3,92	3,50	0
INTERNAL ROTATION 180°/s			
	PEAK MOMENT OF FORCE (Nm)	TOTAL WORK (J)	AVERAGE POWER (W)
	SG	SG	SG
R	0,92	0,97	0,92
p	0,00000	0,00000	0,00000
t(N-2)	9,71	15,62	10,25

R – correlation, SG – study group

Tab. 6. Correlations fo internal and external rotation at angular velocity of 300°/s between non – dominant limb and dominant traumatic limb in study group and between dominant limb and non – dominant limb in control group for individual isokinetic parameters

EXTERNAL ROTATION 300°/s			
	PEAK MOMENT OF FORCE (Nm)	TOTAL WORK (J)	AVERAGE POWER (W)
	SG	SG	SG
R	0,84	0,82	0,76
p	0,00003	0,00001	4,91
t(N-2)	6,62	6,06	0,0001
INTERNAL ROTATION 300°/s			
	PEAK MOMENT OF FORCE (Nm)	TOTAL WORK (J)	AVERAGE POWER (W)
	SG	SG	SG
R	0,92	0,94	0,88
p	0,00000	0,00001	7,92
t(N-2)	10,25	11,30	0,00000

R – correlation, SG – study group

The most important skill in playing handball, which allows to achieve the highest sport level, is the ability to perform throws precisely. It is directly related to the player's sufficient force and power of the upper limbs, but also to the trunk and lower limbs, which cooperate with upper limbs by carrying kinetic energy through kinematic chains to the area of the shoulder girdle [10].In the case of a right – handed player, a chain of links connected to each other, begins from the left foot and lead through the trunk to the right upper limb. Toyoshima et al., showed that 53.1% of the speed the ball throw is attributed to the upper limb, while the remaining 46.9% is the force generated by the lower extremity and trunk twist. The arm in acceleration phase overcomes the way from the full external rotation to the internal rotation [11].

Frequently repeated movements may result in muscle fatigue and muscle imbalance which increase the risk of injury within the shoulder complex. Therefore, sport activity has a significant impact on the anatomical disturbances within the muscles of the rotator cuff [9]. The role of strength and balance of antagonistic muscle groups of the shoulder appears to be crucial [10]. Accordingly to the significant role of the muscles of the rotator cuff, it seems appropriate to make an objective assessment of muscle strength of internal and external rotators, both in rehabilitation process of the athlete, as well as in training programs – as a protection against possible occurrence of injury [8]. Isokinetic assessment of the strength of the shoulder joint rotators is used by clinicians and physiotherapists to assess possible deficits and imbalance during the concentric work between internal and external rotators [10].

Over the past few decades, isokinetic evaluation of the muscular system in terms of strength imbalances has been widely studied by scientists. In the available literature numerous studies can be found about swimmers (McMaster, Long & Caiozzo, 1991 [13]; Bak & Magnusson, 1997 [14]), baseball players (Brown, Niehues, Harrah, Yavorsky, & Hirshman, 1988 [15]; Warner, Micheli, Arslanian, Kennedy & Kennedy, 1990 [16]; Mikesky, Edwards & Wigglesworth, 1995 [17]; Ellenbecker & Mattalino, 1997 [8]) or players playing water polo (McMaster, Long & Caiozzo, 1992 [12]). A multitude of research on baseball players is clearly dominant, while the number of works on the handball players is much lower, which means that in this matter there is still much confusion and there is a need for further development in this field of study.

Isokinetic examination of shoulder joint rotators and comparing the results of studies among themselves is inseparably accompanied by a number of common problems. The most common problems include: a variety of used equipment and its technical capabilities, different positions of upper limbs during the tests and studies carried out in different angular velocities. Recent research has still not clearly stated the best position for measurements.

Edouard et al. reported that reliable values of peak torque for internal and external rotators can be achieved in a sitting position, with arm abducted to an angle of 45, set in the plane of the scapula [18]. Accordingly to prevailing in the literature data relating to a positive correlation between setting arm in the plane of the scapula and the achieved results, the position used in this study was setting the arm in the plane of the scapula, in abduction to the angle of 90° and in a sitting position. This position seems to be the most physiological and the most similar to the position which handball player takes at the time of the throw.

On the basis of statistical analysis, it was found that the isokinetic parameters for both internal and external rotators are greater in dominant traumatic limb in comparison to non – dominant limb for each angular velocity.The reported statistical significance of differences was recorded mainly for peak torque, total work and average power of internal rotators in both velocities in experimental group. Similar results were presented by Andrade et al, who established isokinetic strength profile of external and internal rotators of the shoulder joint in national handball team for both dominant and non – dominant limbs. Concentric work in internal and external rotation movements was statistically significantly higher in dominant limb than in non – dominant limb in each velocity [10].

Conducted study also shows that there are differences in the values of the selected isokinetic parameters between dominant and non – dominant limbs. Internal rotators in dominant limb, regardless of angular velocity, each time proved to be stronger than internal rotators in non – dominant limb, which is consistent with the results presented in the available literature. Similar disparities noted Wang et al. investigating professional volleyball players from the UK, Silva et al. – studying junior tennis players and Yildiz et al. – studying athletes throwing over their head. Brown et al. showed significantly

greater strength of internal rotation of dominant limb among professional pitchers, Perrin and colleagues among pitcher academic teams and Hinton among pitcher schools. Ellenbecker and Mattalino, studying professional pitchers, also found a clear difference in favor of the internal rotator of dominant limb if the value of peak torque and total work were of peak [8-10,15,19-21].

Several studies, including Wolf et al., Cook et al., and Hinton show that the ratio of external/internal rotation in dominant limb among pitchers is lower (4 – 11%) than in non – dominant limb. This difference is due to the presence of greater strength of internal rotation of dominant limb without a similar effect of dominance of external rotation during the test in terms of concentric contractions [10,21-22]. In other studies, Codina et al. [23] calculated the relationship between the maximum forces of internal and external rotators in untrained persons and in athletes of various disciplines. In untrained people, this ratio was in the range between 1.3 to 1.5, whereas eg. in baseball 1.6 to 2.2 in which there is a clear disproportion between rotators of dominant limb [8]. In these studies similar relationship in which apparently predominance of internal over external rotators is outlined in isokinetic parameters for each limb, in both groups at the angular velocity of 180°/s and 300°/s was noted.

The importance of the difference between the strength of internal and external rotators has been described by Warner et al. [16]. They conducted isokinetic study in patients with joint instability, with impingement syndrome and in healthy patients. The degree of muscle balance between internal and external rotations depends on the presence of the pathological condition of the tissue or lack thereof. The presence of lower unilateral values in dominant limb in isokinetic studies of professional baseball players (Brown et al. [15], Cook et al. [22]), junior tennis players (Chandler et al. [24], Ellenbecker et al. [8]) and academic swimmers (McMaster et al. [13]) has its clinical implications. In athletes who use primarily one limb, lower values of the ratio of external rotation to internal rotation indicate a relative decrease in the strength of external rotation compared to the strength of internal rotation. This ratio shows the selective growth of the concentric work in internal rotation movement among athletes who throw, without a concomitant increase in the strength of external rotation. Studies assessing the unilateral relationship of external and internal rotation and the risk of injury have not yet resulted in obtaining values which could be considered as switches, which could be related to the potential risk of injury of the player [8,13,15,22,24]. Codina et al. clearly emphasize that the differences between the strength of internal and external rotators of both brachial joints can result from the lasting training [23]. Therefore, in handball players using for many years one upper limb as their dominant, within hundreds of throws during training and games, the formation of such imbalances is understandable [8-10,24].

The study also shows that players with dysfunction within the shoulder complex achieved better results with the angular velocity of 180°/s. It is believed that this situation is the result of yet unfinished process of healing (players were examined three months after injury) since the results indicate disorder of control of inhibition reflex and lack of stability reflex mechanism. These results are not compatible with the results of Pontago and Zidens who found that the higher the angular velocity, the greater are differences in the isokinetic parameters. These differences result from the nature of this sport. Handball is a sport associated with dynamic throws which outweigh in frequency force throws. Testing at high angular velocities, which evaluate the speed – dynamic parameters allows to capture these regularities [9,10].

According to such disparities and muscle imbalances within the shoulder girdle, it seems important to implement proper training, the aim of which will be to compensate the unilateral differences in eccentric work and also in concentric work for both internal and external rotators, which will prepare the ground for overcoming bilateral asymmetries. Andrade et al. assume that emphasis should be placed on internal and external rotators training in non – dominant limb. This will prevent possible injuries within the shoulder complex, resulting from the existing asymmetry of forces in the upper limbs. It is also recommended to implement functional eccentric exercises of rotators in dominant limb, both in rehabilitation programs and prevention programs among handball players. Obtained results confirm that strengthening exercises are a very effective tool in dealing with injuries within the musculoskeletal system and it is particularly important to involve them in training programs in sports with the dominance of asymmetric movements [10].

CONCLUSIONS

1. There are differences between dominant traumatic limb and non – dominant limb in analyzed isokinetic parameters. Strength superior of internal rotators in concentric work in dominant limb over non – dominant limb is observed.
2. Prior trauma within the shoulder complex has an impact on obtained results. Values obtained in dominant traumatic limb were higher than those achieved by non-dominant limb, indicating an ability to trigger adaptive and compensation mechanisms.
3. It is assumed that higher values of the analyzed isokinetic parameters isokinetic both in external and internal rotators in experimental group at the angular velocity of 180°/s testify to the unfinished process of motor rehabilitation, because the ability to control movement at the level of inhibition reflexes has not been yet working properly.
4. Medical and rehabilitation team should control treatment, therapy and wellness in newly generated range of motion, because the problem is not the excessive range of motion but a possible overload it may provoke.

REFERENCES

1. Eckenrode BJ, Kelley MJ:Clinical Biomechanics of the Shoulder Complex. [In:] Wilk KE, Reinold MM, Andrews JR. The Athlete's Shoulder. Philadelphia: Churchill Livingstone, Elsevier. 2009:17-41.
2. Ludewig PM, Borstead JD: The shoulder complex. [In:] Levangie PK, Norkin CC. Joint Structure and Function: A Comprehensive Analysis. Philadelphia: F.A. Davis Company; 4 th ed. 2005:233 – 271.
3. Grimshaw P, Lees A, Fowler N, Burden A: Biomechanika sportu. Warszawa: Wydawnictwo Naukowe PWN. 2010.
4. Grygorowicz M, Kubacki J, Bacik Bi wsp.: Pomiary w warunkach izokinetycznych – obszary zastosowania w fizjoterapii. Fizjoterapia Polska 2006;6(3):238 – 244.
5. Ellenbecker TS: Ocena stawu panewkowo-ramiennego, barkowo – obojczykowego i łopatkowo – żebrowego u sportowców wykonujących rzuty ponad głową. [In:] Donatelli RA. Rehabilitacja w sporcie. Wrocław: Elsevier Urban & Partner. 2011:183 – 199.
6. Kelley MJ, Leggin BG, Rogers KJ: General Techniques of Shoulder Rehabilitation. [In:] Iannotti JP, Williams Jr GR. Disorders of the shoulder: Diagnosis & Management. Philadelphia: Lippincott Williams& Wilkins. 2007; 2:1235 – 1264.
7. Speer KP: Anatomy and pathomechanics of shoulder instability. Clinics in Sports Medicine 1995;14(4):751 – 760.
8. Ellenbecker TS, Mattalino AJ: Concentric isokinetic shoulder internal and external rotation strength in professional baseball pitchers. Journal of Orthopaedic & Sports Physical Therapy 1997;25(5):323 – 328.
9. Pontaga I, Zidens J: Shoulder invertors and evertors torque production of handball players. Journal of Human Kinetics 2004;11(8):75 – 82.
10. Andrade Mods S, Fleury AM, De Lira CA i wsp.: Profile of isokinetic eccentric-to-concentric strength ratios of shoulder rotator muscles in elite female team handball players. Journal of Sports Sciences 2010; 28(7):743 – 749.
11. Bayios IA, Anastasopoulou EM, Sioudris DS i wsp.: Relationship between isokinetic strength of the internal and external shoulder rotators and ball velocity in team handball. Journal of Sports Medicine & Physical Fitness 2001; 41(2): 229-235.
12. McMaster WC, Long S.C., Caiozzo VJ: Isokinetic torque imbalances in the rotator cuff of the water polo player. Am J Sports Med. 1991; 19(1):72 – 5.
13. McMaster WC, Long S.C., Caiozzo VJ: Shoulder torque changes in the swimming athlete. Am J Sports Med. 1992; 20(3): 323 – 7.
14. Bak K, Magnusson SP: Shoulder strength and range of motion in symptomatic and pain-free elite swimmers. Am J Sports Med. 1997; 25(4):454 – 9.
15. Brown LP, Niehues SL, Harrah A i wsp.: Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. Am J Sports Med. 1988;16(6):577 – 85.
16. Warner JJ, Micheli LJ, Arslanian LE i wsp.: Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. Am J Sports Med. 1990;18(4):366 – 75.
17. Mikesky AE, Edwards JE, Wigglesworth JK i wsp.: Eccentric and concentric strength of the shoulder and arm musculature in collegiate baseball pitchers. Am J Sports Med. 1995;23(5):638 – 42.
18. Edouard P, Samozino P, Julia M I wsp.: Reliability of isokinetic assessment of shoulder-rotator strength: A systematic review of the effect of position. Journal of Sport Rehabilitation 2011; 20(3): 367 – 383.
19. Wang HK, Cochrane T: Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. J Sports Med Phys Fitness. 2001;41(3):403 – 10.
20. Perrin DH, Robertson RJ, Ray RL: Bilateral Isokinetic Peak Torque, Torque Acceleration Energy, Power, and Work Relationships in Athletes and Nonathletes. J Orthop Sports Phys Ther. 1987;9(5):184 – 9.
21. Hinton RY: Isokinetic evaluation of shoulder rotational strength in high school baseball pitchers. Am J Sports Med. 1988;16(3):274 – 9.
22. Cook EE, Gray VL, Savinar-Nogue E, Medeiros J: Shoulder Antagonistic Strength Ratios: A Comparison between College-Level Baseball Pitchers and Nonpitchers. J Orthop Sports Phys Ther. 1987;8(9):451 – 61.
23. Codine P, Bernard PL, Pocholle Mi wsp.: Influence of sports discipline on shoulder rotator cuff balance. Medicine and Science in Sports and Exercise 1997; 29:1400 – 1405.
24. Chandler TJ: Testing and Training the Upper Extremity. [In:] Brown LE. Isokinetics in Human Performance. Champaign, Illinois: Human Kinetics; 2000;149 – 170.