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SHOULDER MUSCLES ADAPTATION TO THROWING MOTION IN ADOLESCENT HANDBALL PLAYERS

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SUMMARY

Sport specializations with regular, repeated throwing motions cause increase of the shoulder internal rotator muscles produced torques and power in a dominant (prevailing throwing) arm in comparison with a non-dominant arm muscles.

An aim of our investigation is to determine an asymmetry of the dynamometry characteristics in the dominant and non-dominant arm muscles, and a relationship between the shoulder rotator muscles isokinetic dynamometry characteristics and the ball throwing speed in the adolescent handball players.

Fourteen elite adolescent handball players participated in the investigation detecting by an isokinetic dynamometer system the muscles characteristics in the shoulder external–internal rotation movements. The eccentric–concentric muscles contractions obtained by the dynamometer system partly reproduced the handball throwing movement. The throwing speed of the ball was measured by a reflected light method.

A difference between dominant and non-dominant arms muscles characteristics in the concentric contractions is none significant. After the eccentric contractions of the shoulder external rotator muscles the average and maximal power production of the shoulder internal rotator muscles significantly increases. The best correlation is determined between the ball throwing speed and the average power of the internal rotator muscles in concentric contractions after concentric contractions of the external rotator muscles, where $r = 0.78$ and $p = 0.09$.

Key words: shoulder internal rotator muscles, isokinetic dynamometry, eccentric and concentric contractions, throwing speed, handball

INTRODUCTION

Many authors have investigated the shoulder internal–external rotator muscles because they are very important to provide the joint stability (Fleisig, G. S. et al., 1995; Jobe, F. W. and Pink, M., 1993), as well as, the shoulder joint internal rotation is one of components in a throwing motion (Dillman C. J. et al., 1993; Van den Tillaar, R. and Ettema, G., 2004; Werner, S. L. et al., 2001). Sport specializations with regular, repeated throwing motions cause increase of the shoulder internal rotator muscles produced torques in a dominant (prevailing throwing) arm and the torques developed by these muscles are much higher than the shoulder external rotator muscles produced torques in comparison with a non-dominant arm muscles (McMaster, W. C. et al., 1991; Codine, P. et al., 1997; Wilk, K. E. et al., 1993).

The difference between the peak torque produced in the shoulder internal–external rotation motions by the dominant and non-dominant arms internal and external rotator muscles of adult elite handball players tested by an isokinetic dynamometry is none significant at low (60º/s), as well as, at high (180º/s, 240º/s) angular velocity of the movements (Pontaga, I. and Zidens, J., 2004). The significant difference is revealed between the dominant and non-dominant arms internal rotator muscles produced average power only at high angular velocity of the movements (240º/s). Therefore an asymmetry could appear also between the dynamometry characteristics of the dominant and non-dominant arm muscles for adolescent handball players.

One of main aims of handball training is to increase the ball throwing speed. To achieve it high muscles strength and especially the power are required. It is proved by a fact that the maximal power, which is produced by arm muscles in a heavy weight horizontal bar press from a supine position does not differ significantly between the handball players and weight lifters, but the strength for the weight lifters is significantly higher (Izquierdo, M. et al., 2002). A concentric shoulder adductor muscles peak torque value measured by the isokinetic dynamometry allows to predict the ball throwing speed for adult baseball players (Bartlett, L. R. et al., 1989). A. E. Mikesky et al. (1995) could not found significant correlations between the baseball pitchers shoulder rotator muscles produced peak torques in the concentric and eccentric contractions measured by the isokinetic dynamometer at the angular velocities of movement of 90º/s, 210º/s and 300º/s and the ball throwing speed. A. Clements et al. (2001,a) compared the shoulder internal rotator muscles isometric strength and the ball throwing speed for adolescent elite baseball players and a control group of adolescent boys with the same height and weight. The tests showed that fast throwing speeds are achieved by the well-trained sportsmen without changes of the isometric muscles strength in comparison with the untrained adolescents. A. Clements et al. (2001,b) have determined for the adolescent baseball players a significant relationship between an isometric shoulder internal rotator muscles peak torque (a body weight ratio and the ball throwing speed), and between the isokinetic concentric elbow extensor muscles peak torque (the body weight ratio at the angular velocity of movements of 120º/s and the throwing speed). D. B. Cohen and M. A. Mont (1994) have determined the significant relationship between a tennis ball serve speed of elite tennis players and the dominant arm shoulder internal–external rotator muscles peak torques ratio measured by the isokinetic dynamometer at the angular velocity of 60º/s and 180º/s in the concentric and eccentric contractions.

The effect of the shoulder muscles isokinetic dynamometry characteristics on the ball throwing speed for adolescent handball players is not investigated.

PURPOSE

An aim of our investigation is to determine an asymmetry of the dynamometry characteristics in the dominant and non-dominant arm muscles, and a relationship between the shoulder rotator muscles isokinetic dynamometry characteristics and the ball throwing speed in the adolescent handball players.

PROCEDURES

Fourteen elite male adolescent sportsmen trained in the handball seven years five times per week and playing regularly in weekends were informed of possible test risks and participated in the investigation voluntary. The study was performed in conformity with the standards of the Ethics Committee of the Latvian Council of Sciences. All shoulder joints of the athletes were injury free and painless during the investigation. The age of athletes was 14–15 years, height – 176 cm (164–190 cm) and weight – 63 kg (47–80 kg).

The tests were carried out by a dynamometer system "REV – 9000" (Technogym, Gambettola, Italy) using the shoulder isokinetic internal–external rotation movements. The sportsman was seated on the "REV – 9000" bench with an elbow resting on an input shaft (Figure 1). A dynamometer level arm was adjusted to a length of the athlete forearm. The elbow was flexed to 90º. A humerus was abducted in a right angle (90º) to a trunk. The internal and external rotation movements were performed in a scapular plane, which lies parallel to the scapula plane surface. B. H. Greenfield et al (1990) have determined that testing is preferable in the scapular plane because the shoulder external rotational strength values in this plane are significantly higher than in a frontal plane.

A range of movements (ROM) was from 20º of the shoulder external rotation to 100º of the internal rotation (Figure 2). To exclude the trunk movements, a chest and pelvis were

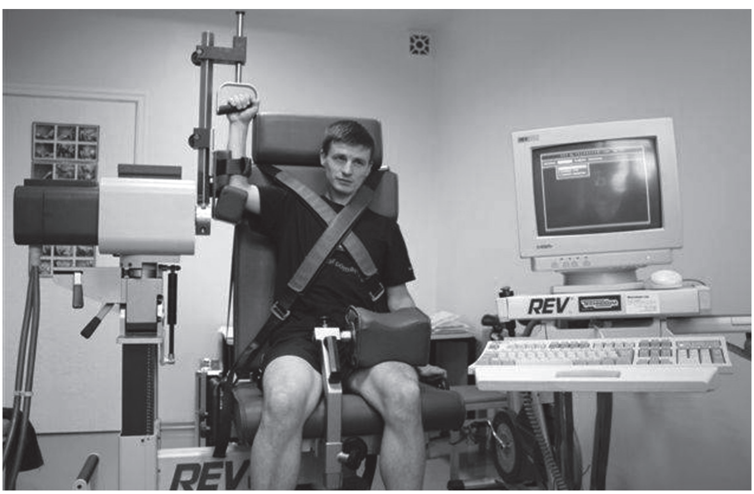

Figure 1. Position of the athlete during the shoulder muscles isokinetic test

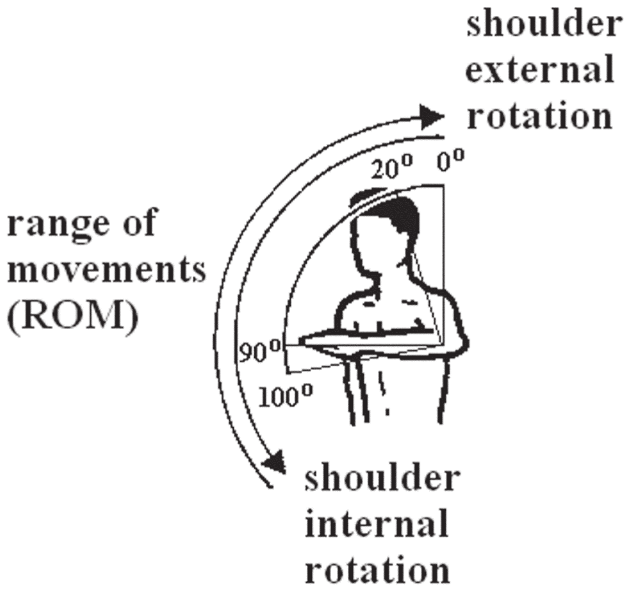

Figure 2. The range of the internal–external shoulder rotation movements

stabilized using straps. The sportsman feet were placed on a support platform. The measurements were corrected for effects of gravity. The shoulder rotator muscles were tested at an angular velocity of 90°/s by the concentric contractions of the internal rotator muscles after concentric contractions of the external rotator muscles and by the concentric contractions of the internal rotator muscles after eccentric contractions of the external rotator muscles.

Just before the investigations and between the tests of the muscles concentric–concentric and eccentric–concentric contractions, passive internal–external rotation motions in the shoulder joint were performed during 90 seconds at the angular velocity of 120°/s. The athletes were familiarized with the dynamometers system performing muscles contractions without developing a maximal force. The internal–external rotation movements were repeated five times at the velocity of 90°/s in the concentric contractions of the internal rotator muscles after these contractions of the external rotator muscles and by the concentric contractions of the internal rotator muscles after the eccentric contractions of the external rotator muscles.

The values of peak torque (Nm) of the internal rotator muscles, its angle (degrees), a time from beginning of the internal rotation movement to reach the peak torque (s), and the peak power (W) were obtained from a best repetition (with the greatest peak torque). The average power of the internal rotator muscles was determined from all five repetitions of the shoulder external–internal rotation in concentric contractions of the external and internal rotator muscles and in the concentric contractions of the internal rotator muscles after eccentric contractions of the external rotator muscles.

The test results were compared for the internal rotator muscles of the dominant and non-dominant arms, and between the different shoulder rotator muscles contractions (concentric–concentric and eccentric–concentric) in the same extremity.

The ball throwing speed (m/s) was measured by a special system "Superschus" (EDV-Beratung Arbeiter, Bremen, Germany). Before the throwing test the athletes performed general warming up for 15 minutes. The handball player threw a 0.4 kg ball at a maximal speed six times holding feet (including a front foot) on a floor. A distance between the athlete and the ball speed measuring device was 2.5 m. The speed was recorded with reflected light rays. A best result (highest speed of the ball) was taken into account.

Mean values and standard deviations for the all characteristics were calculated in the muscles concentric contractions and in these contractions of the internal rotator muscles after the eccentric contractions of the external rotator muscles. A dependent *t*-test for paired data groups was employed to determine differences between the parameters of the dominant and non-dominant arms, and the concentric–concentric and eccentric–concentric contractions of the same extremity muscles. The differences were considered to be statistically significant at $p < 0.05$. A correlation analysis was done to determine the relationships between the dynamometry parameters and the ball throwing speed (significance $p < 0.05$).

RESULTS

The significant difference between the measured characteristics of the shoulder internal rotator muscles of the dominant and non-dominant arms is not determined solely in the concentric contractions, $p > 0.05$ (Table 1). The internal rotator muscles peak torque angle in the shoulder range of movements (RoM), the time from beginning of the internal rotation movement to reach the peak torque, the average power and the peak power differ significantly between the dominant and non-dominant arms only in muscles concentric contractions after the eccentric contraction of the external rotator muscles ($p < 0.05$).

Table 1. Average dynamometry characteristics of the dominant and non-dominant arms internal rotator muscles at the angular velocity of movement of 90º/s at the solely concentric contractions (CC) and CC after the eccentric contractions (EC)

Isokinetic dynamometry characteristics (S.D.)	Dominant arm		Non-dominant arm		Significance of difference between dominant and non-dominant arm	
	CC	EC–CC	CC	EC–CC	CC	EC–CC
Peak torque, Nm	39 ± 11	38 ± 10	36 ± 12	36 ± 11	p = 0.08	p = 0.41
	p = 0.09		p = 0.42			
Angle of the peak torque, degrees	48 ± 10	46 ± 11	50 ± 9	56 ± 12	p = 0.50	**p = 0.03**
	p = 0.41		p = 0.18			
Time to reach the peak torque, s	0.41 ±	0.34 ±	0.43 ±	0.49 ±	0.59 ±	**p = 0.01**
	0.15	0.13	0.12	0.15		
	p = 0.07		p = 0.21			
Average power, W	**37 ± 12**	**51 ± 19**	**31 ± 11**	**39 ± 14**	p = 0.10	**p = 0.02**
	p = 0.06		**p = 0.06**			
Peak power, W	**40 ± 15**	**60 ± 20**	36 ± 14	39 ± 17	p = 0.17	**p = 0.03**
	p = 0.01		p = 0.68			

The significant correlations are between the ball throwing speed and the internal rotator muscles peak torque, and the average power in the muscles concentric–concentric and eccentric–concentric contractions (Table 2). After the eccentric contraction of the external rotator muscles the throwing speed additionally correlates with the internal rotator muscles peak power.

The best correlation is between the ball throwing speed and the average power of the internal rotator muscles in concentric contractions after concentric contractions of the external rotator muscles, where r = 0.78 and p = 0.09.

Table 2. Correlation coefficients between the dominant arm's shoulder internal rotator muscles isokinetic dynamometry characteristics at the angular velocity of the movement of 90º/s and the ball maximal throwing speed

Isokinetic dynamometry characteristics	CC	Significance of correlation	EC–CC	Significance of correlation
Peak torque, Nm	**0.76**	**p = 0.02**	**0.77**	**p = 0.01**
Average power, W	**0.78**	**p = 0.09**	**0.62**	**p = 0.02**
Peak power, W	**0.71**	**p = 0.04**	0.41	p = 0.15

DISCUSSION

In the present investigation for the adolescent handball players in the concentric contractions of the shoulder internal and external rotator muscles the significant asymmetry between the dynamometry parameters of the internal rotator muscles of the dominant and non-dominant arms is not detected. The significant difference between the parameters of the internal rotator muscles measured by the isokinetic dynamometry (the angle of the peak torque in the ROM, the time from beginning of the shoulder internal rotation movement to reach the peak torque, the average and peak power) of the dominant and non-dominant arms is determined only in the concentric contractions of the internal rotator muscles after the eccentric contractions of the external rotator muscles ($p < 0.05$). F. W. Jobe et al. (1983) obtained similar shoulder muscles asymmetry in concentric–eccentric muscles contractions in male amateur baseball players. They have detected insufficiency of the shoulder rotator muscles (deltoid, subscapularis, infraspinatus and teres minor) activity in a dynamic electromyography during acceleration stage of the throwing and pitching motions. It can be observed only in the eccentric contractions of the muscles.

Even the fastest isokinetic velocities (450º/s – 500º/s) do not approach the joint angular velocity recorded in actual sporting situations (Malone, T. R. and Garret, W. E., 1996). C. J. Dillman et al. (1993) and S. L. Werner et al. (2001) have determined relationships between an arm throwing kinematics and the shoulder motions of the baseball pitchers using a three dimensional, high-speed video data. S. L. Werner et al. (2001) detected that the shoulder internal rotation velocity mean value is 8286º/s, but according C. J. Dillman et al. (1993) this value is 6940º/s. These velocities are much higher than the angular velocity used in our test (90º/s). We applied the medium angular velocity because it was not easy for the adolescent handball players to tolerate high level of the muscles exertion required in the slow (30º/s – 60º/s) isokinetic exercises. The risk of injury is great also in the eccentric contractions at the high velocities (Cohen, D. B. et al., 1994).

The lack of isokinetic peak torques differences between the dominant and non-dominant arms internal rotator muscles of the athletes performing ball throwing prevailing with one arm in the present and other (Mikesky, A. E. et al., 1995; Wilk, K. E. et al., 1993; Pontaga, I. and Zidens, J., 2004) investigations is determined because the shoulder motions in the tests were not the same like the throwing movement. Throwing is a complex task, which required coordinated motions of the legs, trunk and arms. The shoulder external rotation range produced by the isokinetic dynamometers is small in comparison with the real throwing movement (Dillman, C. J. et al. 1993). From our investigation the peak power of shoulder internal rotator muscles has significantly higher value in the concentric contractions after the eccentric contractions of the external rotator muscles than in solely concentric contractions only for the dominant arm. It can be explained by eccentric shoulder muscles action in performance of different kinds of throws in handball to maintain the shoulder joints stability in the range of movements.

CONCLUSIONS

The significant differences between the dynamometry characteristics of the adolescent elite handball players shoulder internal rotator muscles of the dominant and non-dominant arms (the angle of peak torque in the range of movements, the time from beginning of the shoulder internal rotation movement to reach the peak torque, the average and peak power) are determined in the concentric contractions of the internal rotator muscles after the eccentric contractions of the external rotator muscles ($p < 0.05$). In solely the concentric muscles contractions significant asymmetry is not detected ($p > 0.05$).

The peak power of solely the dominant arm internal rotator muscles in the concentric contractions after the eccentric contraction of the shoulder external rotator muscles has significantly higher value than in the concentric muscles contractions ($p < 0.05$).

The best correlation is determined between the ball throwing speed and the average power of the internal rotator muscles in concentric contractions after concentric contractions of the external rotator muscles, where $r = 0.78$ and $p = 0.09$.

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ADAPTACE SVALŮ RAMENE NA HOD U MLADÝCH HÁZENKÁŘŮ

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SOUHRN

Sportovní specializace s pravidelným opakováním hodů vyvolává zvýšení síly vnitřních rotátorů ramene odhodové paže ve srovnání se svaly paže neodhodové. Cílem šetření je vymezit asymetrii v dynamometrických charakteristikách svalů odhodové a neodhodové paže, zjistit vztah mezi izokinetickými dynamometrickými charakteristikami rotátorů ramene a určit rychlost vystřeleného míče u mladých házenkářů.
Vyšetření charakteristik vnějších a vnitřních rotačních pohybů svalů ramene systémem isokinetického dynamometru se zúčastnilo 14 vybraných mladých házenkářů. Odstředivé a dostředivé svalové kontrakce zjištěné na dynamometrickém systému částečně reprodukují pohyb při házenkářském hodu. Rychlost vystřeleného míče byla měřena metodou odraženého světla.

Rozdíl v charakteristikách dostředivé kontrakce svalů odhodové a neodhodové paže není významný. Maximální i průměrná síla vnitřních rotátorů ramene významně vzrostla po odstředivé kontrakci vnějších rotátorů. Nejvyšší korelace ($r = 0{,}78$, $p = 0{,}09$) byla zjištěna mezi rychlostí vystřeleného míče a průměrnou silou vnitřních rotátorů v dostředivé kontrakci po dostředivé kontrakci vnějších rotátorů.

Klíčová slova: vnitřní rotátory ramene, izokinetická dynamometrie, odstředivá a dostředivá kontrakce, rychlost vystřeleného míče, házená

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