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ABSTRACT

We examined differences in muscle power between the dominant and non-dominant upper limbs of 33 healthy right-handed university baseball players (mean age, 20.4 ± 1.1 years) with an average baseball experience >11 years. After measuring maximal voluntary contraction (MVC) of hand grip, elbow flexion, and shoulder internal rotation in both upper limbs, the muscle power of each joint was measured at 40%, 50%, and 60% MVC. No significant differences were observed in the main factors affecting MVC and elbow flexion power loads between dominant and non-dominant upper limbs. For hand grip power, load factors at 40% MVC in the dominant hand were lower than those at 60% MVC in the same hand and those at 50% and 60% MVC in the non-dominant hand. Significant differences were observed in shoulder internal rotation power between dominant and non-dominant upper limbs, with the dominant limb having greater power at all loads. Correlations between muscle power of both upper limbs for hand grip and elbow flexion were significant and moderately high at all loads. For shoulder internal rotation power, the degree of correlation was significant and moderately high at 40% MVC but low to moderate at 50% and 60% MVC. Baseball players therefore have marked lateral dominance in shoulder internal rotation power unlike hand grip and elbow flexion power, although the relationship between shoulder internal rotation muscle powers of both upper limbs becomes lower with increasing load. The dominance of muscle power of each joint varied even in the same upper limb. It is thus beneficial for baseball players to train with even loads on both arms or adopt simultaneous workout of both arms after adjusting for strength differences.

Keywords: laterality, strength training, prevention injury

INTRODUCTION

Movements of the upper limbs are performed by smooth and mutually coordinated movements at the shoulder, elbow, and wrist joints (7) when reinforcing both arms, such as when exercising using a barbell. Because the upper limbs are often overused in many competitive sports, joint disorders of the shoulders and elbows are common (11, 15, 20, 22) and may progress to serious problems, thereby influencing the future competitive life of athletes; therefore, they cannot be ignored. Joint disorders of the upper limbs, such as baseball elbow (medial epicondylitis) and rotator cuff tears, are common in baseball players because of overuse and pitching with a bad technique, e.g., incorrectly throwing a breaking ball repeatedly (8, 11, 13).

Recently, guidelines for the prevention of joint disorders, particularly in pitchers, have been reported (8, 9, 13). In addition to mastering the correct pitching technique, the guidelines emphasized the necessity to restrict the number of pitches thrown. However, the influence of favoring one side of the body on the differences in muscle power between the upper limbs has not been examined in detail (13, 15). For example, in movements associated with pitching and batting while playing baseball, the upper limbs are not used in a bilateral and symmetrical method, in contrast to swimming; instead, one upper limb is overused. With the exception of players such as switch hitters, almost all players have a dominant upper limb for batting or throwing. During competition, players repeatedly perform one-sided movements that can result in unilateral development of the muscles or range of motion of the upper or lower limb (3, 17, 20). Muscle imbalance in itself can cause joint disorders (22). Indeed, if a player with a muscle imbalance is trained using equal loads on both the left and right sides of the body, it could cause joint disorders because the weaker side may become overloaded. Therefore, training with both arms using a barbell at the same time, e.g., the arm curl, results in equal loading on both arms. However, equal distribution of a load can also cause joint disorders when the difference in muscle power between the upper limbs is very large. In particular, in the case of athletes such as baseball players who tend to use specific parts of their bodies, it is highly possible that the strength difference is also large (21). If the imbalance in muscle power is known beforehand, it may be possible to take suitable measures to prevent subsequent joint disorders. In particular, because pitching and hitting in baseball are asymmetrical motions, there is a high possibility that a strength difference between the upper limbs is large. Therefore, the present study focused on strength differences between the upper limbs and evaluated differences in muscle power of hand grip, elbow flexion, and shoulder internal rotation between the dominant and non-dominant arms of baseball players. In addition, these differences were examined by close isotonic strength exertion to mimic an actual exercise state but not conventional isokinetic or isometric strength. This study aimed to examine differences in muscle power between the dominant and nondominant upper limbs of baseball players, to provide practical applications on how to train the upper limbs more effectively.

METHODS

Experimental approach to the problem

Revealing the differences in muscle power between the upper limbs of baseball players in regard to joints and loads may provide useful knowledge for preventing joint disorders during sports training. In this study, we focused on the upper limbs of baseball players and examined the differences in muscle power between the dominant and non-dominant upper limbs and evaluated the correlations between muscle power of both the upper limbs according to the load and type of joint. To conduct this study, we developed a muscle power measurement device (original model: Takei Scientific Instruments Co., Ltd., Tokyo, Japan).

The study was based on the following hypothesis: baseball players have imbalance in the muscle power of both upper limbs and the relationship between them is low.

Subjects

The subjects comprised 33 healthy male university baseball players (mean age, 20.4 ± 1.1 years; height, 173.4 ± 6.2 cm; weight, 68.7 ± 7.6 kg; baseball experience, 11.2 ± 1.3 years), who performed exercise for 4-h sessions four times per week. They have carried out batting and fielding practices for respective about one hour, and game practice for about two hours a day. In addition to technical practice, individual strength training was conducted 1–3 times per week. The major weight training exercises for the upper body included bench press, arm curl (with barbell), and arm extension (with dumbbell). All the subjects were injury free at the time of testing and were judged to be right handed on the basis of Demura's Handedness Inventory criteria (5, 18, 19). This study was approved by the appropriate institutional review board, and written informed consent was obtained from all the subjects prior to their participation. All the subjects were fully informed of the possible risks and stresses associated with the study, and they provided consent prior to participation.

Procedures

Measurement of muscle strength and power

Muscle power was determined using a muscle power measurement device (original model: Takei Scientific Instruments Co., Ltd., Tokyo, Japan), which was newly developed to measure the muscle power of the upper limbs and the speed at which a subject can pull a movable hand grip attached to a pulley as well as a suspended weight with the upper limb outstretched (Fig. 1). The muscle power of each tested upper limb joint was measured after determining the maximal static strength.

Because this device differs from the conventional isokinetic dynameter or tensionmeter (the device measuring isometric strength) and can measure the muscle power of isotonic muscle action, it is possible to measure muscle power similar to actual exercise and strength training.

********* Fig. 1 here *********

During the power measurement of each muscle, the subjects were instructed not to perform compensatory or recoil-operated motions. The measurements were made with the subjects in the following postures: For the measurement of hand grip power, the subjects placed the palm to a fixed bar and grasped a handle with four fingers with the thumb hooking the bar and then explosively pulled the handle toward the fixed bar. The subjects sat on an adjustable ergometric chair with the arm supported by an armrest and placed in the sagittal plane and positioned horizontally so that the forearm was perpendicular to the hand in a semiprone position. The grip width could be arbitrarily adjusted for each individual using a dial to achieve up to a 90° angle at the proximal interphalangeal joint. For the measurement of elbow flexion power, the subjects sat horizontally in an adjustable ergometric chair and placed the axilla on the edge of the table with the forearm in supination. The subjects then placed the palm on the handle that was connected to a rope attached to a constant load mass and pulled the handle by explosive elbow flexion. For the measurement of shoulder internal rotation power, the subjects sat in an adjustable ergometric chair immediately beside the fixed bar and placed the axilla on the edge of a table with the forearm in a semiprone position and elbow joint flexed at a right angle (Fig. 2).

The subjects performed the maximal voluntary contraction (MVC) test twice before the power test to determine relative loads, and the highest value was used as MVC. MVC was measured using an attached strain gauge meter, and all measurements were made in the same posture.

********* Fig. 2 here *********

According to the procedures of previous studies, the load was selected as 40%, 50%, and 60% of the MVC measurement, and peak power (*W*) was calculated using the following formula (1, 2, 16, 23):

$$Peak\ power\ (W) = peak\ velocity\ (m/s) \times 9.8\ (m/s^2) \times load\ (kg)$$

The muscle power of each joint was measured twice after two practice trials using the dominant and non-dominant upper limbs.

Statistical analyses

Two-way repeated measure analysis of variance (ANOVA; 2 × 3: dominant, non-dominant × loads) was used to determine the mean differences in the average values of muscle power of each joint. When a significant correlation was found, a multiple comparison test was performed using the Tukey's honestly significant difference method. The mean difference was assessed by effect size (ES). The relationships between the muscle power of each joint in both upper limbs at each load were examined using Pearson's correlation coefficient. We classified correlations as follows: high (±0.80–1.0), moderately high (±0.60–0.79), moderate (±0.40–0.59), and low (±0.20–0.39). Statistical significance (α) was set at a P-value <0.05.

RESULTS

Table 1 includes the means and standard deviations of the muscle power of each joint in the dominant and non-dominant upper limbs at each load, the results of the two-way ANOVA (dominant, non-dominant × loads), and ES values. As shown, there were no significant differences in the main factors between the dominant and non-dominant upper limbs and loads for elbow flexion power. However, a significant difference in relative load factors for hand grip power was observed, with 40% MVC being lower than 60% MVC in the dominant hand and lower than 50% and 60% MVC in the non-dominant hand (ES = 0.30–0.48). Shoulder internal rotation power showed a significant difference between the dominant and non-dominant upper limbs, with power in the dominant upper limb being greater at all the loads (ES = 0.57–0.66).

********* Table 1 here *********

Table 2 shows the correlation between the power of each joint in each upper limb at each load. Correlations for hand grip and elbow flexion powers were moderately high or high and significant at all the loads ($r > 0.77$). Correlations for shoulder internal rotation power were significant and moderately high ($r = 0.79$) at 40% MVC but low or moderate ($r = 0.36$–0.51) at 50% and 60% MVC.

********* Table 2 here *********

DISCUSSION

Significant differences in hand grip power were observed between loads, with power at 40%

MVC being lower than that at 50% or 60% MVC. However, the differences were not large (ES = 0.30 and 0.48, respectively). In addition, no significant differences in power were observed between the dominant and non-dominant upper limbs for both hand grip and elbow flexion power at all the loads.

The proximal interphalangeal joint (PIP), metacarpophalangeal joint (MP), and elbow joint, unlike the glenohumeral joint, are structured to move in only the direction of flexion; therefore, their motion is relatively simple and stable. Moreover, in addition to the practice of baseball, the non-dominant arm is also frequently used to grab and hold heavy things in daily life. Therefore, even in baseball players, who principally use the dominant upper limb, our study results showed no marked bilateral differences in the power measurements of the hand grip and elbow flexion tests. In addition, there were no differences in the power measurements at any load. Bilaterally symmetrical muscle training using elbow flexion (e.g., arm curls) is often performed using both upper limbs simultaneously using a barbell. In the present study, the correlation between the muscle power of both upper limbs was high because no significant differences were found between the upper limbs. Hence, the possibility of a disorder developing in the elbow joints and the hand during strength training using both the upper limbs simultaneously may be lower. However, athletes may be unaware of this possibility.

Throwing and batting are very important skills in the sport of baseball, and the glenohumeral joint of the dominant upper limb is recurrently used in these actions. Various muscle groups, ranging in size from small to large, are attached to the glenohumeral joints (6). In addition, because the glenoid cavity is shallow with a spherical humeral head, the glenohumeral joint is movable in various directions. For these movements, rotator cuff function is particularly important, and it is possible to elevate and rotate the upper limbs smoothly because of the well-balanced functionality (muscle action) of the rotator cuff muscles (20). The internal rotation power exertion of the glenohumeral joint of the dominant upper limb is important for batting during the period between the end cocking stage and the accelerated stage of wind-up motion (6-8). In addition, the muscle strength for these movements is related to pitching speed (4, 12). On the other hand, the non-dominant shoulder seldom performs glenohumeral joint rotation internally during catching and batting movements and does not exert large muscle power during the pitching motion. In short, our results showed that unilateral dominance of an upper limb in pitching affects the laterality of shoulder internal rotation power. When these changes accumulate over a period of time, smooth movement of the glenohumeral joint becomes limited, potentially leading to future joint disorders. Such an imbalance in strength between arms is characteristic of unilateraldominant athletes. However, maintenance of imbalanced strength and muscle tone between the upper limbs has been reportedly correlated to glenohumeral joint disorders (14, 22). Therefore, appropriate strength training is important to ameliorate strength differences between opposing limbs.

In the present study, we showed a moderately high relationship between the shoulder internal rotation powers of the bilateral shoulders at small loads (40% MVC) (r = 0.79). Similar results were observed for hand grip and elbow flexion powers, although the relationship became less pronounced with increasing load. In short, performance training to enhance shoulder internal rotation power should avoid exercises that forcibly impose the same loads on the bilateral arms with a large strength difference. In particular, while training with loads over 50% MVC, when setting a load based on the stronger arm (the shoulder of the dominant side), the arm would be under an excessive load imposed by the opposite arm; therefore, injury may occur.

PRACTICAL APPLICATIONS

Differences in upper limb muscle power

The imbalance in shoulder internal rotation power between the upper limbs in baseball players, unlike the muscle power of the hand grip and elbow flexion tests, was marked, with the shoulder internal rotation power of the dominant upper limb being greater. In addition, the relationship between the muscle power of the upper limbs tended to differ with load. In short, even in the same upper limb, the muscle power varies across joints. For baseball players with large differences in muscle development between the upper limbs, muscle development training for shoulder internal rotation power with large loads or physical training may increase the risk of glenohumeral joint disorders. Therefore, baseball players and strength/conditioning coaches should consider the above findings when preparing a training plan to prevent glenohumeral joint disorders. In conclusion, it would be desirable for players with a large imbalance in shoulder internal rotation power between arms to adopt a training program to reverse the capability differences. For instance, dumbbell or tube training with light loads could be used to increase the strength of the weaker side subscapular muscles and would help prevent joint damage.

References

1. Aoki, H and Demura, S. Characteristics and lateral dominance of hand grip and elbow flexion powers in young male adults. *J Physiol Anthropol* 27(4): 201-206, 2008.
2. Baker, D, Nance, S and Moore, M. The load that maximizes the average mechanical power output during jump squats in power-trained athletes. *J Strength Cond Res* 15(1), 92-97, 2001.
3. Baltaci G, Johnson R, and Kohl H 3rd. Shoulder range of motion characteristics in collegiate baseball players. *J Sports Med Phys Fitness* 41(2), 236-42, 2001.
4. Bartlett, RL, Storey, DM and Simons, DB. Measurement of upper extremity torque production and its relationship to throwing speed in the competitive athlete. *Am J Sports Med* 17(1), 89-91, 1989.
5. Demura, S, Tada, N, Matsuzawa, J, Mikami, H, Ohuchi, T, and Shirane, H. The influence of gender, athletic events, and athletic experience on the subjective dominant hand and the determination of the dominant hand based on the laterality quotient (LQ) and the validity of the LQ. *J Physiol Anthropol* 25, 321-329, 2006.
6. Escamilla, FR and Andrews, RJ. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Med* 39(7), 569-590, 2009.
7. Escamilla, FR, Fleisig, SG, Barrentine, WS, Zheng, N, and Andrews, RJ. Kinematic comparisons of throwing different types of baseball pitches. *J Appl Biomech* 14: 1-23, 1998.
8. Fleisig GS, Andrews JR, Dillman CJ, and Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med* 23(2):233-239. 1995
9. Fleisig GS, Barrentine SW, Escamilla RF, and Andrews JR. Biomechanics of overhand

throwing with implications for injuries. *Sports Med* 21(6): 421-437, 1996

10. Fleisig, GS, Escamilla, FR, Andrews, RJ, Matsuo, T, Satterwhite, Y, and Barrentine, WS. Kinematic and kinetic comparison between baseball pitching and football passing. *J Appl Biomech* 12: 207-224, 1996.

11. Frostick, SP, Mohammad, M, and Ritchie, DA. Sport injuries of the elbow. *Br J Sports Med* 33(5): 301-311, 1999.

12. Katsumata, Y, Hasegawa, S, Kawakami, Y, and Fukunaga, T. The relationship between ball velocity and muscle strength and muscle volume of baseball pitchers. *Sports Sci Res* 3: 1-7, 2006.

13. Kerut, EK, Kerut, DG, Fleisig, GS, and Andrews, JR. Prevention of arm injury in youth baseball pitchers. *J La State Med Soc* 160(2): 95-98, 2008.

14. Kugler, A, Krüger-Franke, M, Reininger, S, Trouillier, HH, and Rosemeyer, B. Muscular imbalance and shoulder pain in volleyball attackers. *Br J Sports Med* 30(3):256-259, 1996.

15. Lyman S, Fleisig GS, Waterbor JW, Funkhouser EM, Pulley L, Andrews JR, Osinski ED, and Roseman JM. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. *Med Sci Sports Exerc* 33(11): 1803-1810, 2001.

16. Miyaguchi K and Demura S. Muscle power output properties using the stretch-shortening cycle of the upper limb and their relationships with a one-repetition maximum bench press. *J Physiol Anthropol* 25(3): 239-245, 2006.

17. Mulligan IJ, Biddington WB, Barnhart BD, and Ellenbecker TS. Isokinetic profile of shoulder internal and external rotators of high school aged baseball pitchers. *J Strength Cond Res* 18(4): 861-866, 2004.

18. Noguchi, T, Demura, S and Aoki, H. Superiority of the dominant and nondominant hands

in static strength and controlled force exertion. *Percept Mot Skills* 109(2): 339-346, 2009.

19. Noguchi, T, Demura, S, Nagasawa, Y, and Kitabayashi, T. Influence of measurement order by dominant and nondominant hands on performance of a pursuit-rotor task. *Percept Mot Skills* 108(3): 905-14, 2009.

20. Phil P. Shoulder muscle imbalance and subacromial impingement syndrome in overhead athletes. *Int J Sports Phys Ther* 6(1): 51-58, 2011.

21. Shanley, E, Rauh, JM, Michener, AL, Ellenbecker, ST, Garrison, CJ, and Thiqpen, AC. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *Am J Sports Med* 39(9): 1997-2006, 2011.

22. Wang HK, Cochrane T. Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. *J Sports Med Phys Fitness* 41(3): 403-410, 2001.

23. Yamaji S, Demura S, Aoki H, and Yamamoto K. Changes in elbow flexor power with intermittent contractions and various loads. *Percept Mot Skills* 107(2): 597-606, 2008.

Differences in upper limb muscle power

Table 1. Two-way ANOVA (dominant・nondominant × loads)

		dominant		nondominant			Two-way ANOVA		Tukey's HSD	effect size	
		Mean	SD	Mean	SD		F-value	*p* -value			
handgrip	40% MVC	52.4	9.68	51.5	9.19	F1	1.42	0.24		D:40%<60%	0.48
	50% MVC	55.2	11.53	55.0	13.94	F2	6.12 *	0.00	D : 40%＜60% N : 40%＜50%, 60%	N:40%<50%	0.30
	60% MVC	57.5	11.82	55.1	13.58	IN	0.92	0.40		N:40%<60%	0.31
elbow	40% MVC	97.2	20.39	93.7	18.96	F1	2.56	0.12			
flexion	50% MVC	98.3	21.22	95.9	18.69	F2	0.77	0.47			
	60% MVC	96.4	19.67	95.4	18.59	IN	1.10	0.34			
shoulder	40% MVC	69.8	19.66	58.9	15.46	F1	18.52 *	0.00		40%:D>N	0.61
internal	50% MVC	68.3	20.71	57.5	17.01	F2	2.13	0.13	40%, 50%, 60% : D>N	50%:D>N	0.57
rotation	60% MVC	67.7	22.14	54.4	17.59	IN	0.43	0.66		60%:D>N	0.66

* : $p < 0.05$、D: dominant, N: nondominant
F1: dominant・nondominant F2:load IN: interaction

Table 2. Correlations between the dominant and nondominant limbs powers.

N=33	Handgrip		*p*	Elbow flexion		*p*	Shoulder internal rotation		*p*
40% MVC	0.85	*	0.00	0.86	*	0.00	0.79	*	0.00
50% MVC	0.77	*	0.00	0.87	*	0.00	0.51	*	0.01
60% MVC	0.78	*	0.00	0.88	*	0.00	0.36	*	0.04

*: $p<0.05$

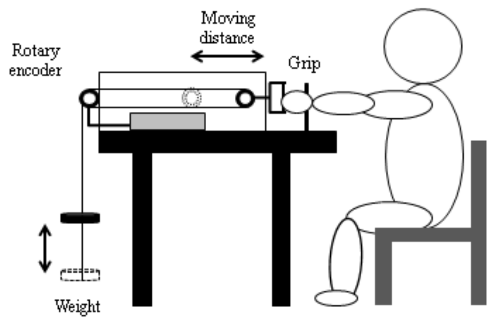

Fig.1 The muscle power measurement device

Fig. 2 Measurement procedures

(From left; handgrip, elbow flexion, and shoulder internal rotation)