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SUBACROMIAL IMPINGEMENT IN FRONT-CRAWL SWIMMING: A PRELIMINARY REPORT

Tanghuizi Du [1], Toshimasa Yanai[2]

[1]Graduate School of Sport Sciences, Waseda University, Tokorozawa, Japan
[2]Faculty of Sport Sciences, Waseda University, Tokorozawa, Japan

The purposes of the present study were to measure the glenohumeral joint motion exhibited during front-crawl swimming and to re-examine the instances at which the subacromial structures were experiencing impingement. A series of glenohumeral configurations indicative the impingement were measured to define the so called "boundary range of motion," which was used to identify if the glenohumeral configurations exhibited at any instant during swimming is indicative of impingement. A simplified kinematic model composed of right scapula, right humerus and thorax was used to describe the shoulder configuration for three collegiate swimmers. The results showed that impingement occurred for 0~ 12% of the stroke time during the front-crawl for the three subjects.

KEY WORDS: shoulder pain, glenohumeral joint, electromagnetic tracking device.

INTRODUCTION: Shoulder pain is the most common problem in competitive swimming. Etiological studies reported that over 47% of competitive swimmers complained of shoulder pain in their swimming career (McMaster and Troup, 1993) and that front-crawl and butterfly swimmers were most susceptible to shoulder pain (Abgarov et al., 2012). The impingement syndrome is a widely recognized shoulder pathology that describes the shoulder pain experienced by the swimmers.

Impingement syndrome is a pathological condition of shoulders introduced by an orthopedic surgeon, Neer (1972). Neer explained a cause of the impingement syndrome as the consequence of repeated impingement of the subacromial structures under the coraco-acromial arch that would occur in the course of normal arm elevation.

The impingement of subacromial structures occurs due to (a) a forcible arm elevation beyond the normal range and (b) the arm elevation above the shoulder height with the arm rotated internally. These shoulder motions indicative of impingement were observed during swimming in a previous study. Yanai and Hay (2000) analyzed the shoulder motions of the members of collegiate men's swim team and found that the shoulder motions indicative of impingement were observed at arm entry into the water, in the first half of the pull phase and in the middle of the recovery phase during front-crawl. The incidence of impingement which defined as the total time over which the swimmer exhibited the shoulder motion indicative of impingement was, on average, 24.8% of the stroke time. This study measured the shoulder motion as the movement of the upper arm relative to the torso which may not represent the glenohumeral joint motion accurately. The obtained results may be contaminated by some sort of systematic error, particularly because the impingement occurs at the glenohumeral joint. The results on instances of impingement during swimming should, therefore, be re-examined.

The purpose of the present study was to measure the glenohumeral joint motion exhibited during front-crawl swimming and to re-examine the instances at which the subacromial structures were experiencing impingement.

METHODS:

The subacromial impingement is known to occur if the arm is elevated above the shoulder height with the arm internally rotated or if the arm is elevated forcedly beyond the normal range. A series of glenohumeral configurations that satisfied these criteria were measured for each subject to define the so called "boundary range of motion," which was used to identify if the glenohumeral configurations exhibited at every given instant during swimming was indicative of impingement.

Three members of men's collegiate swimming team participated in this study (height: 1.77 ± 0.02 m; mass: 68 ± 2.6 kg). A simplified kinematic model composed of right scapula, right humerus and thorax was used to describe the configurations of shoulder structures. An electromagnetic tracking device (LIBERTY; POLHEMUS, VT; USA) was used to record the movements of the three segments by determining the position and the orientation of each sensor relative to the transmitter. Three waterproofed sensors were attached to the skin upon the sternum, the flat area of right acromion and on a plastic cuff that wrapped rounded the right humerus. Three sequential Euler angles, representing horizontal adduction (HA), elevation (EL), and internal rotation (IR), were used to express the glenohumeral joint configuration and the configuration of the humerus relative to the thorax exhibited in the measurement.

After a stretching warm up, each subject underwent two test sessions; a boundary range of motion measurement and a front-crawl motion measurement. In the boundary ROM measurement, each subject was asked to elevate the arm upwards and downwards slowly in several vertical planes with the humerus maximally internal rotated. In the front-crawl trial, the subject performed a "resisted-swimming" for which the swimmer was restrained by a rubber tube so as to stay near the transmitter throughout the trial.

The determined series of IR angles in the boundary ROM measurement were expressed as a function of HA and EL angles. This function was smoothed and interpolated using a cubic function to determine the boundary ROM (the maximum IR angle) for any given combination of EL and HA angles for each subject. The shoulder configuration observed at every given instant during the swimming trial was compared with the individual boundary ROM and if it was equal to or exceeded the boundary ROM, the shoulder was considered impinged. The period over which shoulder was impinged was divided by the stroke time, expressed as a percentage, to represent "incidence of impingement (%ST)" for the subject.

The validity of the measurement procedure for defining the boundary ROM was tested by comparing the maximal IR angles measured with several protocols used for clinical tests with the corresponding values determined from the boundary ROM. The result was 6.6 degree of RMSE. The trial-to-trial reliability and the day-to-day reliability of the measurements of the glenohumeral joint motion were tested in a preliminary study and found that the rout-mean-square error was less than 3.5°.

RESULTS AND DISCUSSION:

The mean value across the subjects for the incidence of impingement was 7.9 ± 6.9% of the stroke time, indicating that, on average, swimmer's glenohumeral joint impinged the subacromial structures for about 8% of the stroke time. The incidence of impingement was 12.1%ST for Subject A, and impingement was observed at and around the arm entry into water, the catch phase and the second half of recovery phase. For Subject B, the incidence of impingement was 11.7%ST (Fig. 1), and impingement was observed at and around the arm entry into water. For subject C, impingement was not observed at all.

In comparison with the previous study (Yanai and Hay, 2000) that reported 24.8% of the stroke time for the incidence of impingement, the present values found from the three subjects were somewhat smaller. One possible reason for the difference might be attributable to the modelling of the shoulder joint; the previous study analysed the motion of humerus relative to torso whereas our study isolated the motion at the glenohumeral joint. We calculated the configurations of humerus relative to the thorax in both swimming and the boundary ROM trials, and determined the period over which the humeral configurations relative to the thorax exhibited during front-crawl trial exceeded the humeral configurations relative to the thorax determined with the boundary ROM measurements (the result of which is the incidence of impingement if the scapulo-humeral rhythm is constant between swimming and boundary ROM trials). The newly determined values were greater than the incidence of impingement for all subjects (Table 1). The mean value across the subjects was 22.2% of the stroke time, which was similar to the incidence of impingement reported by Yanai and Hay (2000). These results indicate that (a) the scapula moved differently between swimming and boundary ROM trials, so that even for the given configurations of humerus relative to the torso, the corresponding glenohumeral configurations were not identical between swimming and boundary ROM trials, (b) the scapula-humeral rhythm was altered in swimming trials and the impingement of subacromial structures that would have occurred without the alteration of the scapula-humeral rhythm was avoided in some part of the stroke cycle, and (c) a use of the humerus-thorax model for identifying impingement may overestimate the incidence of impingement in front-crawl.

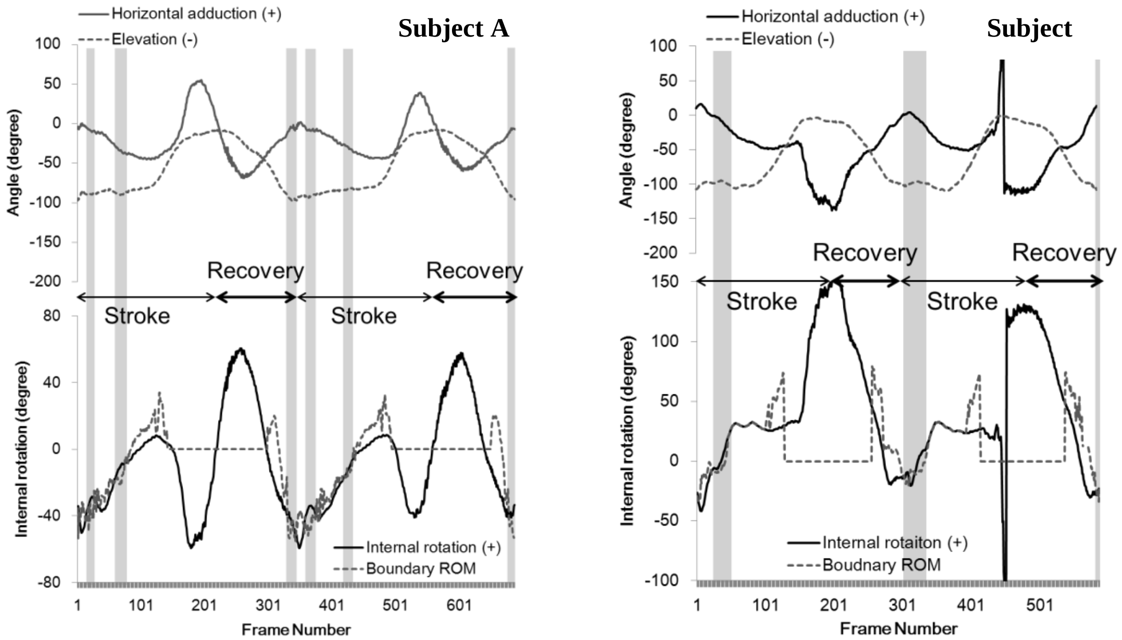

Figure 1: Glenohumeral configurations exhibited during front-crawl and the instances at which impingement occurred for subjects A and B. The gray vertical bands indicate the instances at which impingement occurred.

Table 1: Incidence of impingement determined by shoulder configurations (%ST)

Subject	Incidence of impingement	Newly determined value with humerus-thorax model
A	12.1	24.1
B	11.7	20
C	0	22.5
Mean	7.9	22.2

The scapular movement in swimming can be described by comparing with the configurations of humerus relative to thorax (shorten in H-Th configuration) with the corresponding glenohumeral configurations (Fig. 2). For the subject in Fig.2, the maximum EL angle of the glenohumeral joint was smaller by 50 degrees than the maximum humeral H-Th EL angle. It indicated the scapula rotated in the upward direction when the arm was elevated. The HA angle of H-Th configuration was greater than 0 degree for most of the stroke time, indicating that the humerus was located in front of the frontal plane of the torso for most of the stroke time. The HA angle in the glenohumeral joint, however, was smaller than 0 degree for most of the stroke time. This difference is attributable to the scapular external rotation. The differences between the IR angle of the glenohumeral joint and the corresponding IR angle of the H-Th configuration is attributable to the scapular posterior/ anterior tilt. These results indicate that the scapula moves during front-crawl to reduce the EL and HA angles of the glenohumeral joint. In Figure 2, we can see that the subject avoid the impingement in the catch phase by maintain a large EL angle and reduce the HA angle of glenohumeral joint. It indicates the scapular rotated in downward and internally to prevent the subject from impingement, suggesting that the mobility of scapula might be a key factor to prevent the impingement in front-crawl swimming.

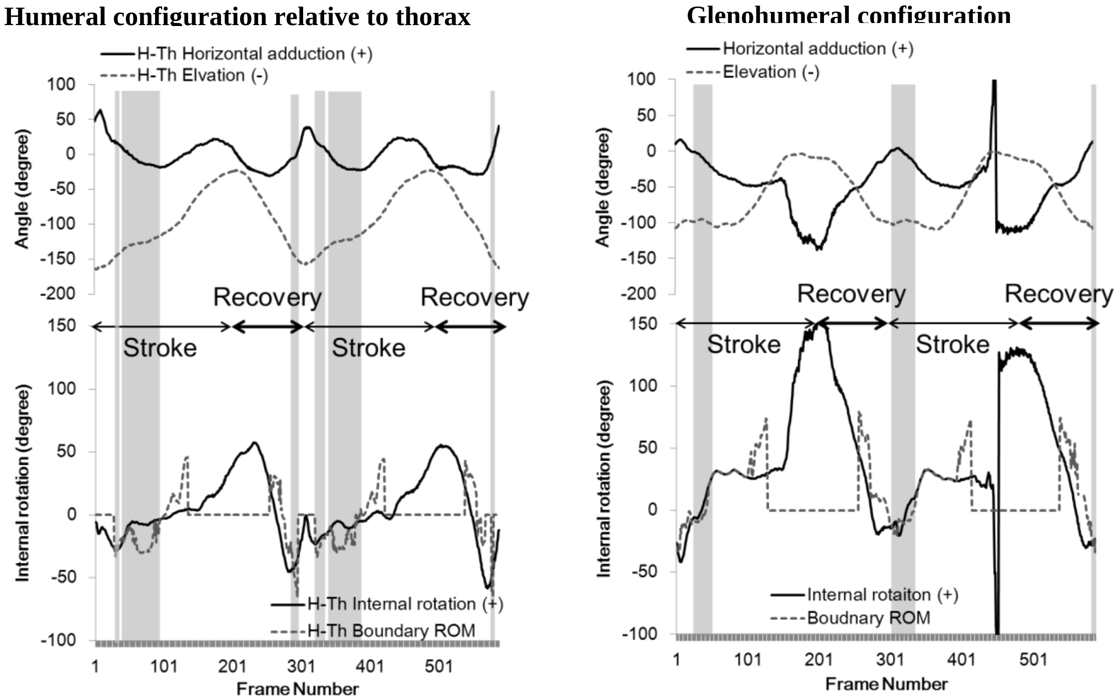

Figure 2: Humeral configuration raltive to thorax (left) and glenohumeral configuration (right) of a subject for two stroke cycles. The gray vertical bands indicate the instances at which the shoulder configurations exhibited in swimming exceeded the range determined with the boundary ROM measuremets.

CONCLUSION: The findings of this study support the following conclusions:

1. Incidences of impingement in front-crawl swimming for three subjects were 12.1%, 11.7% and 0% of stroke time.
2. Impingement was re-confirmed to occur at and around the arm entry into water, the catch phase and the second half of the recovery phase of front-crawl swimming.
3. The scapula moved differently between swimming and boundary ROM trials so that impingement of subacromial structures could be avoided in some phases of front-crawl.
4. Increasing the mobility of scapula might be a key factor for preventing the subacromial impingement in front-crawl.

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