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研究課題名（和文）An innovate approach for altering the stroke technique to protect swimmer's shoulder

研究課題名（英文）An innovate approach for altering the stroke technique to protect swimmer's shoulder

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研究成果の概要（和文）：本研究は、肩甲上腕関節の運動を制限することにより肩にストレスの掛かる動作を回避しつつも、水泳フォーム、とりわけ腕によるプル動作やリカバリー動作を変化させることなく遊泳するための合理的な手法を提案するものである。大学水泳部に所属する選手25人の肩（体幹に対する上腕）運動、肩甲上腕関節運動と肩甲骨運動を記録・分析した。1ストローク周期の8%、肩甲上腕関節がストレスを生じるリスクが高い肢位になったことをクロール泳に観察された。このような肩甲上腕動作を制限し、関節にストレスの掛かる動作を回避しつつも、腕の泳動作が変化させないため、肩甲骨の内転、上方回旋、前方傾斜が必要とすることが明らかになった。

研究成果の概要（英文）：The purpose of the study was to develop an innovative approach for altering stroke technique which does protect the glenohumeral joint from abnormal stress without requiring any changes in the stroking action. Arm-torso motion, glenohumeral motion (scapulo-humeral motion) and scapular motion were measured for 25 swimmers. Twenty-four swimmers were found to exhibited the glenohumeral motion indicative of abnormal stress in the joint during front-crawl swimming with a duration of about 8% of the time spent in a stroke cycle. Increasing scapular external rotation and upward rotation in the second half of recovery phase and scapular anterior tilt and upward rotation in the hand entry phase is an approach for swimmers to avoid the risky glenohumeral motion without requiring any changes in the stroking action. These scapular motion results a decrease of glenohumeral elevation and internal rotation angle and therefore may enlarge the subacromial space to relive the abnormal stress.

研究分野：　スポーツ科学

キーワード：　水泳　バイオメカニクス　肩

１．研究開始当初の背景

As overuse injuries and pain becoming a common problem affected people's daily life, we need to consider how to diagnose and treat the injuries as well as how to prevent the injuries. In competitive swimming, overuse shoulder injuries is the most common problem with an estimated prevalence ranging from 30% to 70% over a typical career (Mountjoy et al., 2010). The clinical diagnosis of the swimmer's shoulder conditions was commonly the pathology on the surrounding structures of the glenohumeral joint (Gaunt et al., 2012). Since the mechanism of the pathology on glenohumeral joint during swimming has not been fully understood, prevention of the shoulder injuries is still a difficult problem to swimmers and coaches at present.

Swimmers, when injured, usually experience severe difficulty in returning to the former competitive level as they may be forced to alter their stroke action to avoid re-injury. Alteration of the current stroke action to reduce shoulder pain and/or to protect affected sites causes undesired results since the current stroke action have been developed and familiarized over many years of training. Any tiny alteration of the stroke action may require competitive swimmers to spend a lot of time in training again to familiarize with it. Therefore, an innovative approach for altering the stroke technique (a) which does not require any changes in the stroking action but (b) which does protect affected sites of the glenohumeral joint was an urgent demand for swimmers.

Shoulder is a complex structure. The apparent shoulder movement (arm-torso motion) represents the glenohumeral joint motion (the configuration of humerus relative to scapula) and the scapular motion (the motion scapula relative to torso). Generally, the glenohumeral joint and the arm-torso motion are known to be in a set ratio (the so-called scapulohumeral rhythm) specific to each individual (Inman & Abbott, 1996). However, this ratio could be adjusted by stretching and strengthen training (Wang et al., 1999; Lynch et al., 2010). It is possible to alter the glenohumeral joint motion and scapular motion for a given arm-torso motion during swimming. In our previous study (Du & Yanai, 2013), different glenohumeral configurations were observed for a given arm-torso configuration. Therefore, modifying the glenohumeral joint and scapular motion for a given arm-torso motion would be an approach to avoid the harmful glenohumeral joint motions which develop the risk of shoulder pathologies during swimming.

Generally, from the biomechanics point of view, the injury on a joint is induced by the abnormal stress on the tissues and structures of the joint occurred suddenly or repeated over time. Anatomical evidences reported in literature indicated that several glenohumeral joint configurations around or beyond the limit of its range of motion develop the abnormal stress to the structures of glenohumeral joint, such as moving the arm forcibly to the maximal elevation angle or internal rotating the arm to the limited range (Yanai et al., 2006; Yamamoto et al., 2009; Giphart et al., 2012). These glenohumeral configurations were observed during swimming for various stroke phases (Yanai & Hay, 2000; Du & Yanai, 2013). With these movement repeated thousands times during the training of competitive swimming, small trauma due to the abnormal stress developed at any phase of the stroke cycle would predispose to develop shoulder injuries. Although not all the glenohumeral joint motion beyond its range of motion was confirmed to induce the abnormal stress to the joint, using the glenohumeral joint configurations within its range of motion during swimming would be an approach to protect affected sites of the glenohumeral joint.

２．研究の目的

The purpose of the study was to develop an innovative approach for altering stroke technique which does protect the glenohumeral joint without requiring any changes in the stroking action.

３．研究の方法

Twenty-five members (11 males and 14 females) of collegiate swimming team were recruited in the study. The shoulder was modelled as a thorax, scapulae and humerus. An electromagnetic tracking device was used to record the three-dimensional position and orientation of these segment at 240Hz. Sensors were attached on the sternum, acromion and humerus of both sides of shoulder. Joint motions were calculated as the relative orientation of segments expressing by three Euler/Cardan angles for each joint.

After a stretch warm-up, each swimmer

was asked to take two measurements; (a) a measurement for determining the boundary of range of motion (boundary ROM) which suggests abnormal stress on glenohumeral joint and (b) a measurement of shoulder motion in front crawl swimming. In the boundary ROM measurement, each subject was asked to elevate the arm with the humerus maximally internal rotated in a series of arm position throughout the shoulder functional range of motion. In the swimming measurement, swimmers were asked to perform a 25m front-crawl swimming and a stroke style they majored in with their maximal effort.

The glenohumeral joint motion exhibited in swimming for the every given instant was compared with the boundary ROM to determine if the movement is under the risk of developing stress in joint. The glenohumeral joint motion exhibited during swimming within its boundary ROM was considered as the safe and feasible motion. If for any given instant the glenohumeral joint moved beyond its boundary ROM, an optimal glenohumeral joint motion which is within the range of motion and best fits to the overall movement patterns of the joint during swimming was calculated for that instant. In details, the boundary ROM was plot as a surface graph of the maximal gleno-humeral internal rotation angle for every given combination of elevation and horizontal abduction angle throughout the functional range of each individual. The optimal glenohumeral configuration was calculated as the data on the surface of boundary ROM which had the shortest distance from the original data observed in swimming. The scapular motion for achieve the optimal glenohumeral motion while maintaining the arm-torso motion during swimming was calculated. The calculated the scapular motion was compared with the original scapular motion observed in swimming to determine the approach for altering stroke technique which does protect the glenohumeral joint without requiring any changes in the stroking action. This result was feedback to each swimmer and the common pattern of modified scapular motion was summarized to determine the stroke technique for protecting swimmer's shoulder.

４．研究成果

The main outcome of the present study were (a) a safe and feasible glenohumeral joint motion during swimming was determined for each competitive swimmer and (b) the scapular motion to achieve such glenohumeral joint motion without requiring any changes in the stroking action was determined.

The phase and duration which glenohumeral joint was under the risk of developing abnormal stress on shoulder during stroke cycles were determined. Ten out of 11 male swimmers and all female swimmers exhibited risky glenohumeral motions during front-crawl swimming. These risky glenohumeral motion mainly occurred in the hand entry phase and the second half of arm recovery phase which arm was high elevated and rotated internally. On average, male swimmers exhibited the glenohumeral joint motions indicative of abnormal stress for 6.2±6.6% of the time spent in one stroke cycles and female swimmers for 9.7±7.3% of the stroke time during front-crawl swimming. No statistic significant difference was fount between male and female swimmers as well as the right and left side of shoulders for the duration of risky motion. The duration of risky glenohumeral motion in other stroke styles were 6.4 ± 5.7% for butterfly stroke, 11 ± 9.6% for breaststroke and 8.9 ± 7.7% for backstroke swimming.

For those phases which glenohumeral joint motion indicative of abnormal stress were found, an optimal glenohumeral joint motion and corresponding scapular motion to achieve the safe and feasible shoulder motion was determined and advised to each swimmer. An overall result of front-crawl swimming in male swimmers was presented here. During swimming phase when arm elevated high and internal rotated excessively, the scapular external rotation, upward rotation and anterior tilt were found to be an approach for achieving a safe and feasible glenohumeral joint motion without altering the stroke actions. In details, during the hand entry phase, a scapular upward rotation and anterior tilt would help swimmers to achieve a safe and feasible shoulder motion. During the second half of recovery phase, a scapular external rotation and upward rotation would help swimmers to avoid the risk of stressful glenohumeral joint motion. These scapular motion results a decrease of glenohumeral elevation and internal rotation angle and therefore may enlarge the subacromial space and relieve the stress in joint when the humerus high

elevated and internal rotated (figure1).

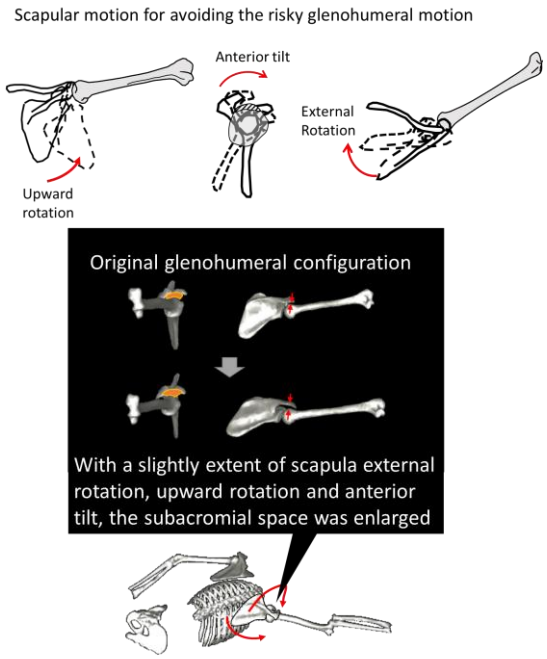

Figure 1, Scapular motion for avoiding the risky glenohumeral motion in swimming

Muscles as serratus anterior, trapezius, pectoralis minor and rhomboids are theoretically contribute to these scapular motion based on the anatomical literature. To determine how these muscles affect scapular motion in swimming, we tried to develop a new methodology for measuring the muscle activities and scapular motion simultaneously. Since no such study was conducted yet, the feasibility and the accuracy of the method should be tested firstly. We focused on four agonist muscles around scapular; the superior, middle, inferior fiber of trapezius and serratus anterior. An order made waterproofed surface electromyography system was used to measure the muscle activities. An electromagnetic tracking device was used to determine the shoulder kinematics simultaneously. The method worked well on dry land, however, cross-talk between the two devices occurred during the underwater measurement. We will modified the method to fit for the underwater measurement in future, for example, by applying a new wireless electromyography system.

In summary, we developed a methodology for determining the stroke technique which does protect the glenohumeral joint without requiring any changes in the stroking action for swimmers. In front-crawl swimming, scapular external rotation and upward rotation in the second half of recovery phase and scapular anterior tilt and upward rotation in the hand entry phase may help swimmers to avoid stressful glenohumeral joint motion. The outcome of this study will make a suggestion for supporting injured swimmers to return to the former competitive level safely. The notion of the study may also be used to protect the shoulder in other overhead sports activities.

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５．主な発表論文等

〔雑誌論文〕（計　１件）

Tanghuizi DU, Toshimasa YANAI. 3D scapular kinematics and scapulohumeral rhythm in swimmers and baseball pitchers. *ISBS-Conference Proceedings Archive* Peer-reviewed. Vol. 36, 2018. (Accepted, in press)

〔学会発表〕（計　2 件）
①Tanghuizi　DU. 3D scapular kinematics and scapulohumeral rhythm in swimmers and baseball pitchers. *36th International Conference on Biomechanics in Sports* (2018.9 発表予定)

②杜　唐慧子. クロール泳に適応した肩甲上腕リズムの検討. 日本体育学会第 68 回大会. 2017

〔図書〕（計　0 件）

〔産業財産権〕

○出願状況（計　0 件）

○取得状況（計　0 件）

〔その他〕
ホームページ等

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