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ORIGINAL ARTICLE

Influence of Brassiere Wearing on Shoulder Kinematics

Takashi Nagamatsu, RPT, MS [a, b] Yoshihiro Kai, RPT, PhD [c] Masafumi Gotoh, MD, PhD [d] Kazuya Madokoro, RPT, PhD [e] Takaki Imai, RPT, MS [b] Junichi Kawakami, RPT, MS [b] and Naoto Shiba, MD, PhD [f]

Objective: Gender differences in scapular kinematics during arm elevation have been reported. Because women wear brassieres (bras) daily, their scapular motion may be restricted by the garment; however, the influence of bra wearing on this motion has not been reported. Therefore, using a three-dimensional electromagnetic tracking device, we investigated the influence of bra wearing on shoulder kinematics during arm elevation. **Methods:** The subjects were 19 healthy women, and the shoulder on the dominant side was evaluated. Subjects performed scapular plane arm elevation while wearing or not wearing bras. Kinematic data were recorded using an electromagnetic tracking device. The glenohumeral elevation angle, scapular upward and internal rotation angles, and the posterior tilt angle were determined from the recorded data. The angles were calculated at 20°–120° arm elevation, and the data were compared between the two conditions. **Results:** The scapular upward and internal rotation angles and the posterior tilt angle were significantly smaller with the subjects wearing bras than not wearing bras. In contrast, the glenohumeral elevation angle was significantly greater when bras were warn. **Conclusions:** Bra wearing may influence shoulder kinematics. Consequently, great care should be taken to account for this factor during the evaluation of kinematics in female subjects.

Key words: arm elevation; brassiere; electromagnetic tracking device; shoulder kinematics

INTRODUCTION

Three-dimensional shoulder kinematic analysis of patients with shoulder disease is frequently performed, and the kinematic characteristics of subjects have been reported.[1–5] These studies typically involve various comparisons, such as between dominant and non-dominant sides,[6,7] unilateral and bilateral elevation,[8] active and passive elevation,[9,10] and elevation speed and external load.[11–13]

In studies involving healthy subjects, a gender difference in scapular motion during arm elevation has been reported.[14,15] Although various factors, such as muscle strength, generalized hyperlaxity, and posture, may play a role in this difference, the details have not been clarified. Most women wear bras daily. Taking into account the structure of bra straps and bands, bra wearing is likely to change the shoulder kinematics by tightening the scapula, clavicle, and thorax. Therefore, the purpose of the present study was to investigate, using an electromagnetic tracking device, the influence of bra wearing on shoulder kinematics in women.

METHODS

Subjects

The subjects were 19 healthy women (19 shoulders on the dominant side). Their mean height, body weight, and age were 157.9 ± 5.2 cm, 52.5 ± 8.7 kg, and 21.0 ± 2.7 years, respectively. The absence of shoulder pain, trauma, or a history

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[a] Department of Physical Therapy, Fukuoka Rehabilitation College, Hakata-ku, Fukuoka, Japan
[b] Kurume University School of Medicine Graduate School, Kurume, Fukuoka, Japan
[c] Faculty of Health Science, Kyoto Tachibana University, Yamashina-ku, Kyoto, Japan
[d] Department of Orthopedic Surgery, Kurume University Medical Center, Kurume, Fukuoka, Japan
[e] Department of Physical Therapy, Technical School of Medical and Welfare Ryokuseikan, Tosu, Saga, Japan
[f] Department of Orthopedic Surgery, Kurume University, Kurume, Fukuoka, Japan
Correspondence: Takashi Nagamatsu, Department of Physical Therapy, Fukuoka Rehabilitation College, 3-29-17 Hakataekimae, Hakata-ku, Fukuoka-shi, Fukuoka 812-0011, Japan, E-mail: nagamatsu@ebc.ac.jp

of shoulder disorders was confirmed before the experiments, and subjects with hyperlaxity were excluded.

The present study was approved by the Ethics Committee of Kurume University (#09078), and written consent for participation was obtained from all subjects.

Instrumentation

Three-dimensional kinematic data for the humerus, scapula, and thorax were collected and analyzed using the LIBERTY electromagnetic tracking device (Polhemus, Colchester, VT, USA) and Motion Monitor software version 8.43 (Innovative Sports Training Inc, Chicago, IL, USA). This allowed simultaneous tracking of the sensors at a sampling rate of 120 Hz. The system consisted of a transmitter, seven sensors (receivers), a stylus (digitizer), and a system unit. The transmitter generated a low-frequency electromagnetic field that was detected by each sensor. The accuracy of angular orientation is reportedly 1.3°.[16] The root mean square error generated as a result of skin motion artifacts was less than 5° when the arm elevation was less than 120°.[17]

Procedure

A global coordinate system was established using a transmitter mounted on a rigid wooden base frame and aligned with the cardinal planes of the body. Electromagnetic sensors were attached to the sternum, acromion, and humerus on the dominant side of the body. The bony landmarks were palpated and digitized while the subject sat on a plastic chair with the arm on the dominant side relaxed against the side of the body. The local coordinate system was selected in accordance with the recommendations of the International Society of Biomechanics: [18] the spinous processes of the seventh cervical and eighth thoracic vertebrae, the suprasternal notch, and the xiphoid process were the thoracic landmarks; the glenohumeral joint rotation center (estimated using the rotation method) and the medial and lateral epicondyles were the humeral landmarks; and the acromial angle, the root of the spine of the scapula, and the inferior angle were the scapular landmarks. The Z-axis, X-axis, and Y-axis were oriented laterally, anteriorly, and superiorly, respectively.

While lumbo-pelvic upright sitting on a chair, the subjects performed scapular plane elevation (30° anterior to the frontal plane) with their dominant arm from a relaxed position at the side to the full available range of motion at a velocity that completed the motion in approximately 3 s. Subjects practiced scapular plane elevation before the measurements to minimize variations in the elevation speed. After the practice motion was confirmed to be satisfactory, measurements were performed twice in each of two conditions: bra worn and bra not worn. The bras worn were those owned by subjects for everyday wear.

Data Reduction

Using the recorded three-dimensional data for each segment, the arm elevation, glenohumeral elevation, and scapula rotation angle were calculated using Euler angles in accordance with the recommendations of the International Society of Biomechanics.[18] The arm elevation and glenohumeral elevation angles were determined using the second rotation of the *Y'XY''* sequence. The scapular motion angles were determined using the *YXZ* sequence (first rotation: internal rotation, second rotation: upward rotation, third rotation: posterior tilt). For the calculated angle data, 20°–120° arm elevation was regarded as the analytical range, and the glenohumeral elevation and scapular rotation angles were analyzed at every 10° of elevation.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 17.0; IBM, Tokyo, Japan). To evaluate the inter-rater reproducibility of the glenohumeral elevation and the three scapular rotation angle measurements, the intraclass correlation coefficient [ICC (1, 1)] was calculated for each of the two conditions. Two-way repeated measures analysis of variance (bra wearing condition × arm elevation angle) was used to evaluate the influence of bra wearing on glenohumeral elevation and scapular rotation. When a significant interaction between bra wearing and the arm elevation angle and/or a main effect of bra wearing was detected, the post hoc Bonferroni test was used to determine the significance of differences between the bra wearing conditions. The level of statistical significance was set at $P < 0.05$.

RESULTS

With subjects wearing a bra, the ICC (1, 1) values were as follows: for glenohumeral elevation, 0.990 (95% confidence interval [CI]: 0.987–0.992); for scapular upward rotation, 0.965 (95% CI: 0.954–0.973); for internal rotation, 0.911 (95% CI: 0.885–0.932); and for posterior tilt, 0.933 (95% CI: 0.913–0.949).

With the subjects not wearing a bra, the ICC (1, 1) values were as follows: for glenohumeral elevation, 0.996 (95% CI: 0.994–0.997); for scapular upward rotation, 0.982 (95% CI: 0.977–0.987); for internal rotation, 0.933 (95% CI: 0.913–0.949); and for posterior tilt, 0.955 (95% CI: 0.942–0.966).

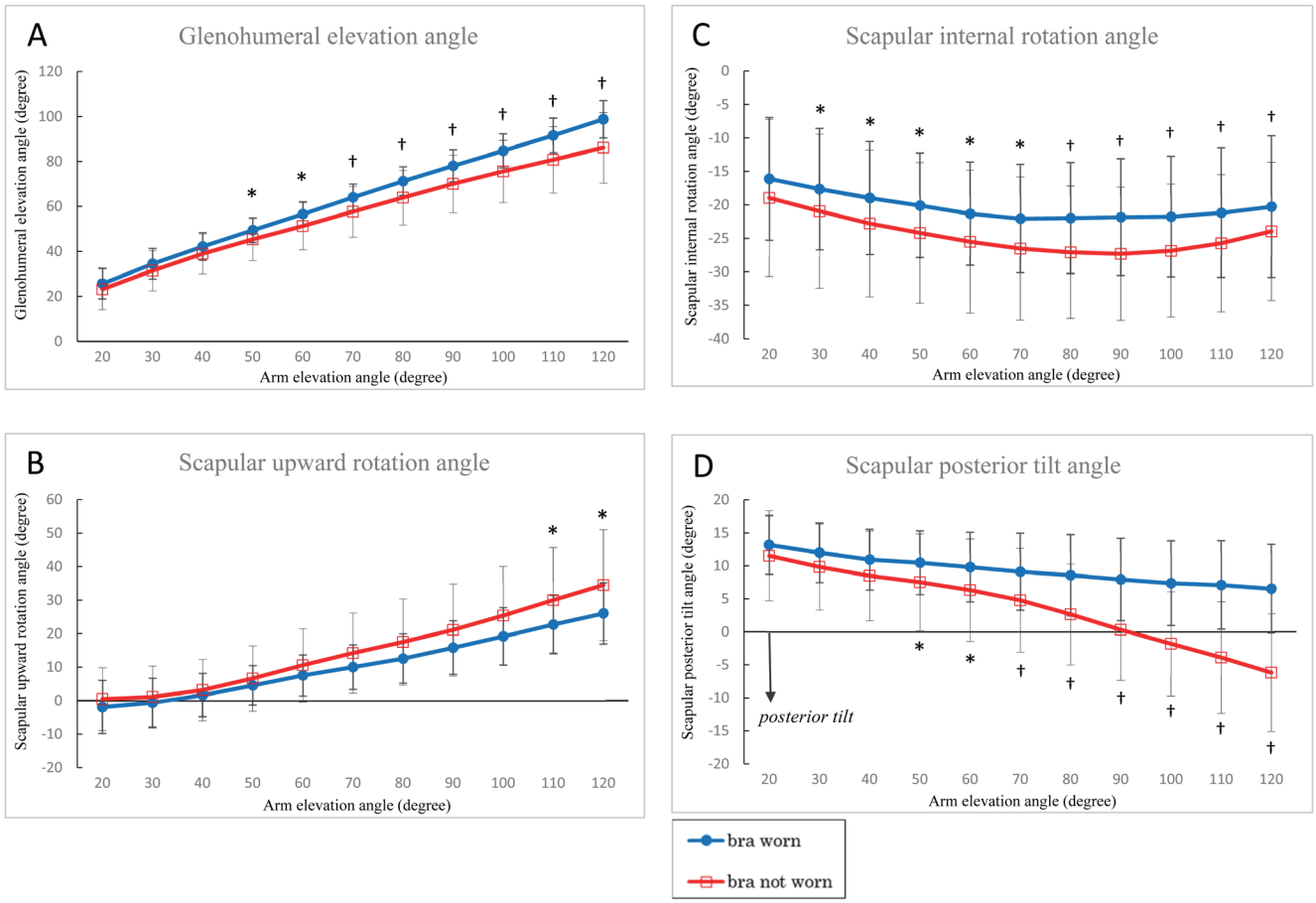

Fig 1. Glenohumeral joint and scapular kinematics during scapular plane elevation: (A) glenohumeral elevation, (B) scapular upward rotation, (C) scapular internal rotation, (D) scapular posterior tilt. *P <0.05; †P <0.01.

Glenohumeral Elevation

A significant interaction was detected between bra wearing and the arm elevation angle (F=9.83, P <0.01). In addition, a main effect of bra wearing was detected (F=9.28, P <0.01). The glenohumeral elevation angle was significantly greater when subjects wore a bra than when subjects did not wear a bra in the arm elevation range of 50°–120° (P <0.05 and P <0.01, **Fig. 1**).

Scapular Upward Rotation

A significant interaction was detected between bra wearing and the arm elevation angle (F=5.23, P <0.05). The scapular upward rotation angle was significantly smaller when subjects wore a bra than when subjects did not wear a bra at 110° and 120° arm elevation (P <0.05, **Fig. 1**).

Scapular Internal Rotation

No significant interaction was detected between bra wearing and the arm elevation angle (F=1.77, P=0.18). However, a main effect of bra wearing was detected (F=11.48, P <0.01). The scapular internal rotation angle was significantly smaller when subjects wore a bra than when subjects did not wear a bra within the arm elevation range of 30°–120° (P <0.05 and P <0.01, **Fig. 1**).

Scapular Posterior Tilt

A significant interaction was detected between bra wearing and the arm elevation angle (F=24.82, P <0.01). In addition, a main effect of bra wearing was detected (F=21.50, P <0.01). The scapular posterior tilt angle was significantly smaller when subjects wore a bra than when subjects did not wear a bra within the arm elevation range of 50°–120° (P <0.05 and P <0.01, **Fig. 1**).

DISCUSSION

Recent studies have reported gender differences in shoulder kinematics during arm elevation. This study examined

the effects of bra wearing on shoulder kinematics, and revealed that bra wearing reduces the upward rotation, internal rotation, and posterior tilt of the scapula, and increases the glenohumeral motion.

Bra straps hold breast weight, and straps exert downward traction of approximately twice the breast weight on the upper lateral scapular region, with an average pressure of 2.4 kg on each side (range, 1.0–5.5 kg).[19,20] In a study that examined the pressure exerted by bras, the average pressure was 1838.8 Pa in the strap and 2556.8 Pa in the band region, showing that the band exerts relatively high pressure on the lateral thoracic wall.[21] These results may support our findings that bra wearing reduces scapular upward rotation, internal rotation, and posterior tilt movement, and increases the glenohumeral motion. An electromyographic study showed that bra wearing significantly increased the upper trapezius activity during arm elevation.[22] In addition, the trapezius activity varies depending on the type of bra strap, with parallel straps significantly increasing the muscle activity compared with crossed straps.[23] Given the findings of the present study, bra wearing may increase the load on the upper trapezius muscle and the glenohumeral joint.

Numerous studies have reported that women have a higher risk of work-related neck/shoulder disorders than men.[24–26] These disorders may be affected by gender differences in muscle strength, motor control, fatigue, pain, and stress response.[27] However, the results of this study suggest that in addition to these factors, bra wearing is also a risk factor for shoulder disorders. Previous studies have reported that the subacromial space on active arm elevation increases by assisting upward and posterior tilt of the scapula.[28] Conversely, it has been reported that scapular upward rotation and posterior tilt during arm elevation are decreased in patients with subacromial impingement syndrome or multidirectional instability.[29–33] In these patients, bra wearing may result in a higher risk of overloading the shoulder.

This study has several limitations. First, measurements were obtained during scapular plane elevation only. Because scapular upward rotation and internal rotation vary depending on the elevation plane,[34] further study on elevation in the sagittal and coronal planes is required. Second, this study did not examine the breast size. A study involving 605 Asian women showed large differences in breast volume (91.8–919.2 ml).[35] Thus, the distribution of breast volumes in the participants of this study could have affected the results.

Using an electromagnetic tracking device, we studied the effects of bra wearing on shoulder kinematics during arm elevation. The results showed that bra wearing significantly reduced scapular upward rotation, internal rotation, and posterior tilt, and increased the glenohumeral motion. We propose that these effects be considered when evaluating or treating women with shoulder disorders in clinical practice.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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