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## Original Works

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# An easy and Stable Method to Measure the Shoulder Internal Rotation Angle

Motoyuki Horii<sup>1,2\*</sup>, Toru Morihara<sup>2,3</sup>, Hiroaki Honda<sup>2</sup>, Shuichi Kubo<sup>3</sup>  
Ryuichi Komori<sup>3</sup>, Rie Kushida<sup>3</sup>, Shoko Kawabe<sup>3</sup> and Toshikazu Kubo<sup>2</sup>

<sup>1</sup>*Department of Postural Control and Bone Metabolism,  
Kyoto Prefectural University of Medicine Graduate School of Medical Science*

<sup>2</sup>*Department of Orthopaedics,  
Kyoto Prefectural University of Medicine Graduate School of Medical Science*

<sup>3</sup>*Unit of Rehabilitation Medicine, University Hospital,  
Kyoto Prefectural University of Medicine*

**Abstract:** We have devised an easy and stable method to measure the shoulder internal rotation (IR) using a rod and a special plate (SIR plate) that we developed. We evaluated whether the rod motion is equal to the actual IR (experiment 1), and whether the rod motion can be measured accurately using the SIR plate (experiment 2).

The study participants were 20 healthy volunteers (40 shoulders). In experiment 1, accuracy of the rod movement during IR at 90° abduction (participants were in the supine position) was assessed by comparing the movement of the rod with the motion of the flexed forearm on photographs. In experiment 2, a similar approach was used to compare the actual degree of rod movement with the measurement on the SIR plate.

There was a significant correlation (correlation efficient, 0.961) between the range of rod movement and the IR range at 90° abduction. Even in the IR with the arm at the side, there was a significant correlation (correlation efficient, 0.983) between the actual movement of the rod and the measurement on the SIR plate.

Our new measurement method using the SIR plate may be useful for quantitative assessment of the range of shoulder IR with the arm at the side.

**Key Words:** Shoulder, Range of motion, Internal rotation, Quantitative evaluation.

## Introduction

The measurement of the range of motion is one of the most important assessments for the clinical evaluation of joints. Rotation of the shoulder with the arm at the side is an important motion for this measurement. Although external rotation is easy to measure by flexing the elbow, documentation of internal rotation (IR) is difficult because the trunk obstructs the normal arc<sup>1)</sup>. Usually, physicians record the position reached by the outstretched “hitchhiking” thumb in reference to the posterior anatomy<sup>1-4)</sup>. This method of determining the functional IR of the shoulder has been criticized because it does not

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Received: March 4, 2011. Accepted: April 25, 2011

\*Correspondence to Motoyuki Horii 465 Kajii-cho, Kawaramachi-Hirokoji, Kamigyo-ku, Kyoto 602-8566 Japan  
horii@koto.kpu-m.ac.jp

measure pure IR of the glenohumeral joint<sup>1)</sup>. Furthermore, the functional IR is affected by concurrent pathologic conditions in the elbow, wrist, or thumb, and it may not be easy to determine bony landmarks of the spine. In addition, this qualitative assessment of IR can be influenced by shoulder extension and mobility of other joints of the upper extremity<sup>4-7)</sup>. A method using the interepicondylar line of the humerus was proposed for documenting shoulder rotation with the elbow extended<sup>5)</sup>.

In this study, we present an easy and stable method in which shoulder IR with the elbow extended was measured using a rod and a special plate—the shoulder IR (SIR) plate (Fig. 1). We examined whether the motion of the rod is equal to the actual IR of the shoulder (experiment 1), and whether rod motion can be measured accurately using the SIR plate (experiment 2).

### Materials and methods

The subjects in this study were 20 healthy volunteers (40 shoulders) without shoulder disorders (15 men, 30 shoulders) and with a mean age of 31 years (range, 22-48 years). Written informed consent was obtained from all participants.

#### 1. Experiment 1

Accuracy of the rod movement during IR motion at 90° abduction (Fig. 2)

Subjects were in the supine position with shoulder abducted to 90° and the elbow extended. The proximal one-third of the upper arm was placed on the bed. A rod was attached to the cubital fossa with a rubber bande so that it vertically crossed the upper limb (Fig. 3). To stabilize the rod, the rubber band was placed in such a way that it surrounded the olecranon with adequate, uniform tension. According to previous reports, the camera was centered at the axis of rotation of the shoulder and placed in the

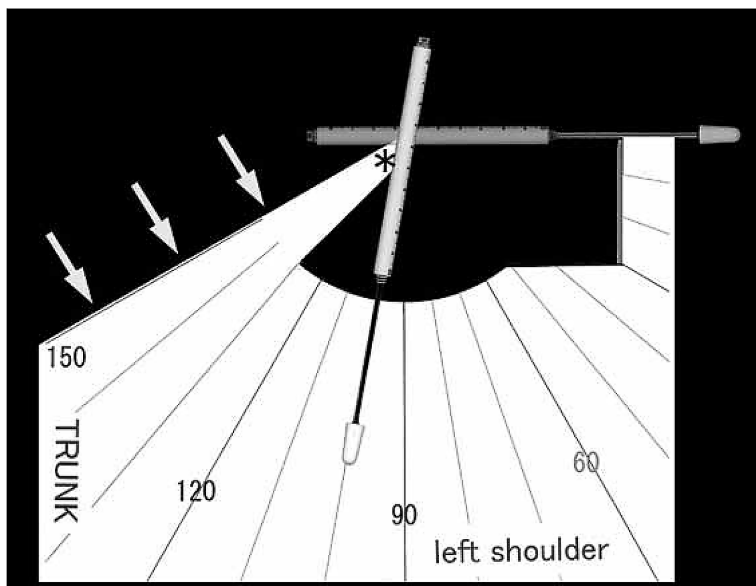


Fig. 1. Shoulder internal rotation (SIR) plate (for the left shoulder)

The asterisk at the tip of the mechanism indicates the rotation center of the rod during internal rotation. The chamfer (arrows) enables measurement without obstruction by the trunk. Typical movement of the rod is shown.

plane of rotation movement to minimize the parallax error<sup>8)</sup>.

First, the elbow was flexed at an angle of  $90^\circ$  with the shoulder in the neutral position (Picture A, Fig. 2-a); next, the elbow was fully extended with care (Picture B, Fig. 2-b). The subjects were asked to internally rotate their shoulder without moving the scapula (Picture C, Fig. 2-c). At this moment, their forearm was pronated. The elbow was passively flexed at  $90^\circ$  with the assistant's thumb and index finger placed on the lateral and medial epicondyles to prevent the shoulder from rotating during this process. Finally, the forearm was returned to the neutral position (Picture D, Fig. 2-d).

The IR range was determined every  $1^\circ$  by measuring the angle between a line passing through the olecranon and ulnar styloid processes<sup>8)</sup> on pictures A and D. The range of the rod movement was determined every  $1^\circ$  on the pictures B and C. The measurement was performed 3 times for each shoulder.

The range of the rod movement during IR motion at  $90^\circ$  abduction was compared to the IR range measured with the forearm (elbow  $90^\circ$  flexed) on the photographs.

## 2. Experiment 2

Accuracy of the measurement of IR ranges with the arm at the side using the SIR plate (Fig. 4)

Subjects sat on a stool with the arm at the side. A rod was attached to the cubital fossa with a rubber bande so that it vertically crossed the upper limb. The shoulder was positioned in the zero

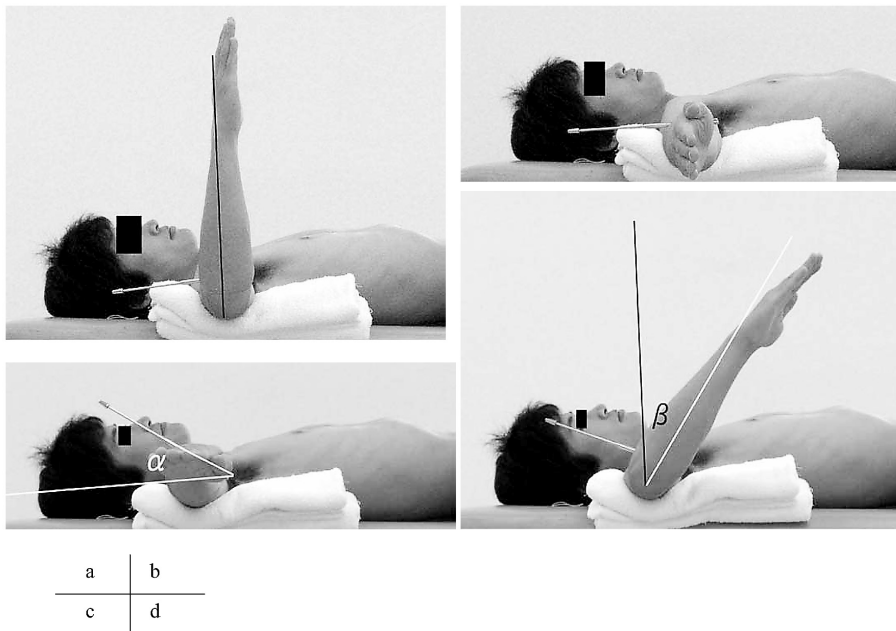


Fig. 2. Accuracy of the rod movement during internal rotation (IR) motion at  $90^\circ$  abduction

- The forearm was in the starting position (Picture A).
- The elbow was fully and passively extended and the rod was in the starting position (Picture B).
- Subjects were asked to internally rotate their shoulder (Picture C). The white line shows the starting position of the rod. The range of the rod movement was determined ( $\alpha$ ).
- The elbow was passively flexed to  $90^\circ$  (Picture D). The black line shows the starting position of the forearm. The IR range was determined ( $\beta$ ).

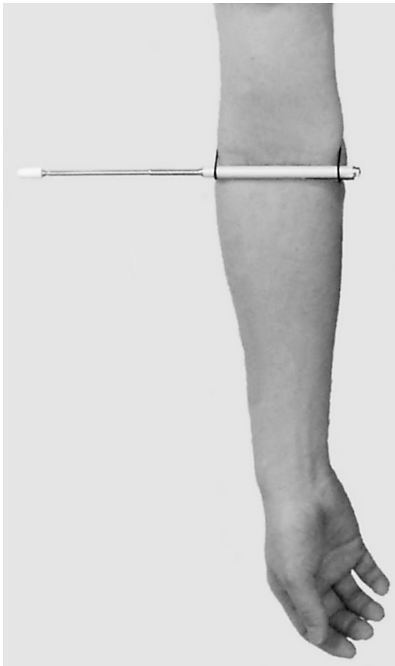
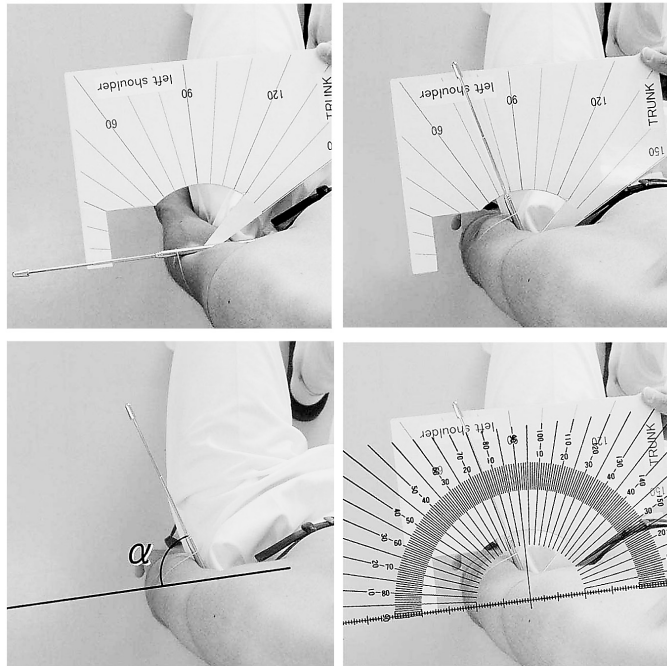


Fig. 3. A rod was attached to the cubital fossa with a rubber band so that it vertically crossed the upper limb.



a	b
c	d

Fig. 4. Accuracy of the measurement of internal rotation (IR) ranges in the zero starting position by using the shoulder internal rotation (SIR) plate.

- a. The shoulder was placed in the zero starting position with the elbow passively flexed. Next, the elbow was fully extended with care and the SIR plate was applied so that the rod overlapped with the starting line on the plate (Picture E).
- b. The shoulder was actively fully rotated (Picture F).
- c. The SIR plate was removed while the subjects maintained their IR position (Picture G). The black line shows the starting position of the rod, and the actual rotation of the rod was measured ( $\alpha$ ).
- d. The SIR plate measurement was carried out using a graduated ruler overlapping the scale on the plate on picture F.

starting position with the elbow passively flexed. The camera was set just above the shoulder on the axis of shoulder rotation. Next the elbow was fully extended with care while keeping the forearm in the neutral position (pronation/supination). The SIR plate (Fig. 1) was applied so that the rod overlapped with the starting line on the plate (Picture E, Fig. 4-a). Subjects were asked to internally rotate their shoulder without moving the scapula (Picture F, Fig. 4-b). An assistant held the SIR plate carefully to prevent its rotational movement. Finally, the SIR plate was removed while the subjects remained in the IR position (Picture G, Fig. 4-c).

The degree of rotation was read every 1° on the SIR plate with a graduated ruler overlapping their scales

in Picture F (SIR plate measurement, Fig. 4-d). The actual rotation of the rod was also measured every 1° using pictures E and G (actual measurement, Fig. 4-c). The measurement was performed 3 times for each shoulder.

The IR range measured using the SIR plate with the arm at the side was compared to the actual movement of the rod on the photographs.

### Statistical analysis

The Pearson product-moment correlation coefficient was calculated using the software Stat View for Windows Version 5.0 (SAS Institute Inc, Cary, NC).

## Results

### 1. Experiment 1

The IR range was 17°-67° (mean, 42°) at 90° abduction, while the range of the rod movement was 18°-68° (mean, 42°), indicating a significant correlation ( $p < 0.0001$ ) with a correlation coefficient of 0.961 (Fig. 5). The difference between the 2 measurements was 0°-7° with a mean (SD) of 3° (2°). The mean difference (SD) of all triplicate measurements was 3° (2°). The good correlation between the measurements showed that the rod movement correctly reflected the IR.

### 2. Experiment 2

Our healthy volunteers experienced no difficulties in applying the SIR plate because the design of

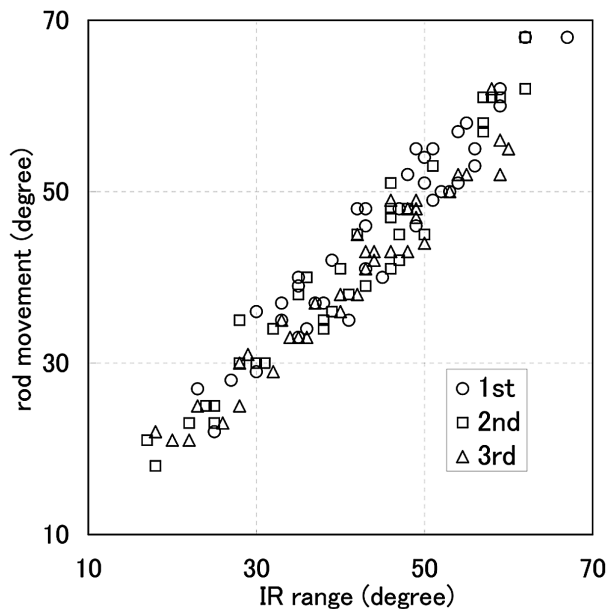


Fig. 5. Internal rotation (IR) range and the range of rod movement at 90° abduction

We found a significant correlation ( $p < 0.0001$ ) with a correlation coefficient of 0.961.

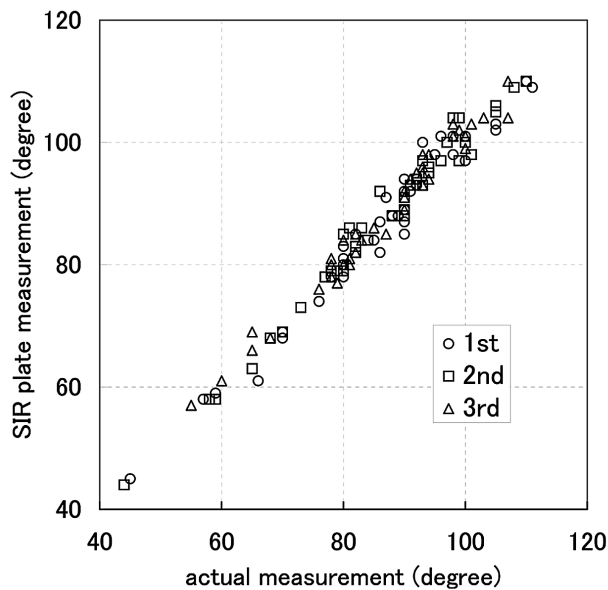


Fig. 6. The actual range of rod movement and the range measured using the shoulder internal rotation (SIR) plate.

We found a significant correlation ( $p < 0.0001$ ) with a correlation coefficient of 0.983.

the plate (Fig. 1, arrows) precluded obstruction by the trunk during the measurement.

The maximum IR value in the assessment with the SIR plate was below  $130^\circ$ , which was the highest value that could be measured with the plate. The IR range in the measurement using the SIR plate was  $44^\circ$ - $110^\circ$  (mean,  $87^\circ$ ), whereas that of the actual measurement was  $44^\circ$ - $110^\circ$  (mean,  $87^\circ$ ), thereby indicating a significant correlation ( $p < 0.0001$ ) with a correlation coefficient of 0.983 (Fig. 6). The difference between the 2 measurements was  $0^\circ$ - $7^\circ$  with a mean (SD) of  $2^\circ$  ( $2^\circ$ ). In the first, second, and third measurement of each shoulder, the mean differences (SD) were  $2^\circ$  ( $2^\circ$ ),  $2^\circ$  ( $2^\circ$ ), and  $2^\circ$  ( $1^\circ$ ), respectively. We found a good correlation between the IR ranges measured using the SIR plate and the actual movement of the rod.

## Discussion

The IR of the shoulder is usually measured by determining the position of an outstretched “hitchhiking” thumb with reference to the posterior anatomy<sup>1,2)</sup>. However, this method had<sup>3)</sup> disadvantages<sup>5)</sup>. First, the motion is a combination of extension, adduction and IR<sup>4)</sup>. Second, the assessment is affected by the mobility of the elbow, radioulnar, and wrist joints as well as the joints of the thumb. Thus its use is invalid in rheumatoid or generalized arthritis<sup>9)</sup>. Third, it is not always easy to determine the bony landmarks of the back. In addition, there are difficulties in statistical analysis. This problem can be averted by abducting the arm to  $90^\circ$ ; this method has been used successfully<sup>10)</sup>. However, patients with a stiff, painful shoulder cannot abduct their arm to  $90^\circ$ . In addition, the neutral position is a more functional position, and the IR in this position yields more clinically useful

information. Kumar and Satku proposed a method using the interepicondylar line of the humerus with the elbow extended<sup>5)</sup>. In this method, the epicondyles were palpated with the examiner's thumb and index finger during the measurement. This method is simple, but it may not yield consistent results.

We presented a new and easy method to measure the shoulder IR by using a rod attached to the cubital fossa. The good correlation between the range of rod movement and the IR range at 90° abduction showed that the rod movement correctly reflected the IR.

In the IR measurement with the arm at the side, the starting position should be the position in which the forearm is in the sagittal plane when the elbow is flexed. In the IR measurement using a rod with the elbow fully extended, it is difficult to maintain the exact initial rod position during measurement with a conventional goniometer. The SIR plate has a mechanism for locating the rotation center of the rod during IR, which may minimize parallel and rotational translation of the plate to the rod, thereby enabling exact measurements. The shape of the SIR plates was designed to avoid obstruction by the trunk during the measurement. The upper and lower surfaces of the plate were used for measurements on the right and left sides, respectively.

In the IR with the arm at the side and with the elbow fully extended, the actual rod movement was measured on the SIR plate with a mean difference of 2° and a maximum of 7°.

Since the range of motion is usually recorded at intervals of 5°, measurement using the SIR plate will be sufficient for clinical measurement of the IR range.

The requirement of special tools and the possible difficulties in using the plate in extremely obese patients are some of the drawbacks of using the SIR plate. Further studies are required to confirm the feasibility of this method for measuring the IR range in children and patients with problems of the elbow. However, our new measurement makes possible interpatient comparison of the pure IR range. Periodical measurement using SIR plate, once a month for example, in addition to the daily or weekly conventional measurement may provide the more precise assessment of the IR range.

We conclude that our new measurement method using the SIR plate may be useful for the quantitative assessment of the range of shoulder IR with the arm at the side. In addition, this approach may simplify the statistical analysis.

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〈和文抄録〉

### 肩関節下垂位での内旋可動域測定法の工夫とその有用性の検討

堀井 基行<sup>1,2</sup>, 森原 徹<sup>2,3</sup>, 本多 宏明<sup>2</sup>, 久保 秀一<sup>3</sup>  
小森 隆一<sup>3</sup>, 櫛田 里恵<sup>3</sup>, 河邊 祥子<sup>3</sup>, 久保 俊一<sup>2</sup>

<sup>1</sup>京都府立医科大学大学院医学研究科身体支持制御・骨代謝学講座

<sup>2</sup>京都府立医科大学大学院医学研究科運動器機能再生外科学（整形外科）

<sup>3</sup>京都府立医科大学附属病院リハビリテーション部

肩関節下垂位では内旋可動域は体幹で測定が妨げられる。われわれは肘伸展位で、肘前方に取り付けた指示棒の動きでの内旋可動域計測を試み、補助具として測定板（SIR plate）を作製した。指示棒の動きが実際の内旋角度と一致するか（実験1）、SIR plateで指示棒の動きを正確に読み取れるか（実験2）を検討した。

対象は健常ボランティア20人40肩で、男性が30肩、平均年齢は31歳（22～48歳）であった。実験1では被検者を仰臥位とし、肩関節90°外転位で肘前方に取り付けた指示棒の動き（指示棒法）を前腕の動き（従来法）と写真上で比較した。実験2では、被検者をイス座位とし、実際の指示棒の動き（実測値）をSIR plateでの計測結果と写真上で比較した。

実験1において内旋可動域の平均は従来法の42°（17～67°）に対し指示棒法で42°（16～68°）、測定値の差は平均3°（0～7°）で、相関係数は0.961と良好な相関を認めた。実験2において指示棒の動きの実測値とSIR plate上での計測値の平均値はともに87°（44～110°）、測定値の差は平均2°（0～7°）で、相関係数は0.983と良好な相関を認めた。通常関節可動域測定最小単位は5°程度であることから、SIR plateを用いた内旋可動域測定法は臨床上有用と考える。

キーワード：肩関節，関節可動域，内旋，定量評価。