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Original Article

The reliability and validity of joint range of motion measurement using zoom and a smartphone application

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Abstract. [Purpose] This study aimed to evaluate the reliability and validity of measuring the range of motion of joints using a remote videoconferencing system (Zoom) and a smartphone application. [Participants and Methods] This study included 16 young and healthy adults. The participants were instructed to perform shoulder joint flexion exercises in a seated position, with automatic motions, and maintain that posture throughout the measurement. Two measurements were performed: 1) angle measurement using a three-dimensional (3D) motion analyzer, and 2) angle measurement using the videoconference software, Zoom, and a smartphone application. Intra- and inter-rater reliabilities were calculated using the intraclass correlation coefficients (ICC). The degree of agreement between the representative values of each measurer and the 3D motion analyzer was examined. [Results] ICC (1, 1) for intra-examiner reliability were 0.912 and 0.996. For the inter-rater reliability, the ICC (2, 1) was 0.945. The correlation coefficient between each examiner's value and the value of the 3D motion analyzer was 0.955 and 0.980, respectively. The Bland–Altman analysis results indicated no systematic error. [Conclusion] The method of remotely measuring joint range of motion using Zoom and a smartphone application demonstrated high reliability and validity.

Key words: Range of motion, Zoom, Reliability

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INTRODUCTION

Telerehabilitation has attracted more attention due to the advancement of telecommunications equipment and the effects of COVID-19[1–3]. Telerehabilitation has been found to be as effective as, if not more effective than, conventional therapy or doing nothing[4, 5], and it will probably continue to be developed in the future. There are many reports on treatment and its effectiveness in telerehabilitation, but none on evaluation methods.

Consequently, in this study, we focused on a smartphone application (Guriddosen satuei apuri Professional, Naradewa, Inc., Tochigi, Japan) that measures joint angles from images. This application has been confirmed to be highly reliable and valid in the country where it was developed in Japan[6]. Applications to the measurement of joint range of motion have already been reported[7]. This smartphone application can also measure angles from stored images, and it might be feasible to measure joint angles remotely when using a videoconferencing system. However, when a remote videoconferencing system is used, the image is projected onto a different device through the lens of the notebook PC and then further through the communication environment, and it is uncertain whether the actual angle matches the angle seen as an image through the remote videoconferencing system.

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Therefore, the purpose of this study is to evaluate the reliability and validity of measuring the range of motion of joints using a remote videoconferencing system and a smartphone application.

PARTICIPANTS AND METHODS

This study included participants who were 16 young healthy adults (6 males and 10 females). The mean height and weight (standard deviation) of the participants were 165.1 (7.5) cm and 58.2 (10.2) kg, respectively. The Declaration of Helsinki was followed in the implementation of this study, and the participants of this research were fully informed of the purpose and methods of the study and their written consent was obtained. The study was approved by the Ryotokuji University Life Ethics Review Committee (Approval No. 3011). The reflex markers were attached to the participant's lateral humeral epicondyle, humeral greater tuberosity, acromion, and trunk vertically lowered from the acromion to the floor. The participants sat in front of a prepared PC. The participant was instructed to perform exercises for shoulder joint flexion in a seated position with automatic motion and maintained that posture throughout the measurement. Two measurements were performed: angle measurement using a three-dimensional (3D) motion analyzer (UM-CAT2; Unimec, Inc., Tokyo, Japan) and angle measurement using the videoconference software Zoom [Ver. 5.11.1 (6602), Zoom Video Communications, Inc., San Jose, CA, USA] and a smartphone application (Guriddosen satuei apuri Professional, Naradewa, Inc., Tochigi, Japan). A laptop computer was connected to the center of a 3D motion analyzer to conduct the measurements using Zoom and the application (Fig. 1). On Zoom, it was determined that the participant was maintaining the flexed shoulder joint position, and the screenshot was saved. Opening the saved image in the application, the angle was then measured. The measurement method using the application was carried out in accordance with the previous studies in Japan of development, and its line was moved so that it crossed over the four reflective markers (Fig. 2). Two raters performed the measurements in Zoom and in the application, and the smartphones used were AQUOS sense 5G (manufactured by Sharp, Osaka, Japan) and iPhone XS (manufactured by Apple, Cupertino, CA, USA), respectively. For each examiner, the joint angle using the application was measured 3 times. Intra- and inter-rater reliabilities were calculated using the intraclass correlation coefficients (ICC) for the measurement results of the Zoom and application. The representative value was the average of 3 times. The degree of agreement between the representative values of each measurer and the 3D motion analyzer was examined using the Pearson product–moment correlation coefficient and the Bland–Altman analysis[8]. The Bland–Altman analysis calculated 95% confidence intervals of minimal detectable change (MDC_{95}) after a systematic error was confirmed. R2.8.1 was used for all statistical procedures, with a significance level of 5%.

RESULTS

The intrameasurement reliabilities of measurements using Zoom and the application ICC (1, 1), for examiner A and B measurements, were 0.912 and 0.966, respectively. The intermeasurement reliability, ICC (2, 1), for examiner A and B measurements was 0.945 (Table 1). The correlation coefficient between each examiner's value and the value of the 3D motion analyzer was 0.955 and 0.980, respectively. No fixed or proportional errors were found by the Bland–Altman analysis in the measurements taken by each examiner. The MDC95 were 4.4° and 3.2°, respectively (Table 2).

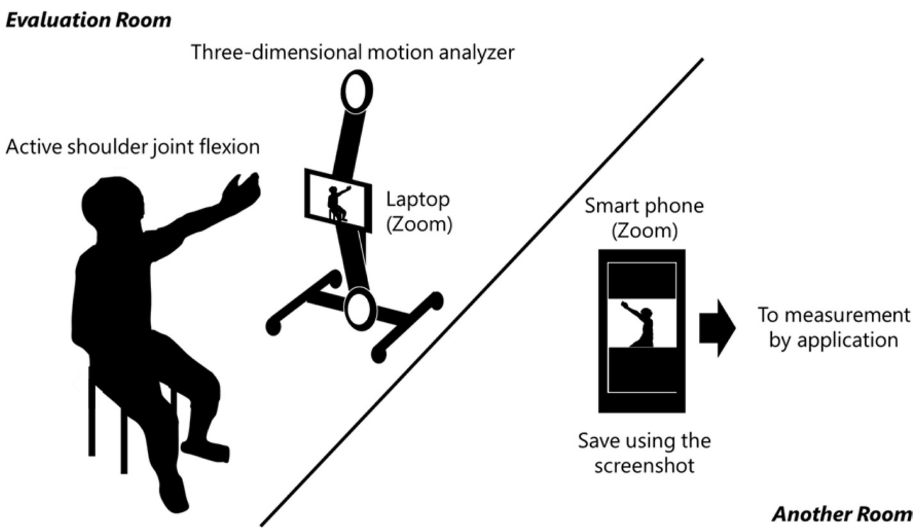

Fig. 1. Measurement method using videoconference software.

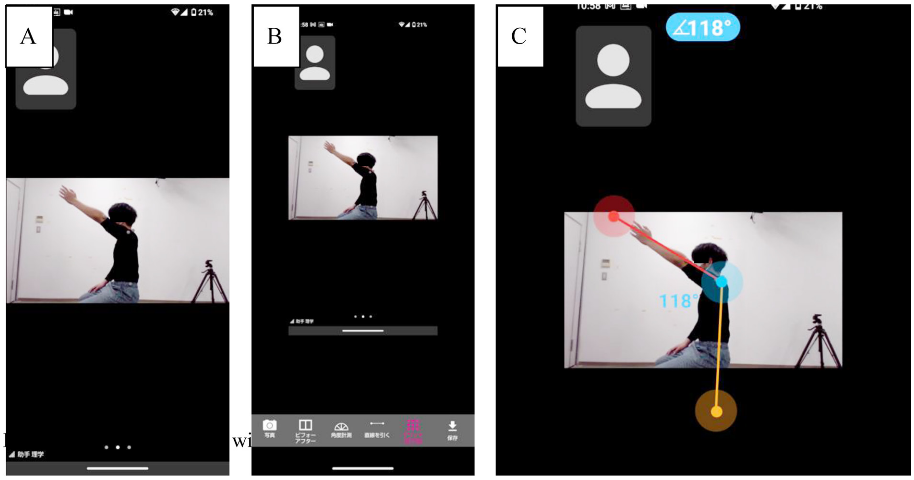

Fig. 2. Measurement screen with application.
A: Screenshot screen, B: Application start up screen, C: Measurement of application screen.

Table 1. Intra- and inter-reliability of measurements using Zoom and the application

Examiner	Measured value (°)* 1st time	2nd time	3rd time	ICC (1, 1)	SEM (°)	ICC (2, 1)	SEM (°)
A	114.8	113.0	113.1	0.912	2.2	0.945	1.8
	(7.2)	(8.2)	(7.0)	[0.814–0.966]		[0.852–0.980]	
B	114.9	114.3	114.0	0.966	1.5		
	(8.0)	(7.7)	(7.7)	[0.925–0.987]			

*: mean (Standard Deviation), []: 95% Confidence interval.
ICC: intraclass correlation coefficients; SEM: standard error of measurement.

Table 2. Correlation coefficient between each examiner's value and the three-dimensional motion analyzer's value

Examiner	Correlation coefficient	Bland–Altman analysis Fixed error†	Proportional error‡	Result	MDC_{95} (°)
A	0.955*	−1.5 to 0.9	0.01	No systematic error	4.4
		(0.6)	(0.9)		
B	0.980*	−1.2 to 1.4	0.06	No systematic error	3.2
		(0.2)	(0.3)		

*: p-value<0.01, †: 95% confidence interval (p-value), ‡: value of the slope for a regression line (p-value).
MDC_{95}: 95% confidence interval for the minimal detectable change.

DISCUSSION

In this study, using a remote videoconferencing system and a smartphone application, we tested the reliability and validity of a method for measuring the range of motion of joint. It follows that this measurement method has a high level of reliability and validity.

First, for reliability, the ICC was very high at 0.9 or higher for both intra- and inter-rater reliability. A reliability coefficient of 0.41–0.60 is classified as moderate, 0.61–0.80 as substantial, and ≥0.81 as almost perfect[9]. Therefore, this measurement method showed very high levels of intra- and inter-rater reliability. The standard measurement error is 2.2°, which is comparable to or better than other reports of angle measurements using smartphone applications[10, 11].

Next is validity, which is verified by comparing the results to those of the 3D motion analyzer. The results revealed a high correlation (r=0.955 and 0.980) between each examiner's measurements using the 3D motion analyzer and those measurements using the Zoom and smartphone application. The Bland–Altman analysis showed no systematic errors, and the MDC_{95} were 4.4° and 3.2°, respectively. The results of this MDC_{95} were comparable to those of the previous studies[12, 13] that examined the reliability of this method in measuring the range of motion of shoulder joint, indicating that this measurement method using the Zoom and application is a method with high agreement and validity using the 3D motion analysis device.

This study is extremely noteworthy in that it has made it possible to conduct the evaluation in remote rehabilitation, despite the fact that this measurement method is limited to automatic exercise. Further development of remote evaluation methods is expected to improve the quality of telerehabilitation in the future. Because this study mainly focused on shoulder joint flexion, it has limitations on the reliability and validity of the measurement in other movements. In this study, reflective markers were applied during measurements to allow comparison with a 3D motion analyzer; however, without reflective markers, it may be challenging to determine the measurement point due to the condition of the clothing, which may affect the reliability. Therefore, it is necessary in the future to examine reliability in conditions without reflex markers and in exercises other than shoulder flexion.

In conclusion, the method of measuring joint range of motion remotely using Zoom, a remote videoconferencing system, and a smartphone application has proven high reliability and validity.

Funding and Conflict of interest

None.

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