

Technical Note/Tips from the Field

# Can a Patient use an App at Home to Measure Knee Range of Motion? Utilizing a Mobile App, Curovate, to Improve Access and Adherence to Knee Range of Motion Measurements

Nirtal Shah<sup>1</sup> <sup>a</sup>, Corey Grunberg<sup>2</sup>, Zahra Hussain<sup>3</sup><sup>1</sup> Faculty of Kinesiology and Physical Education, University of Toronto, <sup>2</sup> Physical Therapy, University of Toronto, <sup>3</sup> Dalla Lana School of Public Health, University of Toronto

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### Introduction

Knee range of motion is a critical measure of progress after knee injury and knee surgery. However, many patients do not understand the importance of knee range of motion and most do not have a way to self-monitor their knee range of motion at home. The patient being able to measure their own range of motion can provide improved access to this critical health metric, and could improve adherence with their daily knee range of motion exercises. The purpose of this technical report is to determine if a mobile app, Curovate, can provide reliable measures of knee range of motion compared to standard goniometric measurements.

### Procedures

There were four positions of knee flexion and four positions of knee extension each measured twice with a standard goniometer and four different mobile devices with the app Curovate. The reliability and validity of the Curovate app was tested across mobile devices and operating systems and compare to goniometric knee range of motion measurements. A total of 80 measurements were taken. All testing was completed on a healthy 23-year-old male with no knee pathology.

### Results

A strong positive correlation, Pearson's  $r > = 0.9985$ , for all positions of knee flexion and extension across all four mobile devices as well as each mobile device compared to standard goniometric measurements.

### Conclusions

This article presents a unique method for patients to measure their knee range of motion using the mobile app Curovate. Overall, the mobile app, Curovate, was found to have a strong positive correlation across four mobile devices with varying operating systems and compared to goniometric measurements.

### Level of evidence

4

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<sup>a</sup> **Corresponding author:**

Nirtal Shah DPT, MScPT, MPH, FCAMPT  
Faculty of Kinesiology and Physical Education  
55 Harbord Street, Toronto, ON, M5S 2W6  
University of Toronto  
Canada  
[nirtal.shah@utoronto.ca](mailto:nirtal.shah@utoronto.ca)

## INTRODUCTION

The ability of clinicians and patients to obtain accurate joint angle measurements of the knee joint is key to monitoring progress following surgical repair or arthroplasty.<sup>1</sup> Adequate knee range of motion is a necessary component of many activities of daily living, including walking, climbing stairs and entering a bathtub.<sup>2</sup> However, patients rarely have access to their own knee range of motion measurements. Typically, the physical therapist measures the patient's knee extension and flexion at a healthcare facility with a standard goniometer and explains this measurement to the patient. The physical therapist utilizes these measures to monitor patient progress, documents the measurements, and reports these values back to the patient.<sup>3</sup> The patient may not always understand these measures, do not remember the actual numbers, and most do not have a reliable way to measure this on their own. Previous researchers have reported that patients who are disengaged with their home rehabilitation have lower rates of rehabilitation adherence.<sup>4,5</sup> Digital methods exist for measuring knee range of motion. Hancock et al. demonstrated that goniometric measurements using digital inclinometer technology are more accurate than both manual goniometry and clinician estimation for full knee flexion, full knee extension and three other angles of knee flexion on six knees for a total of 300 measurements.<sup>6</sup> However, many physical therapists and most patients do not have access to digital inclinometers. This disconnect between an important clinical measure that is inaccessible by the patient may contribute to poor patient adherence and lower levels of patient engagement and participation in rehabilitation exercises aimed at restoring knee range of motion.

The explosion of mobile health technology has made it possible for health metrics to be accessed by patients in their home. In addition, various forms of mobile health are aimed at improving patient adherence with health behaviours such as smoking cessation, taking prescription medications and improving adherence to exercise all while being patient-centric and at a lower cost than conventional healthcare.<sup>7</sup>

There are various apps that are capable of measuring knee range of motion. One such smartphone mobile app, Curovate, can be used by both the patient and the physical therapist is capable of measuring knee flexion and extension. Curovate is available for download in the Apple App Store and the Google Play Store.

Curovate is a subscription-based mobile application intended for patients following anterior cruciate ligament (ACL) reconstruction or injury, total knee replacement and total hip replacement. In addition to providing daily video guided exercises specific for each surgery or injury stage, progress tracking, and in-app chat with a licensed physical therapist it also functions as a digital knee range of motion measurement tool. Curovate is free for a five-day trial and then requires either a monthly (\$8.99 USD) or an annual (\$45.99 USD) subscription paid through either the App Store or Play Store.

The purpose of this technical report was to determine if a mobile app, Curovate, can provide reliable measures of knee



**Figure 1. Demonstrating how one angle of knee flexion (F1) was measured and sustained. In this case, the participant's foot is resting on a wedge on a non-slip mat on top of a plinth. A permanent marker was used to delineate bony landmarks for standard goniometric measurements. Two pieces of athletic tape were used to stay consistent when placing the various mobile devices on the leg.**

range of motion compared to standard goniometric measurements.

## PROCEDURES

The participant used during data collection for this technical report was a 23-year old individual with no previous or current pathologies of the knee joint. A healthy subject was chosen for this technical report in order to test the reliability of the mobile app measurement. In future studies subjects with knee injury and pathology will be tested utilizing the mobile app. Data collection presented no identifiable risk to the participant. Additionally, no confidential information was collected about the participant during data collection. The participant signed a photograph release form and consented to all testing and images taken for the purpose of this submission.

All goniometric measurements were completed by a licensed physical therapist, with 21 years of clinical experience in orthopaedics and sports medicine with extensive experience measuring knee range of motion in clinical practice. The primary author first manually located the bony landmarks for knee range of motion. Specifically, the midpoint of the lateral malleolus, the lateral aspect of the lateral femoral condyle and the midpoint of the greater trochanter. The bony landmarks were marked with a permanent marker on the participants body for consistency. In addition, the primary author placed two strips of athletic tape above and below the participant's knee with a line on each to consistently place each mobile device on the same spot for all measurements (See Figures 1 & 2).

To test range of motion, four angles of knee flexion (F1-F4) and four angles of knee extension (E1-E4) were measured on the same subject and then repeated (Appen-

**Table 1. Correlation between goniometric measurements and Curovate mobile app knee range of motion measurements on four mobile devices.**

	Goniometer	Samsung S7 Android	iPhone 11 iOS	iPhone XR iOS	iPad Pro iOS
Goniometer	1				
Samsung S7 Android	0.9991	1			
iPhone 11	0.9985	0.9997	1		
iPhone XR	0.9991	0.9998	0.9996	1	
iPad Pro	0.9989	0.9997	0.9998	0.9998	1

dix). Images of all eight angles of knee flexion and extension can be found in the Appendix.

In all measurements the participant was supine on a plinth with a non-slip exercise mat placed under his torso and leg. Each position of knee flexion or extension was sustained with the use of a foam roll, a hard-plastic wedge or the participants foot being in contact with the non-slip mat. During pilot testing it was determined that this allowed the participant to be able to sustain the position consistently without changing the joint angle between measurements.

All knee range of motion measurements were first completed using a standard, long arm, goniometer produced by CME Corporation (Warwick, RI), according to Clarkson, 2020 clinical guidelines.<sup>8</sup> The mobile app Curovate allows the individual to measure, store and track their knee flexion and extension measurements (Figures 3 & 4).

Once the patient has completed the self-measurement they are presented with their current range of motion and they can also view their previous measures within the app (See Figure 4). Previous authors have noted that smartphone-based knee range of motion measures lack reliability on various devices and operating systems.<sup>9</sup> To test this limitation this technical report tested using an iPad Pro (operating system 14.8), iPhone 11 (operating system 14.8), iPhone XR (operating system 14.4.2) and a Samsung S7 Android mobile device (operating system 8.0.0). Goniometric measurements were taken first followed by each mobile device and then repeated the measures again at the same knee angle with the goniometer and then with all four mobile devices.

Pearson’s correlation coefficient was used to determine the correlation between all of the measures. Microsoft Excel (2018, v 16.16.27, Microsoft Corporation) was utilized to calculate Pearson’s r.

## RESULTS

The correlational results of the 80 measurements taken with a standard goniometer and the four different operating systems/devices are presented in Table 1. Strong positive correlations are demonstrated across all mobile devices as well as mobile device measurements compared to standard goniometric measurements. Please refer to the Appendix to see the table of raw measurements for each measurement method (Appendix).



**Figure 2. In this case a hard-plastic wedge was used to simulate a patient who is lacking terminal knee extension. This was one of the positions used to measure knee extension (E2) with all four mobile devices and standard goniometric measurement.**

## DISCUSSION

Patients who have had an anterior cruciate ligament injury or surgery, total knee replacement, or various other knee injuries and surgeries are always advised by their physical therapist to perform daily knee range of motion exercises. The loss of knee range of motion can have detrimental effects on a patient’s functional abilities.<sup>2</sup> Daily life activities such as walking, using the stairs and getting in and out of a seated position all require an adequate amount of knee range of motion.<sup>2</sup> In most cases clinicians have various methods to measure knee range of motion in the clinical environment but patients have no way to measure their own range of motion. This lack of independence and poor understanding of range of motion may be possible to address through mobile health technology. This would provide the patient with access to information regarding range of mo-

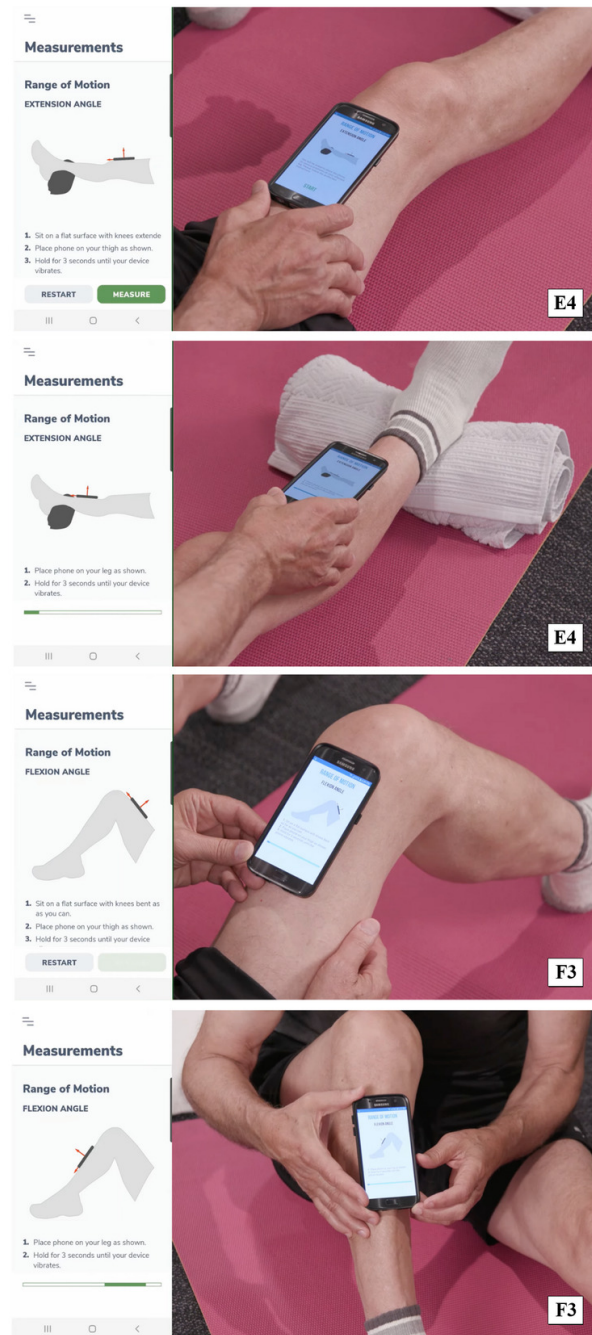


tion measures at home and could motivate them to adhere to their range of motion exercises.

This technical report provides preliminary information regarding the reliability of a mobile app, Curovate, for measurement of knee range of motion. This preliminary testing demonstrated a high degree of positive correlation using Pearson's  $r$  to compare across all mobile devices and operating systems for all angles of knee flexion and extension measured when compared to standard goniometric measurement in a single subject. Based on these preliminary findings the authors suggest that a patient can effectively measure their knee flexion and extension at home independently. This would provide the patient with critical range of motion measures at home which could motivate them to adhere to their home range of motion program.

The limitation of this technique of measurement includes the need for a smartphone and the mobile app Curovate. This limitation is becoming less relevant as smartphone ownership increases globally. Current estimates suggest that 4.92 billion people or 66% of the world population own a mobile device.<sup>10</sup> Another potential limitation is that a patient may not place the smartphone on the same area of their lower leg for subsequent measures which would reduce the reliability of the measure. In this report a piece of athletic tape was used to reproduce the placement of the mobile devices for each measurement. A patient at home would be less consistent and therefore this may reduce the overall reliability and validity of the measure taken by the patient. To address this limitation, a YouTube video guide can be used by a patient to measure their range of motion at home (YouTube link: <https://youtu.be/kzYKnLlxEFA> Supplementary Video #1). Another potential solution would be for the patient to be carefully instructed by their physical therapist on how to place the mobile device to obtain reliable measures of knee range of motion. The additional time spent by the physical therapist would benefit both the patient as well as the physical therapist who could review the patient's range of motion measures at subsequent appointments. As this is a single subject technical report these results are not generalizable to patient with knee injury and surgery. Future research will be focused on testing the reliability and validity of this measure taken independently by patients with knee pathology in their home setting as this is the intended use of the mobile app and comparing these measurements to those obtained by physical therapists in a clinical setting. Further research is required with a large sample size to test the reliability, validity and clinical applicability of this smartphone-based measurement.

This preliminary study for a technical note could have been strengthened by making the range of motion measurements blinded, as well as testing inter-rater reliability with a novice physical therapist and a patient conducting the app measurement. As physical therapists continue to improve patients' independence with range of motion measurements, a future direction of research could be how self-measurement contributes to patient adherence to range of motion home exercises. Another area of future research is how this home measurement can be integrated with telehealth visits, video check-ins, and remote patient monitoring. There is a possibility for cost savings and improving timeliness of care if such measures could automatically



**Figure 3. This image shows how a patient would independently measure their knee extension (E4) and knee flexion (F3) range of motion along with the app screen that is presented in each case.**

trigger clinician alerts while the patient utilizes the app for home rehabilitation.

To provide data transparency, the authors have provided raw values for each measurement in the supplementary table and as much detail as possible to allow other clinicians and researchers to test and evaluate these findings.

## CONCLUSIONS

The results of these preliminary tests demonstrate strong positive correlations across mobile devices and compared

to standard goniometric measurements. This simple and unique mobile app can provide patients with an effective method to measure of their knee range of motion at home. Further study using larger sample sizes is warranted.

CONFLICTS OF INTEREST

The primary author (NS) has a conflict of interest as he is the CEO of Curovate. The second and third authors have no conflicts of interest to declare.

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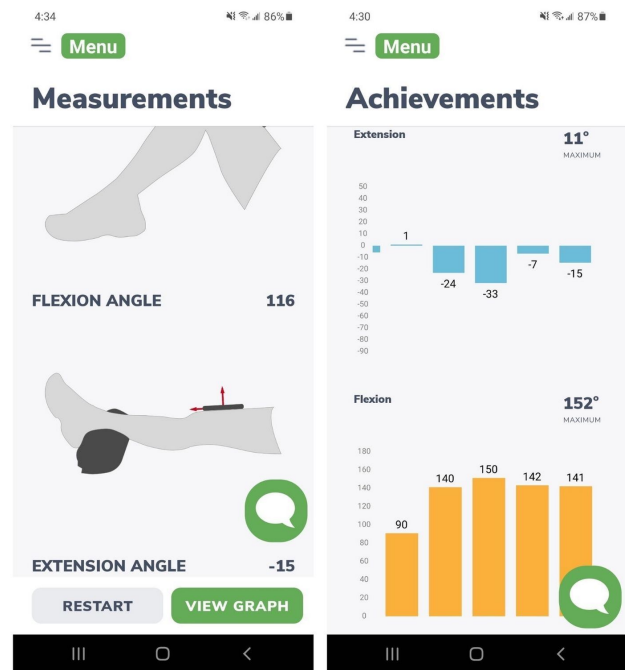


Figure 4. This image shows the results and measurements as they are presented to the patient once they have completed the process of measuring their range of motion as depicted in Figure 3.



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## SUPPLEMENTARY MATERIALS

### Appendix

Download: <https://ijspt.scholasticahq.com/article/33043-can-a-patient-use-an-app-at-home-to-measure-knee-range-of-motion-utilizing-a-mobile-app-curovate-to-improve-access-and-adherence-to-knee-range-of-m/attachment/83453.pdf>

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