# A simple clinical method of recording knee kinematics during functional activity using flexible electrogoniometry and the Strathclyde University Data Logging System (SUDALS) for use in multi-centre RCTs of TKA

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## 1. INTRODUCTION

Functional assessment of the knee following an intervention such as TKA provides valuable information about the dynamic behaviour of the joint, which in turn helps the surgeons and other rehabilitation health care professionals in evaluating the efficiency of their intervention and improve the same. Further, the outcome of such assessments is useful in meeting the increasing demand for evidence based practice. Currently, flexible electrogoniometers are being used for such applications and these transducers are gaining popularity due to their accurate, precise and reproducible nature. [1]. Flexible electrogoniometry system facilitates the precise measurement of knee flexion/extension with time efficiency unlike the conventional motion analysis systems which are expensive and time consuming. [1]. However, among the various commercially available data collecting system for use with a flexible electrogoniometer, there is currently a lack of a user friendly system. What is required is a system where by clicking a single button a user can remotely record and transmit the information pertaining to the flexion/extension of the knee during ADL via a Bluetooth wireless connection. The system should be pre-programmable so that all the user needs to do is attach the instruments, turn on the logger and then initiate data collection by pressing an infra red key fob. During functional activities, the user-friendly system should store the data from these transducers and transfers the same to a PC at the end of the recording period via a bluetooth connection. The logger should be started and stopped at will using the key fob and hence multiple tests can be recorded and only the data of interest is stored. Software on the PC should then display the angular displacement and allows visual inspection of the entire sequence of recordings or particular events of interest. Such a device could be used to quantify the knee joint motion outside the gait laboratory, efficiently, by clinical staff at low cost and hence would be suitable for use in multi-centre RCTs of TKA.

### 1.1 AIM

The aim of this project was to develop such a system which we have called the Strathclyde University Data Logging System (SUDALS). SUDALS is a 6 channel, battery operated, remote control, microprocessor based, system that has the potential to collect kinematic joint data such as flexion/extension of the knee and also mark movement events such as foot falls during various ADL. Flexible electrogoniometers are used to measure the kinematics and force sensing resistors can be used as footswitches or other event markers. Prior to releasing the system for general use, we validated the newly developed system against a gold standard and tested its reliability.

## 2. METHODS

Reliability of the system was tested by carrying out a pilot study with 10 young normal healthy subjects (age range 24 to 30 years) who volunteered for this study. The data pertaining to the flexion/extension of the knee of the subjects was collected via the body mounted transducer (flexible electrogoniometer) interfaced with SUDALS. In addition to this, light weight force sensing resistors (FSR) or footswitches were attached to the first metatarsal area of the toe and to the heel for marking the events by indicating the contact between the foot and the floor. Since the transducer was mounted in the sagittal plane of the knee, the output of the device represented the flexion-extension angle of the knee. Both the electrogoniometers and footswitches were interfaced to SUDALS via thin flexible cables. All the 10 subjects were asked to perform the following 6 activities – Walking, In and Out of a Chair, Stair ascent, Stair descend and deep squat corresponding to daily living. Start and stop commands were given at the beginning and completion of each task and the subjects were asked to repeat these tasks three times for reproducibility reasons. Further, the event marking was taken into account by the FSR's attached to the toes and heels of each subject. The data collected during these activities were averaged for each subject individually and were analyzed for maximum and minimum knee angle. This procedure was carried out for both the left and right knees and was then averaged to provide the group mean.

Test for concurrent validity was carried out by simultaneously recording the knee movement during gait using 7 camera Vicon movement analysis system with the flexible electrogoniometry. Three normal subjects (one male and two females, age range 24 to 30 years) were recruited for this study. A set of retro-reflective markers were attached to the hip, thighs, knees, shanks and feet for gait analysis and the user-friendly system of electrogoniometry was attached to the volunteers as explained above. Both the systems were synchronized by attaching 4 FSR's (2 FSR'S were attached to the toe and another 2 were attached to the heel) to one of the foot (either right or left) of the subjects. Whereby, one pair of foot switches were connected to the vicon and the other pair were connected to the SUDALS. The subjects were asked to start walking using the foot in which all the four FSR's were attached and the data pertaining to the flexion/extension of the knee was recorded from both the systems simultaneously during six free-speed walks across a 7-metre section of level vinyl flooring. Each cycle began with a heel strike and terminated with the next heel strike. This information was used to synchronize the starting and ending of the gait cycles recorded by both the systems. The results from the vicon were then time normalized to percentage of gait cycle and compared with the results from SUDALS.

## 3. RESULTS

The concurrent validation of the SUDALS and Vicon system is illustrated in figure1. The maximum knee flexion/extension values obtained during various ADL from SUDALS was compared against the values published in the literature. This is illustrated in figure 2.

## 4. DISCUSSION

The results of our studies show that the maximum knee flexion values obtained from SUDALS are very similar to those reported in the literature with little variations [2], [3], [4]. The reason for these minimal variations could be that, these researchers have used 3D motion analysis systems instead of flexible electrogoniometer for measuring the knee angle. Also, the results of the validity studies, shows that there is a good concurrent validity among both the systems. The pattern of the trace obtained from both the systems was similar with greatest differences occurring at the end of the stance. However, the maximum knee flexion angles obtained from both the systems are similar with a very little variation of 1° approximately.

## 5. CONCLUSION

In summary, the user friendly system of flexible electrogoniometer (SUDALS) seems to be a reliable system in collecting data from the knee during ADL. Further, compared to the conventional motion analysis systems; it is inexpensive and allows increased mobility of the subjects by eliminating the inconvenience caused by long trailing cables found in hard wired systems. This in turn has facilitated data collection in an unconstrained and daily living environment. The results of the present study in conjunction with the literature review support the use of SUDALS together with flexible electrogoniometers as a complimentary instrument along with other functional assessment questionnaires in providing objective and meaningful clinical data and suitable for use by clinical research staff in multi centre RCTs of TKA.

## 6. REFERENCES

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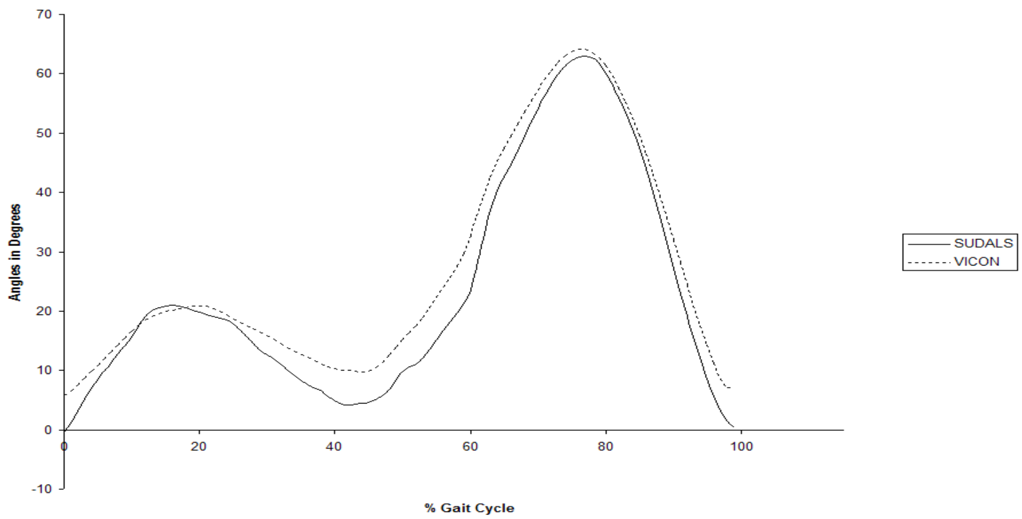


Figure 1 Concurrent validity between SUDALS and Vicon System

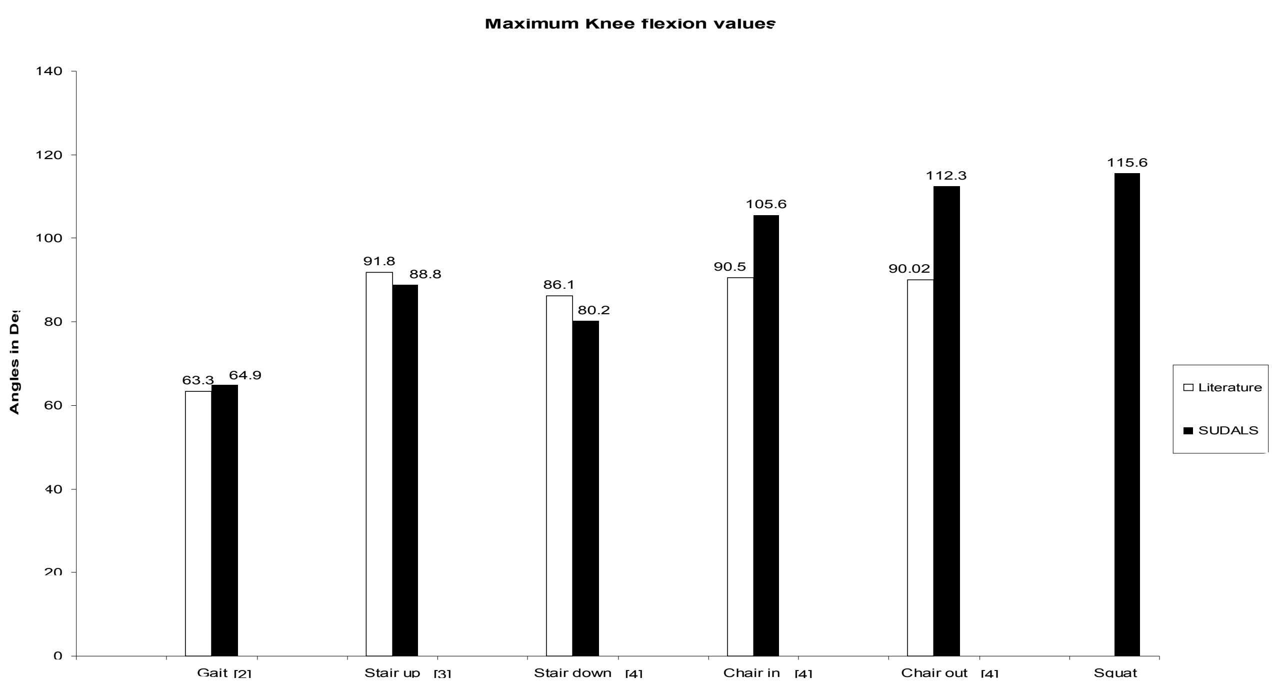


Figure 2 Chart comparing the Maximum knee flexion values during ADL obtained from SUDALS Vs the literature