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Optimising the Validity of Shoulder Range of Motion Evaluation: A Comparative Study

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Abstract: *During the assessment process diachronically conceived in the initial, dynamic, and final stages, data recording is often performed by instrumental measurement using the goniometer. In Romania, the logistics equipment - hardware and software - has a very low or even absent incidence in the conceptual and applicative design of kinetic rehabilitation programmes. Some disadvantages of universal goniometry are revealed by relatively accurate measurements, given that the testing instrument may provide erroneous data when the specific rules are not followed. Moreover, the tester's interpretation of angular values may vary; therefore, in order to objectify and validate the specific assessment and evaluation, we propose a precise angular motion measurement device called Kinesimeter, assisted by specific Labview software designed at the Human Movement Science Discipline of "George Emil Palade" University of Medicine, Pharmacy, Science and Technology of Târgu Mureş. Our purpose was to compare the results and interpret the differences arising from the use of two specific assessment methods for the shoulder range of motion. Thus, the values recorded by two physiotherapists using the manual goniometer were compared with the values recorded with the Kinesimeter. In order to validate the results, we calculated statistical parameters such as correlation and significance. We strongly believe that the proposed hardware and software device for measuring, controlling, and analysing shoulder movements can become a modern performing tool needed by each rehabilitation institution, having a dual role - investigative and monitoring of a rehabilitation programme - both extremely important, additional to current measurements with the goniometer.*

Keywords: *goniometry; shoulder; proprioception; Kinesimeter.*

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Introduction

Many daily activities, such as eating, hair combing, placing an object on the shelf or other activities, are highly dependent on the range of motion of the shoulder (Engdahl & Gates, 2018; Klemt et al., 2018; Miura & Fukushima, 2008; Norkin & White, 2016). Just like the elbow or any other joint, restricted active shoulder range of motion (AROM) leads to serious disability (Van Rijn et al., 2018; Oosterwijk et al., 2018; Raiss et al., 2007).

A healthy person's values for shoulder flexion lie between 160° and 180°, extension between 50° and 60°, abduction between 170° and 180°, internal rotation between 60° and 100°, and external rotation between 80°-90° (Balint et al., 2007; Chiriac, 2000; Magee, 2002; Sbenghe, 1987). A research carried out by Namdari et al. (2012) has highlighted that, for the accomplishment of daily living activities, a person needs approximately 121° of flexion, 46° extension, 128° abduction and 59° external/internal rotation. Similar research has shown that a person only needs approximately 108° for flexion, 105° for abduction, and 79° for internal rotation (Gates et al., 2016). A decrease in active range of motion can be an indicator of tendinitis, bursitis, contusion, fractures, arthritis, sprains, strains, adhesive capsulitis, and other pathologies (Tveitå et al., 2008). Of course, after different traumatic injuries, we can find a degree of limitation in shoulder active range of motion (Bullock et al., 2018; Gillet et al., 2017).

Regarding the start of a kinetic programme, we can say that after taking over the medical history, the patient must be physically and functionally examined, being recorded measurable data (Longo, 2014; Bailey et al., 2017; Sbenghe et al., 2019). For choosing the most appropriate physical therapy interventions, it is mandatory to examine joint integrity and mobility (Kolber & Hanney, 2012). During the assessment process diachronically conceived in the initial, dynamic, and final stages, data recording is often performed by instrumental measurement using the goniometer (Hongmin et al., 2018; Keijsers et al., 2018; Reissner et al., 2019). The universal goniometer (UG) is a simple measuring tool used by physiotherapists, orthopaedic surgeons, rheumatologists, and other physicians (Keogh et al., 2019; Norkin & White, 2016). Besides this universal goniometer, there are also some other tools used for shoulder active range of motion assessment, which includes inclinometry, photography or a smartphone application, and visual estimation (Blonna et al., 2012; Clarkson, 2005; Dent et al., 2020; Ferriero et al., 2013; Kolber & Hanney, 2012; Milanese et al., 2014; Mullaney et al., 2010; Ockendon & Gilbert, 2012;

Werner et al., 2014; Roldán-Jiménez et al., 2019). The Coach's Eye is another instrument to assess the range of motion (Krause et al., 2015). In Romania, the logistics equipment - hardware and software - has a very low or even absent incidence in the conceptual and applicative design of evaluation during kinetic rehabilitation programmes.

Some disadvantages in universal goniometry are revealed by relatively accurate measurements, given that the testing instrument may provide erroneous data when the specific rules are not followed (Bashardoust Tajali et al., 2016; García-Rubio et al., 2019; Lee et al., 2015; Martins Ferreira de Carvalho et al., 2012). Moreover, the tester's interpretation of angular values may vary (Rettig et al., 2015). When referred to intra- and inter-rater reliability, a smartphone application (DrG) had values > 0.86 (Otter et al., 2015), and the inclinometer reported 0.65 (Werner et al., 2013). There is an old general assumption that higher reliability is reached when the universal goniometer is used by an experienced tester (Armstrong et al., 1998; Fish & Wingate, 1985).

Therefore, in order to objectify and validate the specific assessment and evaluation, we propose a precise angular motion measurement device called Kinesimeter, assisted by specific Labview software designed at the Human Movement Science Discipline of "George Emil Palade" University of Medicine, Pharmacy, Science and Technology of Târgu Mureş, Romania.

Our purpose was to compare the results and interpret the differences arising from the use of two specific assessment methods of the active range of motion of the shoulder joint. Thus, the values recorded by two physiotherapists using the universal goniometer were compared with the values recorded with the Kinesimeter. The hypothesis from which we have started this research is that inter-tester differences are lower and some errors can be avoided when the Kinesimeter is used, instead of the universal goniometer.

Methodology

In this ascertaining research, we used the following methods: the bibliographic study method, the observation method, the questionnaire method, the measurement and recording method, the mathematical and statistical processing method, and the graphical method.

Six testers, split into three groups of two (group A, B, and C), used a universal goniometer and a Kinesimeter to measure shoulder flexion, extension, abduction, internal and external rotation on a total of 270 subjects, asymptomatic patients from the Country Emergency Clinical

Hospital of Târgu Mureş, Romania, during a period of nine months (May 2019 - January 2020). An informed consent form was completed by all the subjects and also a questionnaire. In the questionnaire, subjects were asked about their age, profession, arm dominance, health status and state of fitness. Exclusion criteria consisted of frozen shoulder and recent shoulder surgery.

Our measurements were conducted on the dominant arm. The left arm was dominant in 25 of the 270 subjects (9.26%). The mean age of the subjects was 54.6 years. 31.48% of them had a job involving physical work in a field of distribution, agriculture, construction, manufacturing, etc., while 41.48% had a static workplace in the field of technology, online sales, law, human resources, public administration, finance, etc. 27.04% of the subjects were retired. The mean age of the testers was 37.6 years, and the mean of their years of experience was 6.2.

Before the measurements, all subjects performed an approximately five-minute standard warm-up supervised by one tester. At the same time, the test mechanism was explained to the subjects. Subjects were informed that they must be mentally and physically relaxed, comfortably seated and that contracture, fear or non-cooperation may limit their range of motion.

In this research, we used a blinded repeated-measures design. Each subject was measured by two physiotherapists with at least two years of experience through both goniometry and kinesimetry methods. Subjects were asked to move their arm to the end-range and maintain the position until the measurement was performed. Each tester measured all 270 subjects, noted their results, and did not communicate them to the other tester. Group A (tester A1 and A2) measured flexion and extension of the shoulder, group B (tester B1 and B2) measured internal and external rotation of the shoulder, and group C (tester C1 and C2) measured abduction of the shoulder.

The instruments that we used were the Elite Medical Instruments plastic 12" goniometer with the International Standards of Measurement system and the Kinesimeter designed at the Human Movement Science Discipline of “George Emil Palade” University of Medicine, Pharmacy, Science and Technology of Târgu Mureş, Romania. The Kinesimeter consists of a vertical stable stand with a horizontal movable arm, which can rotate around an axis. The Kinesimeter can be connected to a laptop via a N. I. 6008 transducer, and based on a software interface, can reproduce the movements of the mobile arm in the form of a real-time oscillogram.

The active range of motion for flexion and extension was assessed with the subject sitting, holding the arm in anatomical position. The centre of the goniometer and the axis of the Kinesimeter were placed on the lateral part of the scapulohumeral joint. The fixed arm followed the lateral humeral epicondyle, parallel to the mid-axillary line of the trunk, while the movable arm was parallel to the midline of the lateral face of the arm, following the humeral lateral epicondyle.

The active range of motion for the abduction was assessed with the subject sitting, holding the arm in anatomical position. The centre of the goniometer and the axis of the Kinesimeter were placed on the back face of the scapulohumeral joint, in its centre. The fixed arm was on the lateral line of the trunk, while the movable arm was parallel to the midline of the posterior face of the arm, following the middle phalanges. In the case of elbow valgus, the olecranon was followed.

The active range of motion for external and internal rotation was assessed with the subject in dorsal decubitus, with the shoulder in abduction of 90º, elbow flexed at 90º, arm in pronation, and the palm looking towards the head. The centre of the goniometer and the axis of the Kinesimeter were placed on the back of the elbow joint. The fixed arm followed the middle phalanges (perpendicular to the arm), while the movable arm was parallel to the midline of the posterior face of the forearm, also following the middle phalanges.

Results

Comparative analysis (statistically processed using the GraphPad Prism 8 for Windows) of the statistical significance of differences between the results obtained by testers with the help of two specific assessment methods for shoulder active range of motion (universal goniometer and Kinesimeter) and the t-test calculation show the following:

When talking about shoulder flexion assessed by group A at a probability threshold of $P < 0.05$, the difference between the two rows of data (tester A1 and A2) recorded by a goniometer is statistically significant, the calculated t-value being 5.343 and that of $R^2 = 0.05038$, with a 95% confidence interval ranging between 1.379 and 2.984, while the difference between the two rows of data (tester A1 and A2) recorded by the Kinesimeter is not statistically significant, the calculated t-value being 1.933 and that of $R^2 = 0.006895$, with a 95% confidence interval ranging between -0.0126 and 1.546. (Table 1)

Group A also assessed shoulder extension where, at a probability threshold of $P < 0.05$, the difference between the two rows of data (tester A1 and A2) recorded by a goniometer is statistically significant, the calculated t-value being 4.887 and that of R^2 = 0.04251, with a 95% confidence interval ranging between 1.183 and 2.773, while the difference between the two rows of data (tester A1 and A2) recorded by the Kinesimeter is not statistically significant, the calculated t-value being 1.3070 and that of R^2 = 0.003474, with a 95% confidence interval ranging between -0.2381 and 1.334. (Table 1)

Table 1. Comparative analysis of assessment results measured by Group A – Shoulder flexion and extension

Statistical indicators	Flexion		Extension	
	Goniometer	Kinesimeter	Goniometer	Kinesimeter
Significantly different? (P < 0.05)	Yes	No	Yes	No
t, df	t = 5.343, df = 538	t = 1.933, df = 538	t = 4.887, df = 538	t = 1.3070, df = 538
Mean of column A	174.4	174.9	54.64	56.04
Mean of column B	176.6	175.7	56.61	56.59
Difference between means	2.181 ± 0.4083	0.7667 ± 0.3967	1.978 ± 0.4047	0.5481 ± 0.4002
95% confidence interval	1.379 to 2.984	-0.0126 to 1.546	1.183 to 2.773	-0.2381 to 1.334
R-squared	0.05038	0.006895	0.04251	0.003474

Source: results from the statistical processing of data arising from original research

Regarding shoulder external rotation assessed by group B at a probability threshold of P < 0.05, the difference between the two rows of data (tester B1 and B2) recorded by a goniometer is not statistically significant, the calculated t-value being 1.765 and that of R^2 = 0.005687, with a 95% confidence interval ranging between -0.08652 and 1.531, while the difference between the two rows of data (tester B1 and B2) recorded by the Kinesimeter is not statistically significant, the calculated t-value being 0.2937 and that of R^2 = 0.006895, with a 95% confidence interval ranging between -0.6954 and 0.9398. (Table 2)

Group B also assessed shoulder internal rotation where, at a probability threshold of P < 0.05, the difference between the two rows of data (tester B1 and B2) recorded by a goniometer is statistically significant, the calculated t-value being 3.266 and that of R^2 = 0.01944, with a 95% confidence interval ranging between 0.5578 and 2.242, while the difference between the two rows of data (tester B1 and B2) recorded by the Kinesimeter is not statistically significant, the calculated t-value being 0.6614 and that of $R^2 = 0.0008125$, with a 95% confidence interval ranging between -1.117 and 0.5545. (Table 2)

Table 2. Comparative analysis of assessment results measured by Group B – Shoulder external and internal rotation

Statistical indicators	External rotation		Internal rotation	
	Goniometer	Kinesimeter	Goniometer	Kinesimeter
Significantly different? (P < 0.05)	No	No	Yes	No
t, df	t = 1.765. df = 538	t = 0.2937. df = 538	t = 3.266. df = 538	t = 0.6614. df = 538
Mean ± SEM of column A	83.40	83.70	85.63	86.93
Mean ± SEM of column B	84.12	83.82	87.03	86.64
Difference between means	0.7222 ± 0.4117	0.1222 ± 0.4162	1.400 ± 0.4287	-0.2815 ± 0.4256
95% confidence interval	-0.08652 to 1.531	-0.6954 to 0.9398	0.5578 to 2.242	-1.117 to 0.5545
R-squared	0.005687	0.0001603	0.01944	0.0008125

Source: results from the statistical processing of data arising from original research

When talking about shoulder abduction assessed by group C at a probability threshold of $P < 0.05$, the difference between the two rows of data (tester C1 and C2) recorded by a goniometer is statistically significant, the calculated t-value being 2.471 and that of $R^2 = 0.01122$, with a 95% confidence interval ranging between 0.1930 and 1.689, while the difference between the two rows of data (tester C1 and C2) recorded by the Kinesimeter is not statistically significant, the calculated t-value being 0.9721 and that of $R^2 = 0.001753$, with a 95% confidence interval ranging between -0.3743 and 1.108. (Table 3)

Table 3. Comparative analysis of assessment results measured by Group C – Shoulder abduction

Statistical indicators	Abduction	
	Goniometer	Kinesimeter
Significantly different? (P < 0.05)	Yes	No
t, df	t = 2.471. df = 538	t = 0.9721. df=538
Mean ± SEM of column A	172.7	173.1
Mean ± SEM of column B	173.7	173.4
Difference between means	0.9407 ± 0.3807	0.3667 ± 0.3772
95% confidence interval	0.1930 to 1.689	-0.3743 to 1.108
R-squared	0.01122	0.001753

Source: results from the statistical processing of data arising from original research

Conclusion

A first general conclusion that emerges from our investigation, such as an interpretation and analysis of recorded results, is that our hypothesis has been confirmed as follows:

● Statistically significant differences occurred between testers' results during the assessments of the shoulder active range of motion when the goniometer was used in 4 out of 5 measurements (flexion, extension, abduction, and internal rotation).

● When the Kinesimeter was used, thanks to the assistance of the hardware device by its specific software and to data recording in a digital form, inter-tester differences were lower and no statistically significant differences were found between testers in 5 out of 5 measurements of the shoulder active range of motion (flexion, extension, abduction, internal and external rotations).

The current findings conclude that our device is a valid and reliable instrument to measure shoulder active range of motion. The Kinesimeter provides, with the help of its software, information on angles and degrees in real-time and can be used to monitor rehabilitation programmes due to its real-time feedback.

The possibility to adapt the Kinesimeter makes its use possible in the assessment of proprioception or motor suggestibility. We strongly believe that the proposed hardware and software device for measuring, controlling and analysing shoulder movements can become a modern performing tool needed by each rehabilitation institution, having a dual role - investigative and monitoring of a rehabilitation programme - both extremely important, additional to current measurements with the universal goniometer.

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