# fizjoterapia polska

POLISH JOURNAL OF PHYSIOTHERAPY

OFICJALNE PISMO POLSKIEGO TOWARZYSTWA FIZJOTERAPII

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## Ocena wpływu kompleksowej terapii uzdrowiskowej z zastosowaniem wód leczniczych radoczynnych na poziom hemoglobiny – badania wstępne

## Assessment of the influence of comprehensive spa therapy with therapeutic radon waters on hemoglobin levels: preliminary study

## Problem trudno gojących się ran i odleżyn w fizjoterapii

## The problem of difficult to heal wounds and pressure ulcers in physiotherapy



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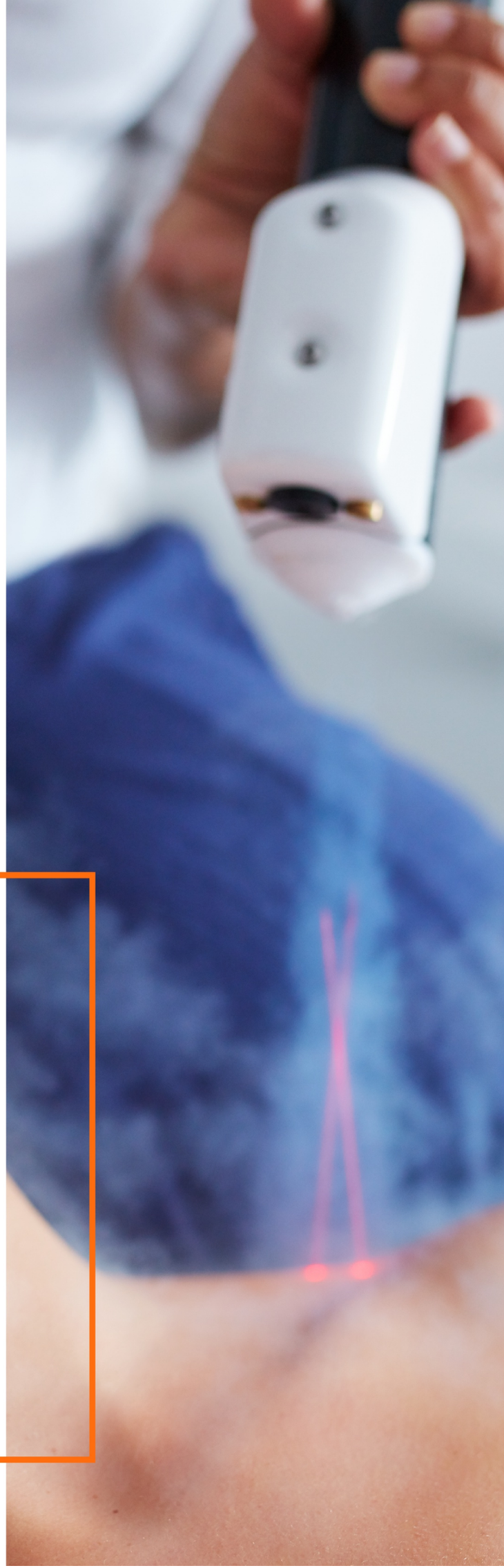

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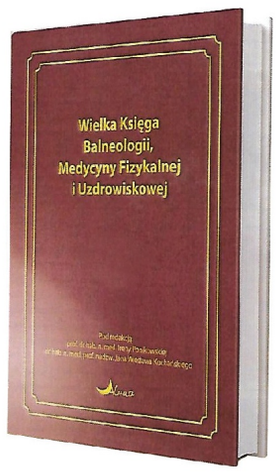


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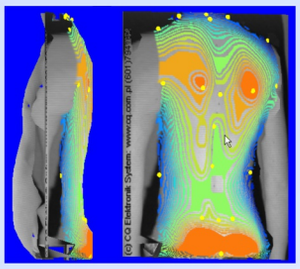

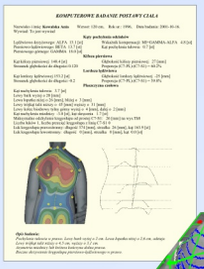

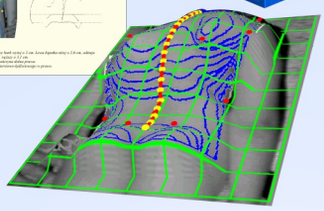

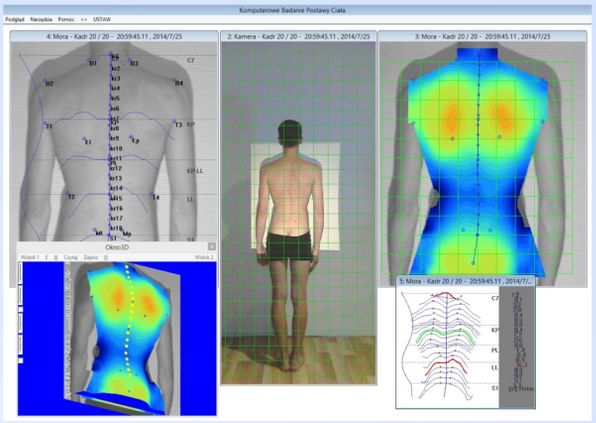

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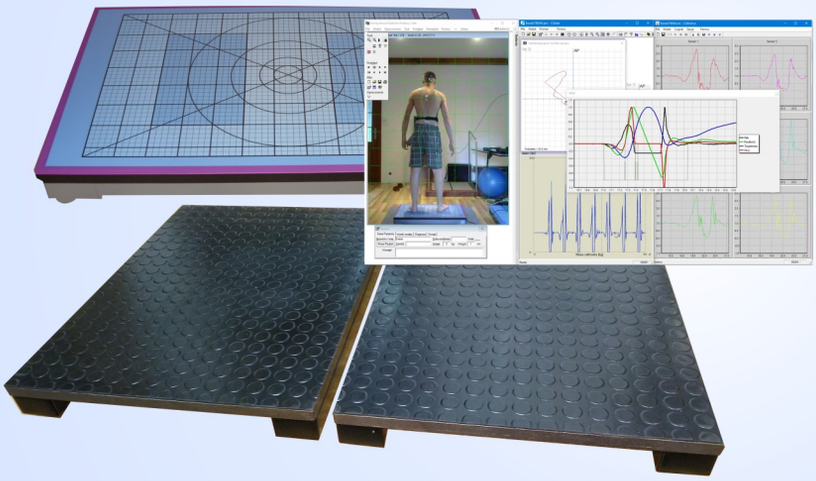

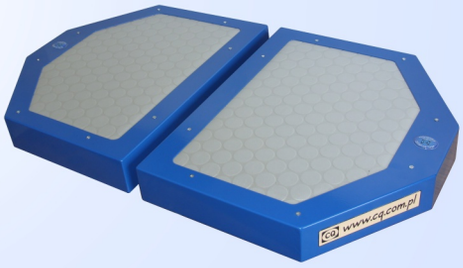

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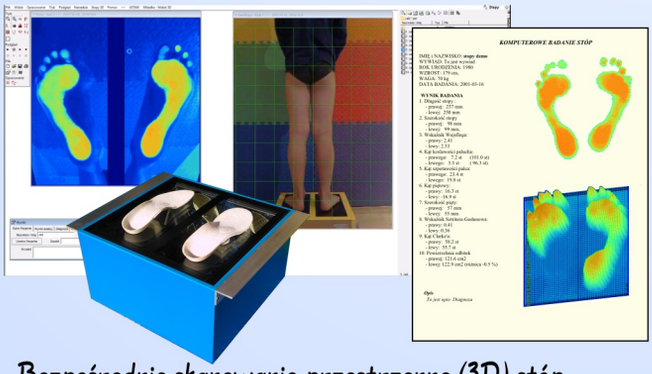

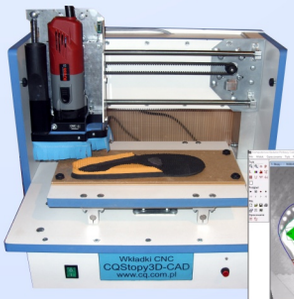

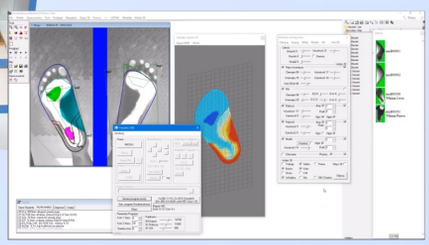

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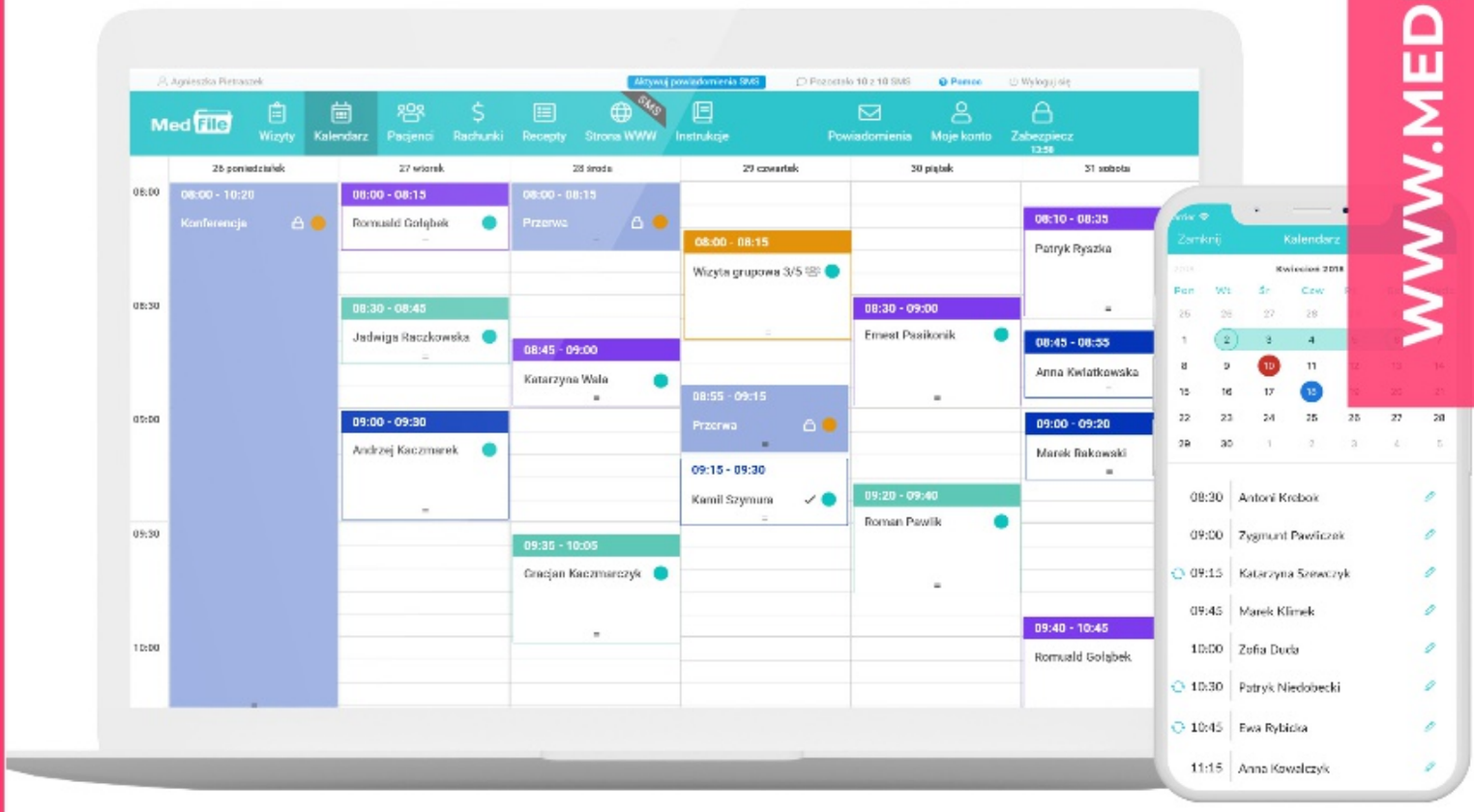


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# Ocena rzetelności pomiarów precyzji ruchów manipulacyjnych palca wskazującego wykonanych urządzeniem własnego pomysłu w kontekście przyszłych zastosowań diagnostycznych

*The precision of index finger manipulative movements as measured with a self-designed device – potential diagnostic applications*

以独创设备进行食指操控技能精确测量的准确性评估，作为未来诊断应用。

**Jacek Polechoński[1(A,B,C,D,E,F)], Jolanta Rojczyk-Chmarek[2(D,E,F)], Kajetan Słomka[3(C)]**

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**Streszczenie**

Cel. W pracy zaprezentowano oryginalne manipulandum do badania parametrów ruchów w stawie śródręczno-paliczkowym palca wskazującego. Przedstawiono wyniki badań rzetelności pomiarów precyzji ruchów wykonanych urządzeniem oraz omówiono możliwości jego przyszłych zastosowań diagnostycznych.
Materiał i metodyka. Badaniami objęto grupę 43 młodych mężczyzn. Precyzję ruchu oceniano opisanym w pracy przyrządem własnego pomysłu. Zadaniem badanych było wielokrotne trafianie do wyznaczonego celu poprzez wykonanie wyizolowanego ruchu. Ocenie podlegały dwa rejestrowane parametry: czas i droga dotarcia do celu. Rzetelność pomiarów szacowano analizą korelacji międzyklasowej.
Wyniki. Wykazano konieczność przeprowadzenia ponad 25-30 powtórzeń w celu uzyskania rzetelnych pomiarów. Rezultaty badań wskazują również na możliwość uczenia się ruchu przez osoby badane.
Wnioski. Manipulandum umożliwia rzetelną ocenę precyzji ruchów pod warunkiem wykonania dość sporej liczby pomiarów, co jednak nie stanowi problemu podczas badań, ponieważ czas trwania pojedynczej próby wynosi zaledwie 1-1,5 s, a ruch w stawie śródręczno-paliczkowym nie powoduje zmęczenia. Aby zminimalizować efekt uczenia się ruchu zasadne wydaje się modyfikowanie warunków wykonywania zadania ruchowego. Autorzy zakładają, że testowane urządzenie może znaleźć zastosowanie we wczesnej diagnostyce schorzeń o podłożu reumatycznym lub neurologicznym, prowadzących do upośledzenia sprawności funkcjonalnej dłoni.

**Słowa kluczowe:**
manipulandum, precyzja ruchu, reumatoidalne zapalenie stawów, mała motoryka

**Abstract**

Aim. The paper introduces a self-designed manipulandum built to assess the parameters of motion at the metacarpophalangeal joint of the index finger. The reliability of movement precision measurements is presented; potential diagnostic applications have been discussed.
Material and methods. The study group comprised 43 young men. Movement precision was evaluated with a self-designed manipulandum. The task was to repeatedly touch the target using an isolated movement. Two parameters were assessed, ie., time and distance to target. Measurement reliability was estimated with intraclass correlation analysis.
Results. 25 to 30 movement repetitions were required to achieve reliable measurements. The findings also reveal that movement repetition might result in movement learning.
Conclusions. provided a large number of repetitions are performed, the manipulandum enables reliable assessment of movement precision. Repetition does not pose a problem since a single trial only lasts for1-1.5 s; furthermore, movement at the metacarpophalangeal joint does not cause fatigue. The conditions of movement tasks should be modified to minimize the effect of movement learning. We believe the device under test might be applied to early diagnosis of rheumatic or neurological disease leading to functional compromise of the hand.

**Key words:**
manipulandum, movement precision, rheumatoid arthritis, fine motor skills

**摘要**

目的。研究中介绍了食指掌指关节运动参数测试用的独创操纵器，给出以设备进行的食指操控技能精确测量结果，并讨论未来以其作为诊断应用的可能性。
材料及方法。共 43 名年轻男性参与试验，并以上述独创设备进行运动精确性评估。受试者的任务在于多次以个别运动方式反复击向指定目标。由两项参数记录进行评估，包括达成目标的时间和路线等，由类间相关分析估计测量的可靠性。
结果。结果显示必须进行 25-30 次以上的重复，才能达成可靠的测量。试验结果显示受试者的运动学习可能性。
结果。使用操纵器得以可靠地评估运动准确性，但必须进行大量的测量，这对测试不会造成问题，因为单次测试所需时间仅 1-1.5 秒，不会造成掌指关节的运动疲劳。要将运动学习效果最小化，修改运动任务的执行条件似乎是合理的。设备创作者发现受试设备可应用于造成手掌功能效能受损的风湿性或神经性疾病的早期诊断。

**关键词：**
操纵器、运动精确性、类风湿性关节炎、低运动技能

## Introduction

Manipulation skills of the human hand allow complex and high-precision movements. These skills are speculated to have developed in the process of evolution along with higher-level cognitive functions [1]. Due to the complexity of movements, an examination of hand functions is difficult to perform. There is no universally recognized method; the majority of assessments are based on subjective experience of the examiner; therefore the conditions for precision hand movements have not been thoroughly investigated. Meinel [2] defined accuracy and precision as those features of movement that lead to the implementation of movement task. The theoretical rationale for investigating the above-defined movement accuracy is Fitts' law discovered by Fitts half a century ago, which concerns relations between movement speed, accuracy and the size of the target at which a movement task is directed [3]. The law is now widely used in ergonomics, spatial arrangement of instruments in advanced computer systems and cockpits design. According to Fitts' law the time needed to acquire a target is a function of the distance to and size of the target. The principle is applicable both to movements performed directly with the hand and those made with pointer devices. Due to a large number of articulations, degrees of freedom as well as diversity and complexity of hand movements, objective assessment of movement precision remains a challenge. Special apparatus and software are needed to assess movement speed, displacement and correct performance of a movement task. It seems well justified to start with simple single-joint movements to facilitate further analysis of more complex movement tasks.

The precision of manipulative hand movements might decrease in the course of diseases of different etiology. The so-called fine motor skills require normal function of the nervous system. Decreased accuracy of manipulative movements might result from neurological disorders including Parkinson's disease, peripheral neuropathy or multiple sclerosis, where the precision of movements becomes worsened due to hand tremor. The symptom also develops in a large proportion of healthy individuals with essential tremor (ET), the most common movement disorder in older people [4].

The accuracy of manipulative movements may also be compromised by rheumatic diseases and especially rheumatoid arthritis (RA), whose symptoms first develop in distal joints of the upper extremity [5, 6, 7]. It might therefore be speculated that patients with early RA stages will also exhibit changes in hand movement parameters, and, consequently, a decrease in the quality of manipulative movements. Joint stiffness, which is typical of this disease, increases passive resistance in joints while muscle strength may decrease to 45% of normal [8, 9]. The resultant decrease in joint stability and biomechanical properties reduces both range of motion and movement precision.

Treatment success largely depends on timely diagnosis and prompt therapy application. Imaging techniques only

identify joint pathology characteristic of RA in the later stages of the disease. Early detection of functional defects may have a significant diagnostic value and hence the need for a method to objectively assess joint function. It seems essential to focus on those structures that are often the first to be affected, ie., the interphalangeal and metacarpophalangeal joints of the hand.

The index finger and thumb play an important role in manipulative movements. Thumb opposition permits the majority of grips, including the pinch grip, which allows holding and manipulating small objects. It is believed that these movements were critical for tool-related behaviors in human evolutionary history [10]; however, they may become compromised resulting from several disorders. Carpal tunnel syndrome, which is a common complication of RA as well as inflammatory lesions within the interphalangeal and metacarpophalangeal joints characteristic of this disease frequently result in impaired muscle and force responses of the index finger [11].

Considering potential diagnostic applications, we assessed the reliability of measurements of flexion and extension movements in the metacarpophalangeal joint of the index finger using a self-designed manipulandum.

## Material and methods

Forty-three healthy and fit students of the Academy of Physical Education in Katowice entered the study (mean age 23.7 ± 2.3 years, body height 183 ± 7.2 cm, body weight 81.0 ± 9.1 kg). All study participants were right-handed; none had previously suffered a hand injury that might compromise their manual dexterity.

We used a patented self-designed Manipulandum for Testing Parameters of Flexion and Extension Movements in the Metacarpophalangeal Joint of the Index Finger [12] (Figs. 1, 2, 3). The device was working in combination with Fritz software specialty made to test Fitts' law.

The manipulandum consists of a ferromagnetic stand (1) on which a supporting pillar is mounted (2) with a stabilizer bearing (3). An axle (4) connects the bearing to an angular displacement sensor (5) on one side, and an index finger bed (6) on the other side. The bed has a belt (7) to stabilize the index finger. The bed and belt accurately transfer the movement in the metacarpophalangeal joint of the index finger onto the axle of the angular displacement sensor. A rotating rod (8) is also mounted on the stand, which ensures a stable index finger bed position before measurements start. There is also a vertically- and horizontally-adjustable hand-support system (9) consisting of a plate (10) with an element separating the index from the middle finger (11). The plate is mounted on a pillar (12) enabling plate height adjustment using a mechanical lock (13). A lever-steered (14) built-in on-off magnetic switch (15) makes it possible to move the pillar along stand surface as well as on-stand fixation (Figs. 1 and 2). Pre- and post-movement hand positions on the manipulandum are presented in Fig. 3a and 3b.

The study task was moving the index finger bed through flexion of the metacarpophalangeal joint. The movement was shown on a computer monitor in the form of movement indicator displacement; the indicator was to be placed and fixed within the target area in the shortest possible time. Each trial started with a sound signal. The movement indicator was a circle moving along a straight line; the target area corresponded to a surface between two segments vertical to movement indicator course. The study parameters were as follows: the distance between movement indicator's initial position and target area (d) and the width of the target area (w) (Fig. 4). At the start of the measurement, the target area was shown on the monitor; then, after a randomly selected time interval (2-5 s), the movement indicator appeared. Trial duration was the time between the initiating sound signal and the moment of the indicator being fixed in the target area. To familiarize with the experimental procedure, the participants first performed a mock task followed by ten study trials.

Fritz software allows presentation of measurement parameters in pixels (px). The following parameters were used in the study: target area – right side of the monitor, target area width (w) – 40 px, movement indicator radius – 18 px, distance between movement indicator and target area (d) – 300 px, movement indicator direction – movement towards the target area was initiated by flexion of the metacarpophalangeal joint of the index finger. The monitor was a VGA monochrome with resolution of 640×480 px.

Following approval of the Ethics Committee, the experiment was carried out in the Laboratory of Human Motor Behavior, Academy of Physical Education in Katowice, Poland.

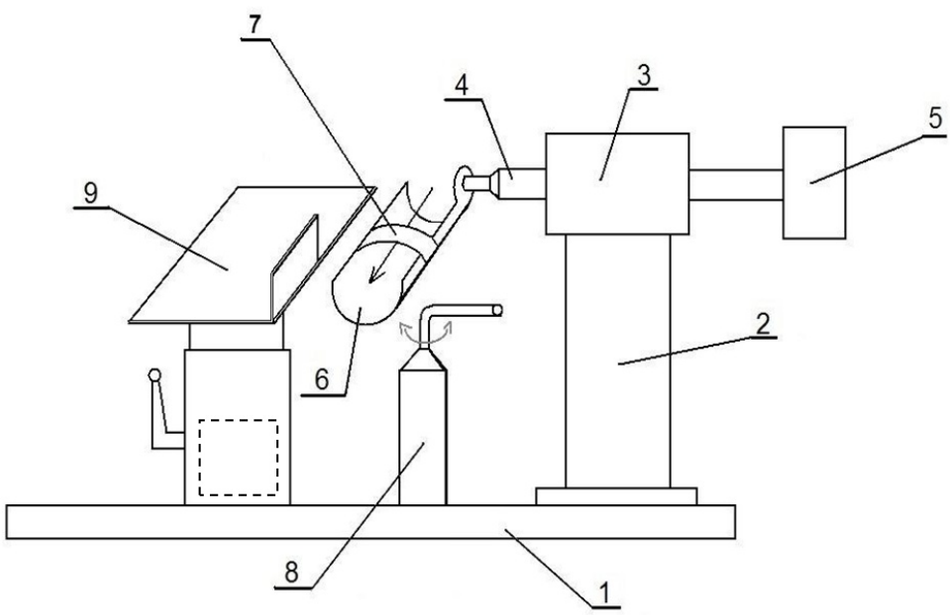


**Fig. 1. A manipulandum for testing parameters of flexion and extension movements in the metacarpophalangeal joint of the index finger: ferromagnetic stand (1), supporting pillar (2), stabilizer bearing (3), axle (4), angular displacement sensor (5), index finger bed (6), belt (7), rotating rod (8), hand-support system (9)**

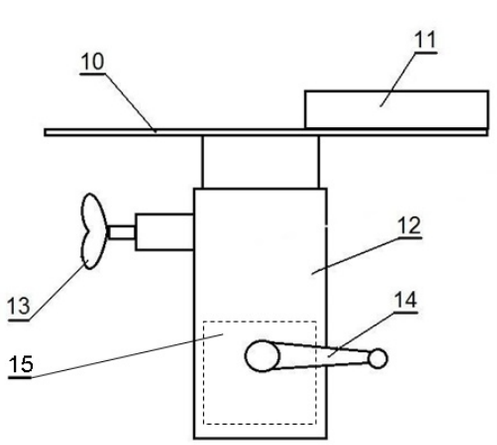


**Fig. 2. Hand-support system: plate (10), element separating the index from the middle finger (11), pillar (12), mechanical lock plate height adjustment (13), lever (14), on-off magnetic switch (15)**

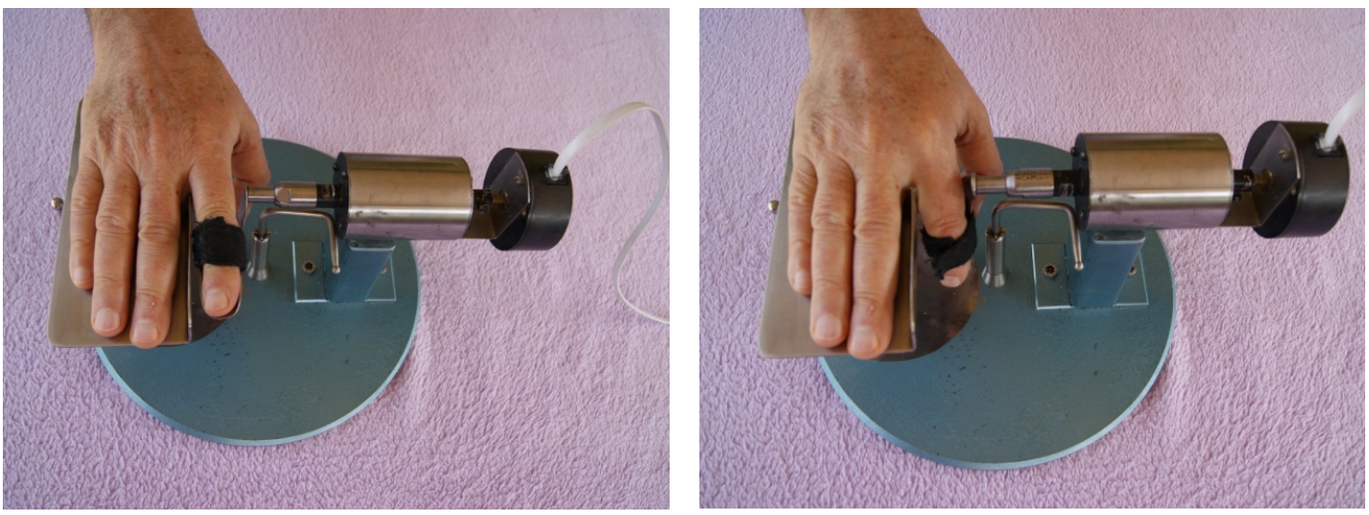

**Fig. 3. Pre- (a) and post-movement (b) hand positions on the manipulandum**

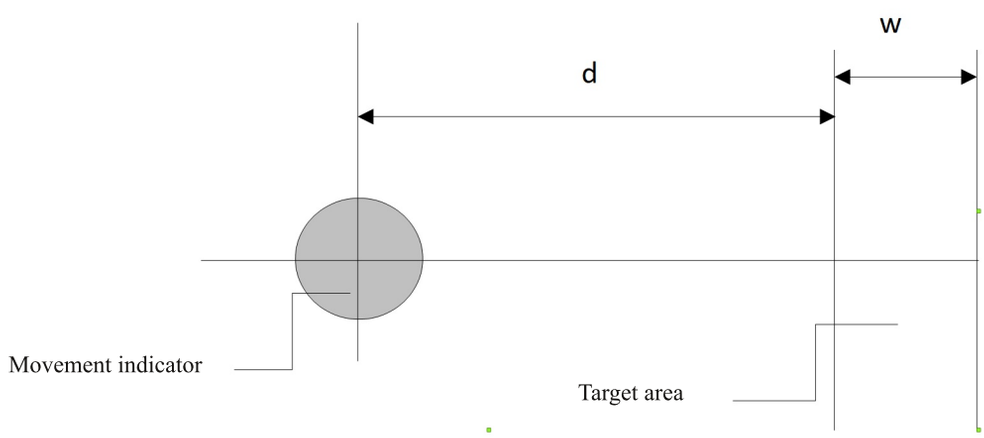


**Fig. 4. Experiment scheme: w – target area width, d – distance between movement indicator's initial position and target area**

Two parameters were assessed: time of movement indicator reaching the target area [s] and the distance covered by the indicator (the number of measurement units – pixels [px]). It was assumed that the shorter time- and distance-to-target, the higher the precision of movement performance.

There were two stages of data analysis. A hypothesis was put forward that ten attempts to do the same task might cause movement learning and, as a consequence, reduce time-to-target. In order to support / reject the hypothesis, inter-trial results were compared using the Friedman test followed by post-hoc tests. The reliability of time-to-target and distance-to-target measurements was analyzed with intraclass correlations as described by Shrout and Fleiss [13]. Intraclass correlation coefficients (ICC) are calculated based on analysis of variance and are used to compare the intraobserver and interobserver variability of measurements (Formula 1).

$$ICC_{2,1} = \frac{MS_B - MS_E}{MS_B + (n-1)MS_E + n(MS_R - MS_E)/k}$$

where are mean squares of two-way ANOVA, n is the number of participants and k is the number of trials.

Statistica software was used to estimate a reliability coefficient (R) The reliability coefficient falls between 0 (no reliability) and 1 (perfect reliability). According to Enderlein and Fleiss [14] it should be interpreted as follows: R < 0.4 – low reliability, R = 0.4-0.7 – moderate reliability, R > 0.7 – perfect reliability.

Calculations were performed using Statistica 12.0 StatSoft, Inc.

## Results

Since the analyzed data did not fit a normal distribution, time-to-target and distance-to-target measurements of subsequent trials were analyzed with the Friedman test (the nonparametric alternative to one-way ANOVA). The obtained results seemed to indicate that trial number might significantly affect both time-to-target ($chi^2$ (43, 9) = 45.784; p = 0.001) and distance-to-target ($chi^2$ (43, 9) = 50.635; p = 0.001).

However, following post-hoc tests, it was found that significant differences in time-to-target and distance-to-target only occurred between trial 10 and trials 1, 2, 3, 4, 5, 8 (Fig. 5).

A significant difference in distance-to-target was noted between trials 3 and 7, which could be considered an artifact (Fig. 6).

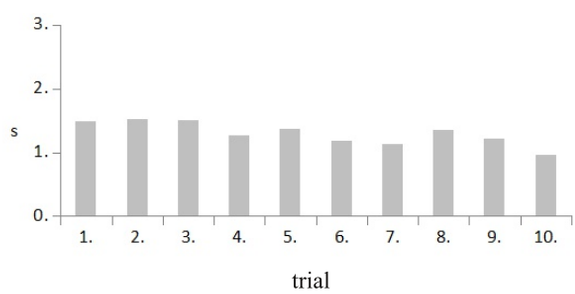


**Fig. 5. Time-to-target in subsequent trials**

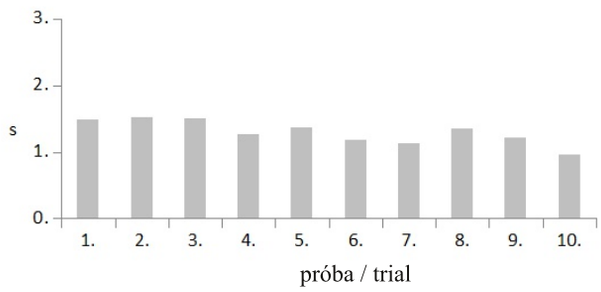


**Fig. 6. Distance-to-target in subsequent trials**

The results of intraclass correlation analysis presented in Table 1 indicate a need to perform thirty measurements of the "time-to-target" and twenty-five measurements of the "distance-to-target" parameters to obtain a reliability coefficient of R = 0.7.

**Table 1. Results of intraclass analysis**

| Parameter | ICC2,1 | ICC2,k | R = 0.7 |
|---|---|---|---|
| Time-to-target | 0.073 | 0.442 | 30 |
| Distance-to-target | 0.087 | 0.489 | 25 |

## Discussion

Our analysis of intraclass correlation coefficients indicates a large number (30 and 25) of movement precision measurements are necessary to yield an acceptable correlation coeffcient. The number of repetition should not pose a problem during an experiment since a single trial only lasts for 1-1.5 s; furthermore, flexion and extension movements at the metacarpophalangeal joint do not cause fatigue. It should be mentioned that other procedures used to test movement precision last much longer and require much more concentration and effort on the part of experiment participants. For example, classic measurement of movement precision (Line Tracking) consists of moving a pen-stylus along a groove of a curved line without touching the groove's walls and takes approximately 25-30 seconds [15, 16]. Such assessments are usually performed several times using Motorische Leistungsserie (MLS), version 3.00 included in the Vienna Test System. Each contact of the stylus tip with the wall of the groove is registered as an error. The following parameters are analyzed: error number, error time-point and test duration [17, 18].

As expected and further confirmed by the Friedman test, a sequence of repeated flexion and extension movements performed in the manipulandum might cause movement learning. The post-hoc tests demonstrated distinct improvement of the results following ten repetitions of

the experimental task. Considering the fact, it seems reasonable to modify experimental conditions after several trials. An increase or decrease in movement indicator's distance to target area or shifting the indicator into another position will cause changes in movement amplitude and/or direction. If the effect of some external influences (eg., confounding factors) on movement precision is studied, it is advisable to use the cross-over design which helps eliminate the effect of learning on measurement results.

Studying the determinants of movement precision seems complicated and especially in the context of complex multi-articular movements. Therefore, an analysis is needed of isolated movements based on short biokinematic chains. Our study [15] showed that limited tactile feedback compromised movement accuracy of the hand and upper extremity. The relationship between tactile feedback and final accuracy was only significant when tactile information from hand receptors was severely impaired. This finding indicates that the effect of external factors is greater during localized hand performance than in more global arm movements. Hence, testing movement in one simple joint seems an optimal solution to facilitate result interpretation.

Rojczyk-Chmarek et al. previously used a similar single axle manipulandum to study parameters of elbow flexion and extension in patients with rheumatoid arthritis (RA) [19,20]. The aim of the study was to verify this simple and objective elbow function assessment as a method of determining the severity of elbow lesions and disease monitoring. The study comprised 82 individuals, who performed flexion and extension movements with different angular velocities. The measurements were carried out prior to and after a 3-week physiotherapy intervention. Movement parameters in patients with rheumatoid arthritis differed significantly compared to normal ranges. Movement speed and amplitude were decreased. Considerable asymmetry of cyclic flexion and extension movements was also observed. The authors speculated that movement abnormalities detected in RA patients were mainly caused by elbow stiffness resulting from pain and pathology-related resistance. It should be noted that several parameters of flexion and extension movements improved following the 3-week therapy. Rojczyk-Chmarek et al. concluded that manipulandum-assisted biomechanical analysis allowed objective evaluation of intra-articular pathology as well as therapy efficiency.

Rheumatoid arthritis is considered a symmetrical disease typically affecting small joints of the hand, ie., metacarpophalangeal, proximal interphalangeal and wrist joints. Knee, ankle, shoulder, cervical spine and elbow involvement is less common [5, 6, 7]. Hence, biomechanical analysis for diagnosis of rheumatoid arthritis should start with functional evaluation of distal joints. This was the idea behind the studies of Hellivell et al. [21, 22], who assessed hand function of RA sufferers based on grip strength endurance. Our manipulandum for testing parameters of flexion and extension movements in

the metacarpophalangeal joint of the index finger was designed to serve a similar purpose. We hope the device might be applied to early diagnosis of rheumatic or neurological disease leading to functional compromise of the hand.. It might also enable immediate assessment of disease progression and monitoring of treatment efficacy. However, these speculations should first be verified by a series of investigations comprising specially selected patient groups.

At present, manipulative hand movements are of particular importance considering the operation of different devices including a tablet computer and mobile phone. More and more household appliances are equipped with touch panels including television, washing machines, microwave and electric ovens, fridges etc. Impairment of fine motor skills might become extremely troublesome considering self-service activities. Early detection, rehabilitation and control of the rehabilitation process might reduce functional deficits. Examination and analysis of manipulative digit and hand movements might also facilitate the selection of orthopedic appliances.

## Conclusions

1. The manipulandum for testing flexion and extension movements in the metacarpophalangeal joint of the index finger enables reliable assessment of movement precision provided a considerable number of repetitions are made (25-30). Such repetitions should not pose a problem since a single trial only lasts for1-1.5 s and the movement at the metacarpophalangeal joint does not cause fatigue.
2. As expected, a sequence of repeated flexion and extension movements performed in the manipulandum might cause movement learning. It is therefore reasonable to modify the conditions of a movement task after several trials (eg., change in movement amplitude). If the effect of some external influences (eg. confounding factors) on movement precision is studied, it is advisable to use the cross-over design to eliminate the effect of learning on measurement results.
3. Our intention was, among others, to confirm the potential applicability of the manipulandum as a diagnostic tool in patients with rheumatic or neurological disease leading to functional compromise of the hand. We believe this device might also enable immediate assessment of disease progression and monitoring of treatment efficacy. However, these speculations should first be verified by a series of investigations comprising specially selected patient groups.

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