All papers submitted for publishing to the RECENT® journal are subjected to the scientific review procedure.

The objective of scientific review is to ensure that all papers accepted for publishing meet the requirement of an adequate scientific level and provide original and significant contributions to the respective field.

The scientific review procedures practiced by the RECENT® journal are: *"Expert Peer-Review"* (scientific review by experts, including the members of the Scientific Board of the journal) and *"Editorial Board Peer-Review"* (review, scientific included, by the members of the Editorial Board). All members of the Scientific Board and of the Technical Board of the journal are holders of PhD degrees, are members of the scientific community and experts in their respective fields of activity.

The complete scientific review procedure of submitted papers practiced by the RECENT® journal is available at http://www.recentonline.ro/PeerRew.htm

RECENT®

REzultatele CErcetărilor Noastre Tehnice

Industrial Engineering Journal

Transilvania University of Brasov, Romania

Vol. 14 (2013), No. 4(40) **ISSN 1582 - 0246**

ICEEMS 2013
7th International Conference on Economic Engineering and Manufacturing Systems

- selected papers -

iceems

40

November 2013

CONTENTS

Vol. 14, no. 4(40), November, 2013

All papers submitted for publication to the RECENT® journal undergo a peer-review procedure.

The objective of peer review is to verify and endorse that all papers accepted for publication are of adequate scientific level and include original and significant contributions in their respective field.

The RECENT® journal provides *Expert Peer-Review*, including by members of the Scientific Panel as well as *Editorial Board Peer-Review* by the members of the Editorial Board. All members of the Scientific Panel and of the Technical Panel have PhDs, are members of the academic community and experts in their respective fields of activity.

The received papers undergo initial *Editorial Board Peer-Review* by the members of the Technical Panel of the RECENT® journal, conducted mainly by the scientific secretaries. Evaluation concerns with priority whether the paper matches the fields covered by the journal and meets its standards.

Complete scientific evaluation procedure is available at http://www.recentonline.ro/PeerRew.htm

Electronic version of RECENT® journal, ISSN 2065-4529, is available at www.recentonline.ro

PNEUMATICALLY-ACTUATED DEVICE FOR WRIST REHABILITATION

Ovidiu FILIP, Tudor DEACONESCU
Transilvania University of Brasov, Romania

Abstract. This paper submits a pneumatically actuated device, which may be used in the continuous passive motion, with a view to rehabilitating the wrist and the metacarpophalangeal joints. This equipment resorts, for actuation purposes, to a pneumatic muscle, which sets in motion the support whereon the palm rests. The palm support is based on the "Fin Ray Effect" concept. The device has been designed for the purpose of rehabilitating the joints of both hands.

Keywords: CPM, rehabilitation equipment, palm, pneumatic actuation

1. Effects of human body immobilisation

In case of prolonged immobilisation, the body will experience muscle hypotrophy, metabolism decrease, osseous demineralisation, dysfunctions of the circulatory system and respiratory tract [1, 5].

In order to avoid muscle impairment, depending on the type of medically advised motion, kinesiology may be either active or passive. Active kinesiology is applicable in patients who have motion skills and control their balance function. In the case of passive kinesiology, the patients do not have the biological resources wherewith they should command and perform various movements.

Kinesiology aims at preventing the formation of defective compensatory skills, at correcting the functions of the impaired body parts, at improving the motion skills and at maintaining the patients' high spirits during treatment. This should be applied at the earliest, as the delay may result in longer treatment with worse results. Considering the variegation of body reations, in the case of the kinesiologic treatment, there is recommended its individualisation for every patient.

Muscle hypotrophy represents the decreasing diameter of the muscle micro-fibres; in more severe cases, it can lead to muscle atrophy. Muscle atrophy irreversibly affects muscular function and leads to paralysis.

In order to restore muscle tone, there is recommended passive kinesiology or, where applicable, excito-motory therapy (the case of muscle atrophy by denervation).

The immobility caused by muscular contracture may result in musculo-tendinous retractions affecting the capsule-ligamentous apparatus. In order to avoid joint blockage, the kinesiotherapist need stress the joint mobilisation at full capacity.

The lack of exercise that is likely to appear in immobile patients requires the passive mobilisation even in irreversibly injured patients [1].

The decreasing muscle activity will lead to increasing catabolic processes, catabolism being the process where the body substances decompose and yield energy. The lack of exercise occurs simultaneously with the appetite loss, which may bring about anorexia; denutrition sometimes endangers the patient's life.

So that a bone might normally develop, it should be mechanically stressed on a regular basis by muscles and adjacent bones. Without these stresses, the bone will become less rough, its resistance will be lower, blood circulation will decrease, depriving the bone of the necessary nutrients.

The decreasing motion will also impair the cardiovascular system. Low muscle activity will reduce cardiac activity, which will result in orthostatic hypotension and defective peripheral irrigation. Poor circulation may provoke oedemas (abnormal retention of liquid within tissues).

The patient's immobilisation may cause dysfunctions in the respiratory tract and the diminution of the oxygen quantity necessary for the body. The immobilisation in decubitus position may result in the reduced elasticity of the thorax. Hence, some lung parts no longer ventilate, are blocked, reducing even more the pulmonary capacity.

Considering the negative effects of the immobilisation, one infers the necessity of achieving equipment that may be used by the patient even without the therapist's surveillance. At this point, there are used various equipment within rehabilitation clinics. This equipment achieves various movements of the human body, at variable speeds.

2. Rehabilitation equipment

Figure 1 shows a portable device destined for wrist rehabilitation [7].

This equipment achieves a fist flexion ranging between 0º - 90º and an extension ranging between 0º - 90º. The rotation speed is of 180º/min, and the developed torque varies between 2.9-4.0 N·m.

Figure 1. W2 Wrist [7]

The following equipment is more complex and is meant to rehabilitate the wrist, the finger joints and it may also turn the forearm round its longitudinal axis [8]. Unlike the previously submitted device, this is fixed equipment.

In terms of flexion, according as the palm is fixed on the device, the latter will rotate at most 90º if the palm attaches to the device and 140º if the proximal phalanges attach to the device (Figure 2). The palm extension will be at most 50º on this device. The speed of this equipment ranges between 150 º/min and 440 º/min.

Figure 2. Kinetec Maestra Hand and Wrist CPM [8]

The company Kinetic Muscles Inc produces a hand-rehabilitation device, called The Hand Mentor. Unlike the equipment submitted so far, this device is actuated by a pneumatic muscle. A medical study performed with this device, as well as its description is presented in paper [3]. This company has likewise been patented for an upper-limb rehabilitation device, which is actuated by pneumatic muscles [2] (Figure 3).

Figure 3. Equipment *The Hand Mentor* and patent US8214029 [2]

The following equipment is used for passive hand movements and is driven by a rotary pneumatic muscle [6]. It consists of four plates linked by three torques (Figure 4). On the opposite side of the surfaces whereon the palm rests, on the four plates, an inflatable bag is placed. Depending on the pressure within the bag, the four plates will turn the palm and fingers. Its disadvantage is the lack of control upon the rotation of the plates that move the palm and fingers.

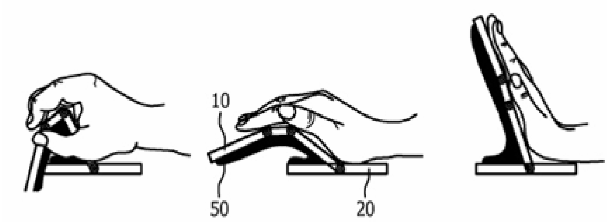

Figure 4. Patent WO2012120393 [6]

There are several companies worldwide which deal with rehabilitation-device production. The vast majority produce electrically driven rehabilitation equipment, with similar structure to the devices presented above. The use of pneumatic actuations paves the way for achieving new devices with different structure from electric drives.

3. Cutting-edge pneumatically actuated rehabilitation device

The wrist may perform several movements, whereof flexion and extension.

The maximum value of the flexion, according to paper [4], is 80º (Figure 5).

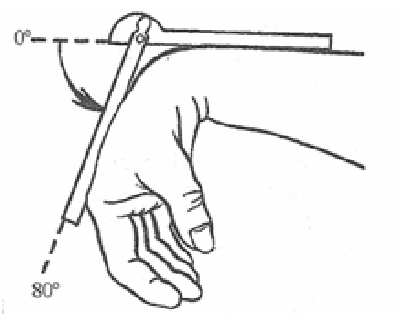

Figure 5. Fist flexion [4]

The fist extension, according to paper [4], is 70º (Figure 6).

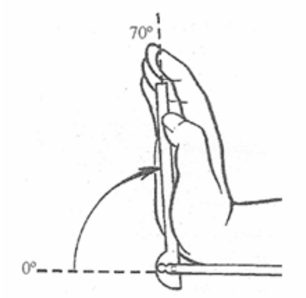

Figure 6. Fist extension [4]

In the case of the fingers, the maximal flexion is 90º and the finger extension ranges between 0º and 45º [4] (Figure 7).

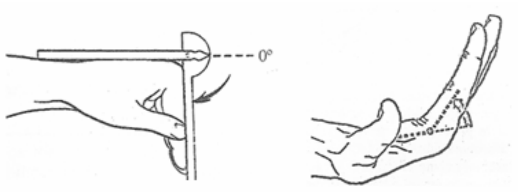

Figure 7. Finger flexion and extension [4]

As regards the functional angles of the hand, we will present as follows a device whereby these angles may be obtained with a tolerance of ± 2º. Finger extension, according to the literature, highly varies from individual to individual. In this respect, this device resorts, for finger extension, to the angle of 0º.

The palm support is based on the Fin Ray effect.

This effect may be explained through the caudal fin of a fish (Figure 8). If a force F acts upon this fin, its tip will move in the opposite direction of the pressing.

Figure 8. Fin Ray effect [4]

A Fin Ray-type structure consists of two elastic elements, united through other parallel elements in a triangular symmetrical structure (Figure 9).

Starting from this structure, we made the palm support. This one consists of two quadrilateral mechanisms linked by two torsional springs. The elastic elements of the *Fin Ray* structure are achieved with the torsional springs.

Figure 9. Fin Ray-type structure [4]

The simulation of the movements made by the mechanism shows the angles in their end positions.

Figure 10 shows that, for maximal fist extension (70º) the finger flexion reaches 91.6 º.

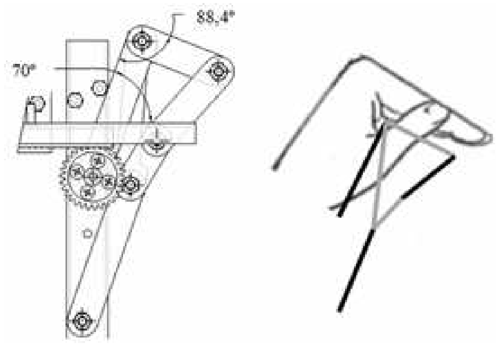

Figure 10. Fist extension

It is worth noting that this type of mechanism follows the physiological structure of the hand. Maximal fist extension will be obtained when the fingers are flexed, and maximal fist flexion will be attained in case of finger extension.

If finger movement during the operation of the mechanism is not wanted, the binding that attaches the fingers to the mechanism may be untied.

In case of maximal fist flexion (80º), a finger extension of 1.9 º (Figure 11) will be obtained.

This deviation of 2 is not a problem, as the bindings between fingers and support is likely to make up for this deviation.

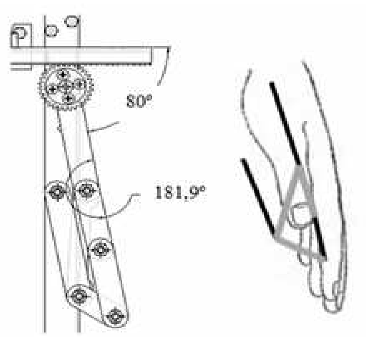

Figure 11. Fist flexion

Figure 12 shows the wrist-rehabilitation device. This one consists of: stands for the stability of the device, a pneumatic muscle actuating the rank pinion mechanism, forearm support and mechanism for palm placing and sitting.

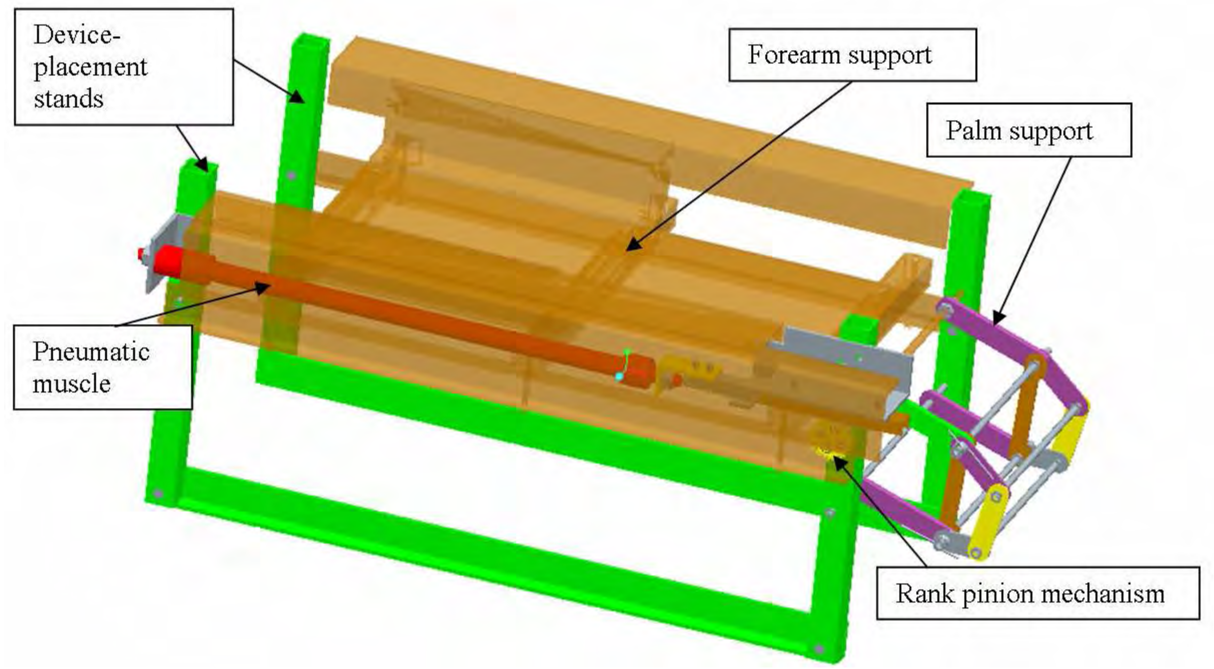

Figure 12. Wrist-rehabilitation device

4. Conclusions

The rehabilitation device displays a few state-of-art elements: it resorts to a pneumatic muscle for actuation purposes, and the palm support may set in motion both fist and fingers across the entire flexion and extension area. With a view to obtaining hand movements, the palm support resorts to a Fin Ray-type structure, whereof only the first two quadrilateral mechanisms were kept (Figure 9).

References

1. Albu, C., Vlad, T.L., Albu, A. (2004) *Kinetoterapia pasivă* (*Passive Kinetotherapy*). Polirom, ISBN 973-681-699-0, Iaşi, Romania (in Romanian)
2. Koeneman, E.J., et al. (2012) *System and method for neuromuscular reeducation*. Patent US 8214029
3. Kutner, N.G., et al. (2010) *Quality-of-Life Change Associated With Robotic-Assisted Therapy to Improve Hand Motor Function in Patients With Subacute Stroke: A Randomized Clinical Trial*. Physical Therapy Journal, Vol. 90, no. 4, (April, 2010), p. 493-504. Available at: http://ptjournal.apta.org/content/90/4/493.full, Accessed at: 14.10.2013
4. Sidenco, E.L. (2009) *Ghid practic de evaluare articulară şi musculară în kinetoterapie* (*Practical guide for articular and muscular evaluation in kinetotherapy*). Editura Fundaţiei „Romania de Maine", ISBN 973-725-246-2 Bucureşti, Romania (in Romanian)
5. Whaley, L., Wong, D., (1998) *Nursing Care of Infants and Children*. The C.V. Mosby Company, ISBN 9780323001502, St. Louis, USA
6. Zhang, J., Liu, Y., Jia, Y., Shen, Z. (2012) *Device for hand rehabilitation*. Patent WO 2012120393
7. *** http://qalmedical.com/w2-wrist-cpm-device/. Accessed: 14.10.2013
8. *** http://www.pattersonmedical.ca/app.aspx?cmd=get Product&key=IF_44726. Accessed: 14.10.2013