INFLUENCE OF EXERCISES IN AN OPEN AND A CLOSED KINEMATIC CHAIN ON PROPRIOCEPTION OF AN ELBOW JOINT

WPŁYW ĆWICZEŃ W OTWARTYM I ZAMKNIĘTYM ŁAŃCUCHU KINEMATYCZNYM NA PROPRIOCEPCJĘ STAWU ŁOKCIOWEGO

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ABSTRACT

The presented study aimed to assess the influence of exercises in an open and a closed kinematic chain on the level of proprioception of an elbow joint. Examination was carried out on 25 patients, aged 19–30. Proprioception at 30, 60, 90 and 120 degrees of elbow flexion was measured for each patient. The exercises were performed within 2 weeks. Results shown that in the left limb there were statistically significant differences after application of exercises in open kinematic chains in position of 60 degrees of elbow flexion ($p \leq 0,02$) and after exercises in closed kinematic chains in 90 degrees of elbow flexion ($p \leq 0,01$). In the right limb, statistically significant differences after exercises in open kinematic chains (30, 60, 90 degrees) and in position of 120-degree flexion in closed kinematic chain, were observed. If there is a desire to improve proprioception above 90 degrees of elbow flexure, it is recommended to apply exercises in the closed kinematic chain.

Keywords: proprioception, elbow joint, kinematic chain

STRESZCZENIE

Celem pracy była ocena wpływu ćwiczeń w otwartym i zamkniętym łańcuchu kinematycznym na poziom propriocepcji stawu łokciowego. Badanie przeprowadzono na 25 pacjentach w wieku 19–30 lat. Oceniano propriocepcję przy 30, 60, 90 i 120 stopniach zgięcia łokcia. Następnie przez 2 tygodnie prowadzono ćwiczenia. W lewej kończynie stwierdzono istotne statystycznie różnice po ćwiczeniach w otwartych łańcuchach kinematycznych w pozycji zgięcia pod kątem 60 stopni ($p \leq 0,02$) i po ćwiczeniach w zamkniętych łańcuchach kinematycznych w 90 stopniach zgięcia łokcia ($p \leq 0,01$). W prawej kończynie zaobserwowano statystycznie istotne różnice po ćwiczeniach w otwartych łańcuchach kinematycznych (30, 60, 90 stopni) oraz w pozycji zgięcia 120 stopni w zamkniętym łańcuchu kinematycznym. Jeśli istnieje potrzeba poprawy propriocepcji powyżej 90 stopni zgięcia łokcia, warto korzystać z ćwiczeń w zamkniętym łańcuchu w ramach terapii.

Słowa kluczowe: propriocepcja, staw łokciowy, łańcuch kinematyczny

1. Introduction

Mobility of joints ensures the proper flexibility. Mobility of the joints depends on passive structures, i.e. articular surfaces, joint capsules and ligaments, as well as on active structures, i.e. muscles [1, 2]. Joints create kinematic pairs that are involved in the kinematic chains. A kinematic chain is an arrangement of segments joined into kinematic pairs with a specific mobility level. In an open kinematic chain, a final link is freely connected only to a single, neighboring link. Each link moves independently. In a closed kinematic chain, the final link is not free. Motion of a single link causes certain movement of other links, and each link segment is connected with at least two other segments [3, 4].

A kinematic pair is a motor connection of at least two segments, which limit themselves mutually through relative motions. A segment is a rigid element of a human body in a form of bones. [2, 3]

Two closed kinematic chains can be specified in a human body [3,4]. One of them is the chest and all of its motion structures engaged in the breathing process. Ribs movements force particular motion of sternum and thoracic spine, and the other way round. There are 56 linked joints, which cooperated during motion of the whole chest [5,6]. Pelvis seems to be another kinematic chain, where trace mobility in sacroiliac joints causes a particular motion of one joint when the other one moves.

A human body is composed mainly from open kinematic chains, while the final links (a foot and a hand) remain free. An open kinematic chain can be described as an isolated motion in a single joint, where distal part moves freely in space, and the force produced by the body is strong enough to overcome the resistance [7,8].

Some of the exercises recommended for rehabilitation process can be qualified as performed in an open or closed kinematic chains. Motion is a combination of movements in an open and a closed kinematic chain. For instance, regular walk include 65% motions in a closed kinematic chain and 35% motions in an open kinematic chain. Along with an increase in the movement speed, the percentage share of movements in the closed kinematic chain drops significantly to 10% during a sprint. Therefore, two motion components are considered in order to make the rehabilitation process effective [9, 10].

Exercises in open kinematic chains are characterized with greater speed, freedom of movement or occurrence of strong shearing forces and lower stability. An example is a resistance exercise of knee joints extensors on an extension machine. [9, 10]

Closed kinematic chains can be described as a certain multi-joint movement, where the distal segment is either stabilized or is encounters strong resistance, which render the movement impossible or highly limited. The force generated by the body is not strong enough to fight the resistance. Muscle systems work in an opposite manner. The final muscle attachment becomes the initial one, and the initial one becomes the final one. Such a situation forces a different nervous and muscle coordination. An example of such reverted series of muscles motions is the work of reserve inspiratory muscles carried out after intensive effort, when work of a diaphragm and its supporting muscles themselves is not enough. A condition for including those muscles in the respiration process is to close the kinematic chain and stabilize upper limbs by opening them at knees or grasping a stable object [3, 6].

1.1 Exercises in open kinematic chains

These exercises are frequently used in the therapy. As effective and isolated exercises of single groups of muscles, they recreate single patterns of motion, and they lead to an increase of the shear forces in relation to compression forces. They stimulate proprioception, by activating agonist and synergist muscles, and are not adequate for every-day activity or sport training [11, 12].

1.2. Exercises in closed kinematic chains

These exercises belong to the most common therapeutic means. They engage large dynamic sections, recreate more functional patterns of motion, and cause an increase in the component of compressing forces in relation to shear forces. Some of them ensure better joints stabilization by a way of co-contraction of surrounding muscles sections. They also give better dynamic stabilization – proprioception, activating agonist, synergist and antagonist muscles at the same time, and are safer than some exercises in open kinematic chains. A significant advantage of the exercises in closed kinematic chains

is the fact that through the multi-joint action and engagement of a greater number of muscles, they improve proprioception to a considerable extent. It must be underlined that a surgery restores just the mechanical stabilization of a given joint, while nervous and muscle control is provided by physiotherapy [11, 12].

2. Aim

The aim of the work was to assess the influence of exercises in an open and a closed kinematic chain, on the level of proprioception. The following research questions were asked:

1. Which kind of exercises, in an open or a closed kinematic chain, improve proprioception more significantly?
2. Is there any difference of the impact of selected exercises on a dominating and non-dominating limb?

3. Materials and methods

Examination was carried out on 25 patients of the Rehabilitation Center "Centrum Rehabilitacji Fizjo-Wysz", aged 19–30. The inclusion criteria were as follows: no pain, no distortions in both proprioception and superficial sensations, no traumas in upper limbs, no practicing any extreme sport discipline professionally, no pharmacotherapy, which could influence proprioception. Before the therapy, proprioception in each patient was measured in 4 positions. Each measurement was repeated three times. The subjects were asked to close their eyes, after what their elbow was flexed in a position of 30 degrees. Afterwards, the subject was asked to recreate the position of the elbow flexed at 30 degrees three times. The same measurements were carried out for 60, 90 and 120 degrees of the elbow flexure.

Afterwards, the therapy in question was carried out in each patient for 2 weeks. The first week embraced exercises in an open kinematic chain, while the second week included exercises in a closed kinematic chain. The authors previous medical practice experience showed that the order of therapy kind has statistically insignificant influence on the total final outcome. Each measurement of proprioception at 30, 60, 90 and 120 degrees of elbow flexure was carried out three times in the following order: before, after the first week and then, when the therapy was completed. All measured parameters created a database analyzed statistically using Statistica 10.0 software. Distribution normality was assessed with the Shapiro-Wilk test. Hence, it was possible to obtain a proper histogram with a density curve of normal distribution, allowing its proper evaluation. The statistical analysis was carried out with T-Student tests for paired samples and the Mann-Whitney U test. The assumed threshold of statistical significance was $p \leq 0.05$.

4. Results

Figure 1 presents results from proprioception measurements after exercises in the open and closed kinematic chains for a left upper limb (non-dominating), with the elbow flexed at 30 degrees.

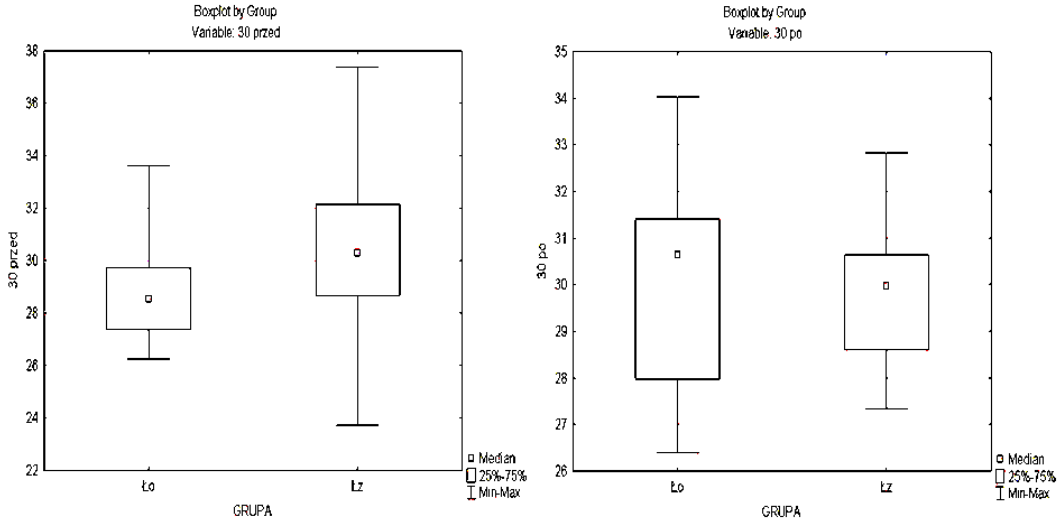

Fig. 1. An analysis of results from proprioception before (left) and after (right) exercises in the open and closed kinematic chain for an elbow flexed at 30 degrees of the upper left limb (non-dominating)

It can be observed that an average angular value after exercises in the closed kinematic chains is closer to the value of 30 degrees, i.e. a starting value of the angular position to be recreated by the patient. The obtained differences are not statistically significant ($p \geq 0.07$).

Figure 2 presents results from proprioception measurements after exercises in the open and closed kinematic chains for a left upper limb (non-dominating), with the elbow flexed at 60 degrees.

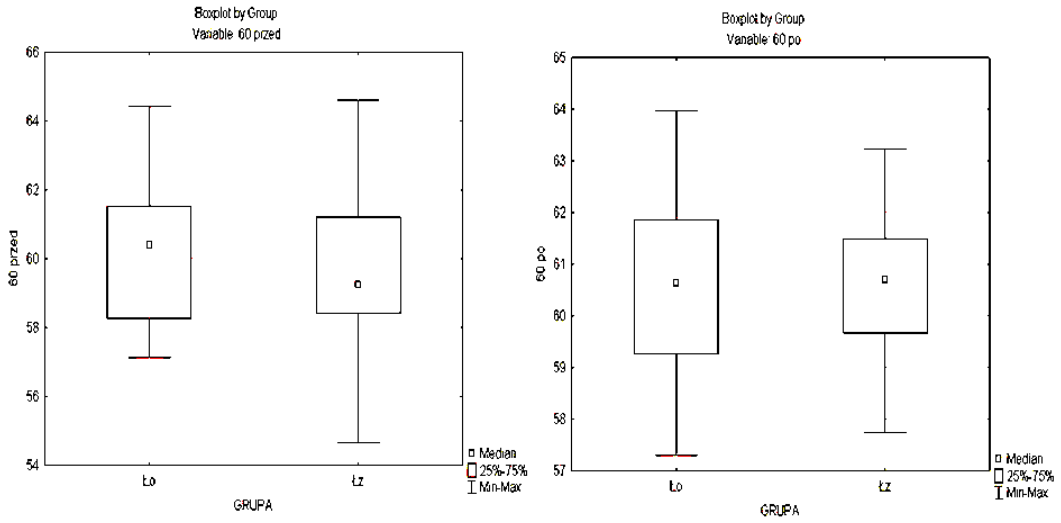

Fig. 2. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 60 degrees of the upper left limb (non-dominating).

It can be observed that an average angular value after exercises in the open kinematic chain is closer to the value of 60 degrees, i.e. a starting value of the angular position to be recreated by the patient. The obtained differences are statistically significant ($p \geq 0.02$).

Figure 3 presents an analysis of results from proprioception after exercises in the open and closed kinematic chain for an elbow flexed at 90 degrees of the left arm (non-dominating).

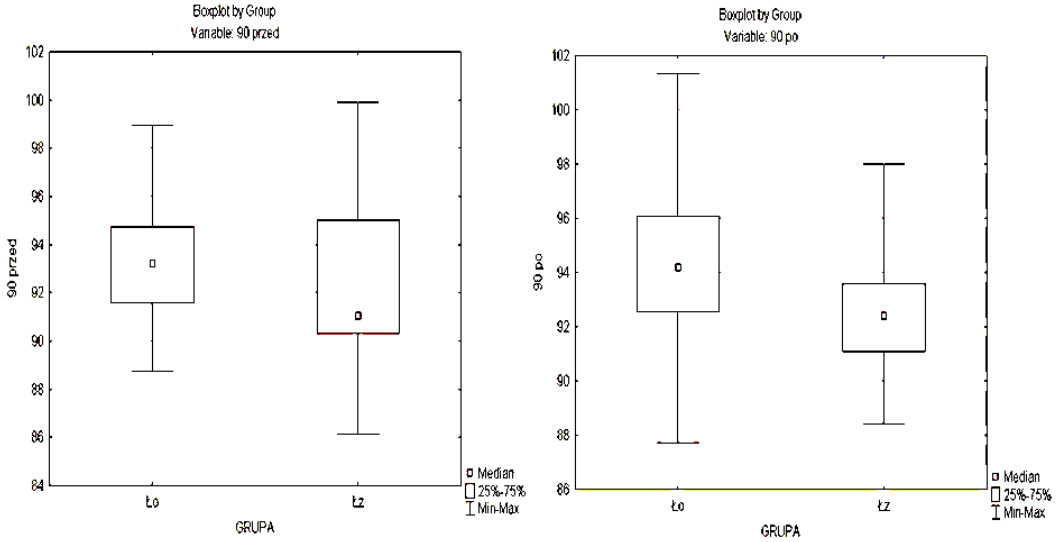

Fig. 3. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 90 degrees of the upper left limb.

It can be noticed that an average angular value after exercises in the closed kinematic chain is more distant from the value of 90 degrees, i.e. a starting value of the angular position to be recreated by the patient, when compared to the results obtained before exercises.

The plot demonstrates that in case of exercises in the closed kinematic chain, the average angular value is closer to the starting point of 90 degrees in relation to exercises in the open chain. The obtained differences are statistically significant ($p \geq 0.01$).

Figure 4 presents an analysis of results from proprioception after exercises in the open and closed kinematic chain for an elbow flexed at 120 degrees of the left upper limb (non-dominating).

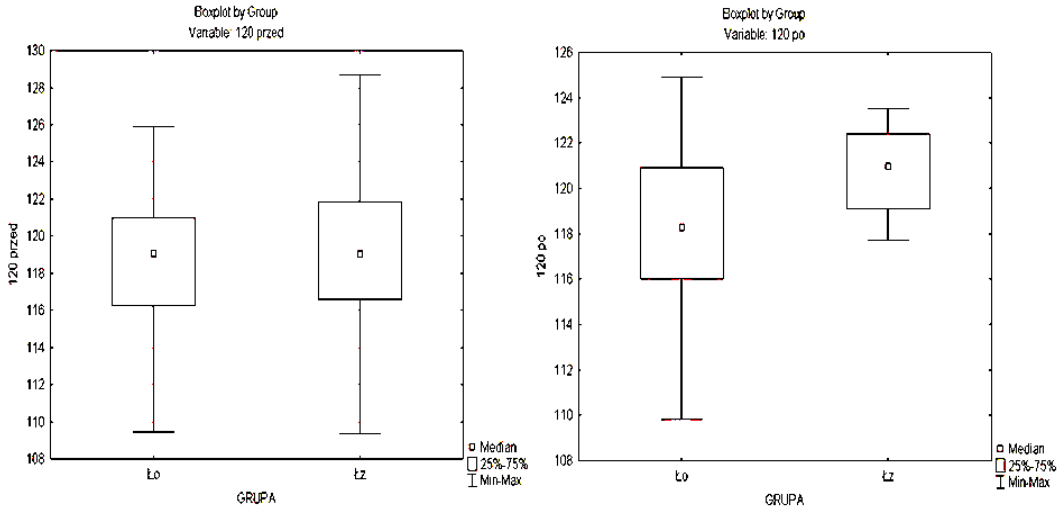

Fig. 4. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 120 degrees of the upper left limb.

It can be observed that an average angular value after exercises in the closed kinematic chains is closer to the value of 120 degrees, i.e. a starting value of the angular position to be recreated by the patient. The obtained differences are not statistically significant ($p \geq 0.08$).

Figure 5 presents an analysis of results from proprioception after exercises in the open and closed kinematic chain for an elbow flexed at 30 degrees of the right upper limb (dominating).

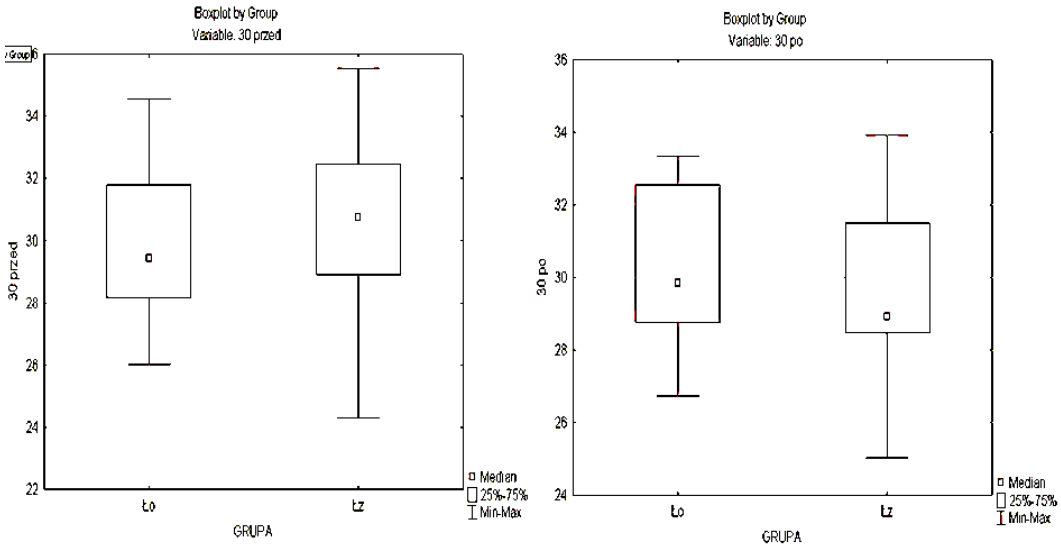

Fig. 5. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 30 degrees of the upper right limb.

It can be observed that an average angular value after exercises in the open kinematic chain is closer to the value of 30 degrees, i.e. a starting value of the angular position to be recreated by the patient.

The plot demonstrates that in the case of exercises in a closed kinematic chain, the angular value median is more distant from the starting point of 30 degrees in relation to exercises in the open chain.

Figure 6 presents an analysis of results from proprioception measurement after exercises in the open and closed kinematic chain for an elbow flexed at 60 degrees of the right upper limb (dominating).

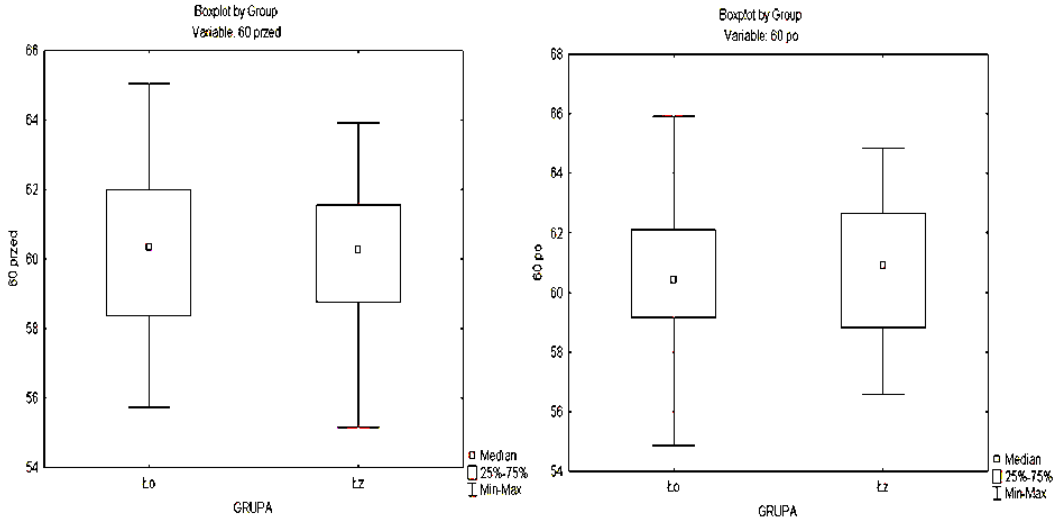

Fig. 6. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 60 degrees of the upper right limb.

It can be observed that an average angular value after exercises in the open kinematic chain is closer to the value of 60 degrees, i.e. a starting value of the angular position to be recreated by the patient. The obtained differences are not statistically significant ($p \geq 0.1$).

The plot demonstrates that in case of exercises in the closed kinematic chain, the angular value median is more distant from the starting point of 60 degrees in relation to exercises in the open chain.

Figure 7 presents an analysis of results from proprioception after exercises in an open and a closed kinematic chain for an elbow flexed at 90 degrees of the right upper limb.

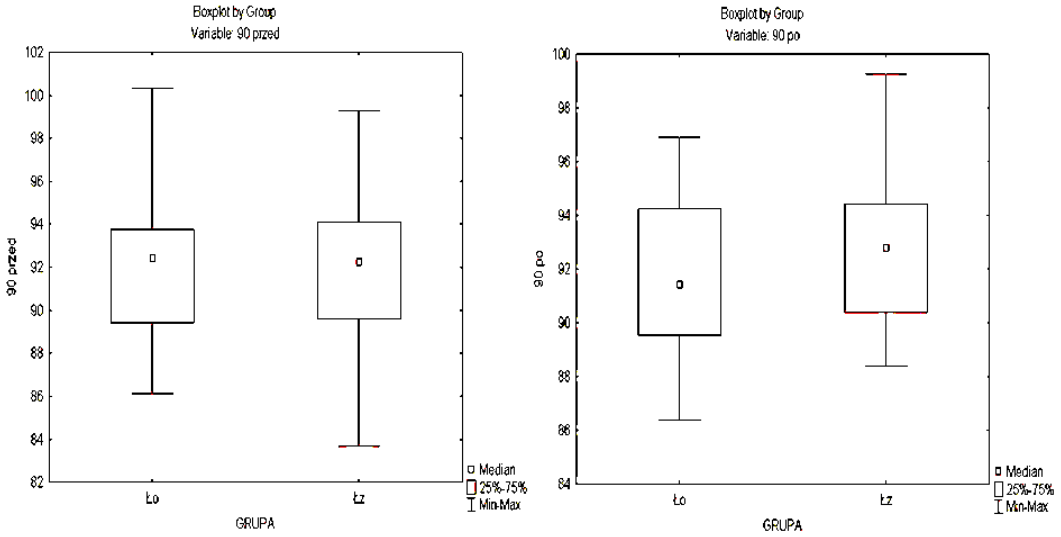

Fig. 7. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 90 degrees of the upper right limb.

It can be observed that the average angular value after exercises in the open kinematic chain is closer to the value of 90 degrees, i.e. a starting value of the angular position to be recreated by the patient.

The plot demonstrates that in case of exercises in the closed kinematic chain, the angular value median is more distant from the starting point of 90 degrees in relation to exercises in the open chain.

Figure 8 presents an analysis of results from proprioception after exercises in the open and closed kinematic chain for an elbow flexed at 120 degrees of the right upper limb.

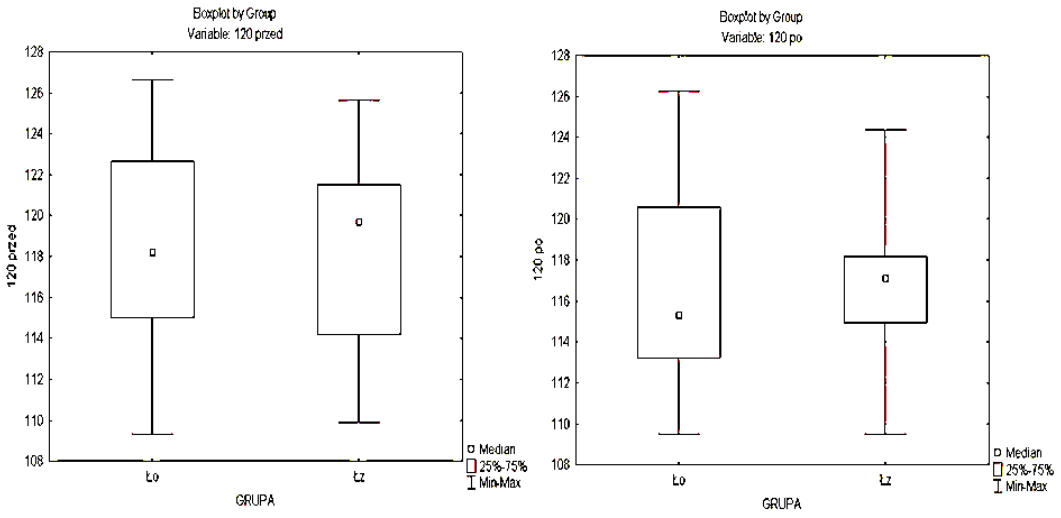

Fig. 8. An analysis of results from proprioception before (left) and after (right) exercises in an open and a closed kinematic chain for an elbow flexed at 120 degrees of the upper right limb.

The plot demonstrates that in case of exercises in the closed kinematic chain, the average angular value is closer to the starting point of 120 degrees in relation to exercises in the open chain.

At the beginning, only one parameter within a limb was compared. When it comes to the left limb,

the greatest differences were recorded in case of the elbow flexure at 30 degrees in the open kinematic chain, and 60 and 120 degrees in the closed kinematic chain.

5. Discussion

There are numerous scientific findings that present various solutions allowing to improve proprioception. Some studies relate to proprioception examination evaluation the impact of elastic bandage on patients with degenerative changes and those after the knee replacement surgery. They proved that application of the elastic bandage improves proprioception of the joint position, however it does not influence improvement of proprioception in healthy individuals [13]. Other researchers observed that proprioception of a joint position is influenced by a soft band [14]. Similar results were observed in case of kinesiotaping applied on the ankle joint [15]. Frequency of other traumas decreased after training on a stable surface, among patients with ankle joint trauma [16]. Proprioception of joint position is increased by improvement of mechanoreceptors functionality, what is reflected also in improvement of joints stabilization, limiting the risk of injury. Within the performed studies, the authors observed improvement in proprioception only partially. Lack of any improvement could have been influenced by the fact that the exercises were performed over the relatively short period.

There were also examinations of influence of the sensory training on nervous and muscle coordination and proprioception. Sensorimotor training was included in the sports trainings of tennis players. The greatest improvement after the lower limbs and torso proprioception training on rehabilitation ball, was observed. Positive responses increased from 64–65% to 93–05% [18]. The training without sensorimotor exercises may cause overloads and microdamages, which will develop into an acute condition, excluding the participant from further trainings or competitions [19]. Not only improving muscle strength or resistance is important, but attention must also be paid to the enhancement or restoration of nervous and muscles proprioception and control [20]. Individuals that take part in a sensorimotor training are capable to analyze the position of their bodies in space, they sense the level of muscle tension more precisely, and they learn new motion actions faster and with greater efficiency [21]. This helps to avoid lesions that would distort the nervous and muscle control and synchronization of static and dynamic mechanisms, leading to joints dysfunction, their destruction and degeneration at the end [22]. There were also studies carried out, confirming that kinesiology taping method can improve proprioception and functionality in glenohumeral joint [23]. Other authors found that the greater the angle of glenohumeral joint flexure in a given direction, the better the capability of sensing the joint position at any moment [24].

In the studies of 2013, Gbiri et al. compared the influence of exercises in the open and closed kinematic chains on proprioception. 25 patients with degenerative changes of the knee were examined. Methodology of proprioception measurements was similar as in our research. The measurements were carried out at 40, 60 and 80 degrees of knee flexure. The authors proved that exercises in closed kinematic chains improved proprioception considerably and lower the pain in the examined group comparing to the group, exposed to exercises in open kinematic chains were applied [25].
Studies carried out by Kwon et al. assessed influence of exercises in open and closed kinematic chains on dynamic equilibrium of healthy persons. The improvement in both groups was observed, however the differences were more significant in the group training in closed chains [26].

Properly selected exercises in the training or therapy will improve proprioception.

6. Conclusions

1. If there is a need to improve proprioception above 90 degrees of elbow flexure, it is worth using exercises in the closed chain.
2. If there is necessary to improve proprioception below 90 degrees of elbow flexure, it is worth using exercises both in the open and closed chain.
3. Further examinations should be carried out on a greater number of subjects.

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