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Małgorzata Pyskir[1], Dorota Ratuszek[1], Ewa Trela[1], Magdalena Hagner-Derengowska[1], Agnieszka Nowacka[2]

PRAGMA DEVICE IN UPPER LIMB REHABILITATION

WYKORZYSTANIE URZĄDZENIA PRAGMA W REHABILITACJI KOŃCZYNY GÓRNEJ

[1]Department of Rehabilitation, Nicolaus Copernicus University, Ludwik Rydygier Collegium Medicum in Bydgoszcz
Kierownik: dr hab. n. med. Wojciech Hagner, prof. UMK
[2] Department of Neurosurgery and Neurotraumatology Nicolaus Copernicus University, Ludwik Rydygier Collegium Medicum in Bydgoszcz
Kierownik: dr hab. n. med. Wojciech Beuth, prof. UMK

S u m m a r y

I n t r o d u c t i o n. PNF patterns are one of the physiotherapeutic methods used in upper limb rehabilitation. Intensification of the effect can be achieved by application of additional resistance. Muscles of the therapist are usually the resistance generator, but in this case there is no possibility to make objective estimation of the applied force value.

M a t e r i a l a n d m e t h o d. In the present study using of accordingly fixed rubbers with different modulus of elasticity is proposed to monitor the resistant overcame by patient's muscles. Values of these forces were determined, both at the beginning and the end of the motion patterns, using six different rubbers.

R e s u l t s. Study shows that a possibility of choices of the initial protraction and a color of rubber allows a smooth and controlled increase of additional forces of resistance along with progress of the treatment.

C o n c l u s i o n s. Knowledge of the value of these forces allows an objective assessment of the patient's motor system abilities.

S t r e s z c z e n i e

W s t ę p. Jedną z metod rehabilitacji kończyny górnej jest wykonywanie ruchów według wzorców PNF. Wzmocnienie efektu można uzyskać poprzez zastosowanie dodatkowego oporu. Zazwyczaj jego źródłem są mięśnie terapeuty, jednak nie ma wówczas możliwości obiektywnej oceny wartości przyłożonej siły.

M a t e r i a ł i m e t o d y. W pracy zaproponowano zastosowanie odpowiednio mocowanych gum lateksowych o różnych współczynnikach sprężystości do monitorowania oporów pokonywanych przez mięśnie pacjenta. Wyznaczono wartości tych sił, zarówno na początku, jak i na końcu wybranych wzorców ruchów dla sześciu różnych gum.

W y n i k i. Pokazano, że możliwość wyboru wydłużenia początkowego oraz koloru gumy pozwala na płynne i kontrolowane zwiększanie siły dodatkowego oporu wraz z postępem rehabilitacji.

W n i o s k i. Znajomość wartości tych sił umożliwia obiektywną ocenę możliwości układu ruchu pacjenta.

Key words: upper limb, rehabilitation, tubing rubber, PRAGMA
Słowa kluczowe: kończyna górna, rehabilitacja, guma tubingowa, PRAGMA

INTRODUCTION

In the upper limb physiotherapy practice, the therapist develops an individualized program of rehabilitation. In some cases, it is overly focused on the absolute desire to achieve the accepted standards such as the normal mobility and muscle strength, although they are not required in daily or professional activities. Complex movements, related to our everyday life (reaching, sitting, walking, lifting, posture maintenance, etc.), are held according to specific movement patterns. Performing arbitrary activities involves the reconstruction of a particular kinetic program (stereotype) of a diagonal and spiral character, which occurs not only in one plane and does not require the full range of motion. Observing the movement of healthy people, and basing on human anatomy, it was found that the natural, physiological movements run in all three planes simultaneously: in the sagittal plane – flexion and extension, in the frontal plane – abduction and adduction, and in the transverse plane – rotation. Complex movement patterns, underlying in human motor activity, are also associated with the Beever's law, which says that 'the brain does not know anything about the action of individual muscles, but it controls the movement as a whole'. This means that the single muscle work cannot be consciously excluded from the particular kinetic activity. A person is able to perform an isolated contraction of individual muscles, but movements of various muscles result from global patterns [1-3].

Therefore, in therapy a particular attention should be given to restore the patient lost motor function, remembering that functional movement is an integrated and multifaceted movement. For this purpose you can use one of the rehabilitation methods based on the neurophysiological basis – PNF (proprioceptive neuromuscular facilitation). Movement patterns of this concept have been developed based on the proper motion and are similar to daily living activities. They are conducted along the oblique (diagonal), placing the course of the pattern components on three lines at the same time: sagittal, frontal and transverse, creating the possibility of activating to work the maximum amount of muscle fibers belonging to the same kinematic chain. The rotation is considered to be the most important component of the motion, according to the oblique course of the majority of skeletal muscles, which determines the strength and coordination of the performed movement [1,4]. Kinematics of the movements performed by the PNF patterns can be studied by using a motion analysis equipment [5]. However, these studies do not provide information about the size of the external forces acting during the performance of motion.

Strengthening the efficiency of the locomotor pattern can be obtained through the use of additional resistance. It is used for muscle contraction; increase of motor control and muscle strength, and also to help the patient achieve movement's consciousness and its direction. The degree of resistance is adjusted so that the movement will be possible to perform smoothly and well coordinated during the both concentric and eccentric muscle work [1, 4]. In the current practice, resistance values are not objectively measurable, because mostly the resistance is a therapist muscular work. A special rubber band with various degrees of elongation, marked with the matching color, can be also used. Depending on the length and color, this band puts a different resistance. The yellow band is considered to be weak, red to be average, green to be strong and blue to be very strong. These four colors are the most commonly used among patients with various diseases. The use of tapes in patterns of movement has a beneficial effect on the stability of the joints. Tubing rubbers made of natural latex can be the band replacement. An important and characteristic feature of rubbers is their linear increase of deformation with the resistance forces increase within the limits extended to about 0.5 m. For larger extensions the relationship ceases to be linear - the same increase in length requires less force to make [6].

In the present study the use of measurable, variable resistance through the use of rubbers with known coefficients of elasticity, is proposed. The variable resistance value is adjusted to the force that a muscle can trigger at a given elongation [7, 8]. Preliminary analysis of the resistance forces has been obtained on the example of the PNF movement patterns.

MATERIAL AND METHOD

Six types of available tubing rubbers of circular cross-section were selected for the analysis. They differ greatly by forces values needed for their extension. Rubbers (straps) are marked by different colors, depending on the coefficient of elasticity. In ascending order of stretching difficulty, there are: yellow, red, green, blue, black and silver. Their elastic properties have been thoroughly tested. A linear dependence of tensile elongation is observed at the beginning of elongation. Further stretching reduces the cross-sectional of rubber and characteristic is no longer linear. However, the preparation of stretching characteristics of each gum allows determination of the force necessary to stretch it to the desired length. Figure 1 shows sample characteristics of two of the used rubbers.

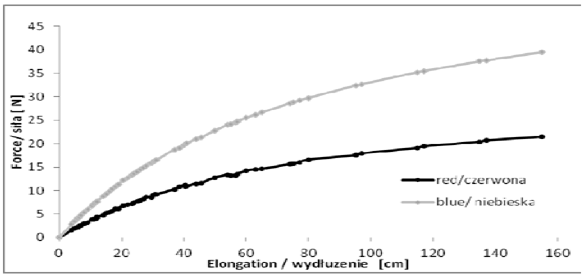

Fig. 1. *Mechanical characteristic of the red and blue tubing rubber in the range of elongation up to 150 cm*

Ryc. 1. *Charakterystyka mechaniczna czerwonej i niebieskiej gumy tubingowej w zakresie wydłużeń do 150 cm*

Each rubber can be fitted to a selected location of the Pragma rehabilitation device [5]. The other end is attached to the handle held in the rehabilitated limb by the patient. During a kinetic pattern performance the patient changes the length of the rubber, and hence the size of the resistance forces overcoming. Volunteers - young, healthy people aged 19 - 21 years without upper limb injuries were invited to perform measurements presented in this study. 25 women and 12 men reported. Apart from weight and height of each individual, the measurements of the upper limb length, straight from the shoulder to the alveolar point of the resistance force - rubber grip, was also performed. Two kinetic patterns were chosen for the initial evaluation of the resistance forces generated by different people by using two selected straps. During the first test, the patient was laying on the exam table on his back, with his upper limb straight along the left hip - right shoulder line, holding slightly stretched rubber. In this study, the volunteers began their move from the length of 100cm, with 83cm length of unloaded rubber. Then, each one performed a move consisted with the PNF pattern: extension - adduction - internal rotation, stretching the rubber with a variable strength. Rubber length measurement was performed in an intermediate position - when the erect upper limb was positioned perpendicular to the trunk and in the final position - right leg at the left hip. The second of the measured movements started from holding the rubber with the left upper limb in the vicinity of the right shoulder. The movement was performed by PNF pattern: extension - abduction - internal rotation. Changes in the stretched rubber length were measured again. In the case of this movement the initial length was 120cm. Then the intermediate position was measured – with the right angle in the elbow and the last extension with the limb next to the left hip and perpendicular setting of the hand to the forearm. On the basis of changes in the length of the rubber, the load traversed while performing a specified motion, was read from its characteristics. The effect of changes in the type of used rubber (different colors) on the size of the applied load was studied. Load changes that can be achieved by changing the initial length of the rubber were also calculated.

RESULTS

Anthropometric data of the study group of men and women, along with standard deviations are shown in Table I. Despite the statistically small number of the test group we managed to find people quite strongly differing in height and weight, which consequently led to the differences in the measured length of the upper limb limited to 12cm in women and 19cm in men. With such a discrepancy it was possible to predict the resistance used in all patients even those physically different from others.

Table I. *Anthropometric data of studied volunteers group, W – women, M – men*

Tabela I. *Dane antropometryczne badanej grupy ochotników W – kobiety, M – mężczyźni*

	Weight/Masa [kg]				Height/Wzrost [cm]				Length UE/Długość KG [cm]			
	Average/Średnia	Min	Max	SD	Average/Średnia	Min	Max	SD	Average/Średnia	Min	Max	SD
W	60,2	42	78	8,8	167	156	177	5,3	60	52	64	3
M	78,8	64	95	10,1	177	163	194	8,4	63	53	72	6

The movement analysis by PNF pattern extension – adduction - internal rotation revealed that among women performing the full movement causes the strap extending change an average by 90cm, while in people over 170cm tall, these values were close to 100 cm (maximum 103cm). The smallest change in the rubber length - about 76cm – was registered in a person of 161cm tall and upper limb length equal 52cm. There was also a relative change in length of rubber in relation to the length of the upper limb of the test person. Despite large differences in cited anthropometric data, an increase in the length of strap in the study group was average 1.5 times larger than the length of the limb with a slight deviation of 7%. Surveyed men were statistically higher than women, which was associated with a greater length of the upper limb. Therefore, in this group a rubber elongation in analyzed kinetic pattern ranged from 79cm in a smaller person, to above 110cm with a height above 185cm. The strap length increase in relation to the length of the upper limb was the same as in women and was average

1.5 with more than the standard deviation in women, which may result from a smaller number of groups of men. The value of tubing rubber elongation does not depend on its color, as each movement begins and ends in the same position. The change of rubber color will only change the limb load change during a specified motion.

During the analysis the attention was paid to the fact of a large increments span of rubbers length in an intermediate position. Observed differences depended on the applicable type (color) of rubber. In case of blue rubber, elongation range values in women ranged from 14cm to 66cm, mean 37 + / - 15.4 cm. In men, rubber elongation in the intermediate position was 44cm average, with 14cm deviation. Such large deviations from the mean values probably stem from the fact that some of the respondents were unable to correctly perform a specified motion using a blue rubber. Compensating the lack of muscle strength in the limb, they flexed elbow, reducing arm strength, which resulted in different location and extension of tubing rubber.

In the second tested kinetic pattern of straps length change, also the set point resistance forces are smaller. In women, the average increase in length was 73cm from the variability in the range from 52cm to 91cm. The men in this movement stretched the tubing rubber by an average of 77cm, with spreads of results ranged from 60cm in lowest to 92cm in high people. This movement starts at the upper limb bent at the elbow, thus extending the size of the strap in relation to the length of the limb is smaller. Both women and men, the average value of this parameter was 1.2.

With the known length of rubber resistance increase, it can be determined for each the value of the force necessary to stretch. It should be noted that in the case of the rehabilitation plan for each patient we must make a measurement of variation of rubber elongation range and on that basis, individually assess the size of the forces generated at a given color rubber. This paper presents examples of resistance forces in three examples, for all the colors of straps:

- a person in whom a range of changes in rubber length during preset movements is the smallest – they are short people, with short upper limbs (MIN),
- a person in whom a range of changes in rubber length during preset movements is the largest – they are tall people, with long upper limbs (MAX),
- for the statistically average value of rubber elongation (AV).

Determined on the basis of individual rubbers resistance characteristics values are shown in the following tables. The values in Table II were determined for the initial length of rubber equal to 83cm (without the initial resistance), in Table III for 120cm.

Table II. *Values of resistance forces in the initial and final position for the PNF pattern extension - adduction - internal rotation for the initial length L_0 = 83cm. W – women, M – men, E - elongation*

Tabela II. *Wartości sił oporu w położeniu wyjściowym oraz końcowym dla wzorca PNF wyprost – przywiedzenie – rotacja wewnętrzna dla początkowej długości rzemienia L_0 = 83cm. W – kobiety, M – mężczyźni, E – wydłużenie*

F_{in} = 0 N		E [cm]	YELLOW/ ŻÓŁTA	RED/ CZERWONA	GREEN/ ZIELONA	BLUE/ NIEBIESKA	BLACK/ CZARNA	SILVER/ SREBRNA
			F_{fi} [N]					
W	MIN	76	12,8	15,9	25,9	29	44,9	55,6
	MAX	103	14,9	18,4	30	33,6	52	64,4
	AV/ ŚRED	90	14	17,3	28,2	311,6	48,9	60,5
M	MIN	79	13,1	16,2	26,4	29,6	45,8	56,7
	MAX	110	15,3	18,9	30,9	34,6	53,6	66,3
	AV/ ŚRED	113	15,5	19,1	31,3	35	54,2	67

Presented results indicate a little change in the resistance during the change of initial elongation for "soft" rubbers (yellow, red) and a strong dependence on the set beginning of the movement for black or silver rubber.

Table III. *Values of resistance forces in the initial and final position for the PNF pattern extension - adduction - internal for the initial strap length L_0 = 120cm. W – women, M – men*

Tabela III. *Wartości sił oporu w położeniu wyjściowym oraz końcowym dla wzorca PNF wyprost – przywiedzenie – rotacja wewnętrzna dla początkowej długości rzemienia L_0 = 120cm. W – kobiety, M – mężczyźni*

		E	YELLOW/ ŻÓŁTA		RED/ CZERWONA		GREEN/ ZIELONA		BLUE/ NIEBIESKA		BLACK/ CZARNA		SILVER/ SREBRNA	
			F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}
		[cm]	[N]											
W	MIN	113	8,4	15,5	10,5	19,1	18,1	31,1	18,9	35	30,1	54,2	37,3	67
	MAX	140	8,4	16,9	10,5	20,8	18,1	34	18,9	38,1	30,1	59	37,3	73
	AVER/ŚRED	127	8,4	16,2	10,5	20,1	18,1	32,8	18,9	36,7	30,1	56,8	37,3	70,3
M	MIN	116	8,4	15,7	10,5	19,3	18,1	31,6	18,9	35,4	30,1	54,8	37,3	67,8
	MAX	147	8,4	17,2	10,5	21,2	18,1	34,7	18,9	38,8	30,1	60,1	37,3	74,3
	AVER/ŚRED	133	8,4	16,5	10,5	20,4	18,1	3,4	18,9	37,4	30,1	57,9	37,3	71,6

A similar effect can be observed in the second of tested kinetic patterns. Results of the analysis carried out for the extension - abduction - internal rotation movement are presented in Tables IV and V.

Table IV. *Values of resistance forces for the PNF pattern extension - abduction - internal rotation in three test cases for the initial strap length L_0 = 83cm. W – women, M – men*

Tabela IV. *Wartości sił oporu dla wzorca PNF wyprost – odwiedzenie – rotacja wewnętrzna w trzech badanych przypadkach dla początkowej długości rzemienia L_0 = 83cm. W – kobiety, M – mężczyźni, E – wydłużenie*

		E	YELLOW/ ŻÓŁTA		RED/ CZERWONA		GREEN/ ZIELONA		BLUE/ NIEBIESKA		BLACK/ CZARNA		SILVER/ SREBRNA	
			F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}
		[cm]	[N]											
W	MIN	52	0	10,3	0	12,8	0	20,9	0	23,4	0	36,2	0	44,8
	MAX	91	0	14,0	0	17,3	0	28,4	0	31,7	0	49,2	0	60,8
	AVER/ŚRED	73	0	12,6	0	15,5	0	25,4	0	28,4	0	44	0	54,4
M	MIN	60	0	11,3	0	13,9	0	22,7	0	25,5	0	39,4	0	48,8
	MAX	92	0	14,1	0	17,4	0	28,5	0	31,9	0	49,4	0	61,1
	AVER/ŚRED	77	0	12,9	0	16	0	26,1	0	29,2	0	45,2	0	56

Table V. *Values of resistance forces in the initial and final position for the PNF pattern extension - abduction - internal rotation in three test cases for the initial strap length L_0 = 120cm. W – women, M – men*

Tabela V. *Wartości sił oporu w położeniu wyjściowym oraz końcowym dla wzorca PNF wyprost – odwiedzenie – rotacja wewnętrzna w trzech badanych przypadkach dla początkowej długości rzemienia L0 = 120cm. K – kobiety, M – mężczyźni*

		E	YELLOW/ ŻÓŁTA		RED/ CZERWONA		GREEN/ ZIELONA		BLUE/ NIEBIESKA		BLACK/ CZARNA		SILVER/ SREBRNA	
			F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}	F_{in}	F_{fi}
		[cm]	[N]											
W	MIN	89	8,4	13,9	10,5	17,2	18,1	28,2	18,9	31,4	30,1	48,6	37,3	60,2
	MAX	128	8,4	16,3	10,5	20,1	18,1	32,9	18,9	36,8	30,1	57	37,3	70,5
	AVER/ŚRED	110	8,4	15,3	10,5	18,9	18,1	30,9	18,9	34,6	30,1	53,6	37,3	66,3
M	MIN	97	8,4	14,5	10,5	17,9	18,1	29,2	18,9	32,7	30,1	50,6	37,3	62,7
	MAX	129	8,4	16,3	10,5	20,2	18,1	33	18,9	36,9	30,1	57,2	37,3	70,8
	AVER/ŚRED	114	8,4	15,5	10,5	19,2	18,1	31,4	18,9	35,1	30,1	54,4	37,3	67,3

DISCUSSION

Results analysis showed that the use of tubing rubbers in the rehabilitation of upper extremity by PNF patterns allows specifying the value and select the appropriate value for the patient's resistance forces. An important feature of that kind of therapy is to change values of the drag force during movement. Working with traditional column boundary is at a constant value of the resistance during the whole movement, which is not adapted to the biomechanical characteristics of muscle. The desired resistance value can be obtained by selecting the appropriate color of rubber and the initial rubber length value. It should be noted that the strength increase is not constant when changing the color of rubber by one degree. For example, at the start of motion equal to the length of the 100cm strap, changing yellow rubber to red, we increase the initial resistance of about 1N (30%). The change from red to green provides almost 4N additionally greater load, which increases by nearly 70%. Similarly, we observe a large increase in resistance between the blue and black rubber. That is why the change of initial length of a concrete rubber color might be so helpful in gradually increasing resistance during exercise. By using both capabilities - the initial load change and then the rubber color used in the rehabilitation change, you can get a very smooth increase of used resistance. This ensures a mild increase in the efficiency of the limb without a fear of too rapid adding resistance, carrying the possibility of overloading. It also allows the control of proper movement implementation. If the resistance is too large for the patient, he tries to compensate the movement by shortening the lever arm. Then we just have to reduce the used resistance so as to allow a proper execution of exercise. A very important feature of the proposed form of rehabilitation is the knowledge of the applied load (which can not be obtained when using therapist’s muscle work). Thus it is possible to objectively evaluate the patient's muscle groups and control the progress of therapy. It should be also noted that similar and also controlled forces of resistance are obtained by implementing movements opposite to those described - then we will resist the work of other muscles. We only need to lay the patient relatively otherwise to the device and possibly change the rubber foothold.

CONCLUSIONS

The use of tubing rubbers with known characteristics in upper limb rehabilitation allows a selection of the mechanical strength of the resistance of known value, changing during movement in a controlled way. The therapist gains the ability to gradually increase the load, which creates a sense of comfort and safety for the patient. With a wide range of elastic straps materials of different colors, both the possibility of using very small forces, working with a yellow rubber, as well as very large, even more than 70N at the hardest exercises with rubber, are obtained. In practice, the black and silver rubber can produce such high resistance that can serve as a device to assist sports training. The use of measurable resistance value allows the objective monitoring of movement and progress of therapy.

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Address for correspondence:
Małgorzata Pyskir
Katedra i Klinika Rehabilitacji CM UMK
ul. M. Curie Skłodowskiej 9
85-094 Bydgoszcz
e-mail:gosia@cm.umk.pl
tel. 052-5853984
kom. 607-14 26 39
fax: 052-5854042

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