

# Is there support for the PNF-concept?

## A literature search on electronically databases

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### **Abstract**

*Context:* The use of the PNF concept or components of the PNF approach is widely spread among physiotherapists all over the world. In modern times Evidence Based Physiotherapy (EBP) is a standard of making the therapy more transparent. Therefore external support for the chosen treatment management is necessary.

*Objectives:* In order to find scientific support for the PNF concept or components of the PNF concept in case this approach is part of the chosen patient management we searched electronically databases to find out to which extend the PNF concept is described and proven to be beneficial for patients.

*Method:* Review of the literature of the last 16 years. We searched Pubmed, Pedro and Academic search elite. We were especially interested in study designs which cover the nowadays view on scientific research within medicine and therapy.

*Results:* We found 42 publications. We had to categorize these publications in groups because of the different fields of studied topics. The groups are again sub categorized in publication design.

*Conclusion:* There is a small amount of support for the PNF concept as an approach for physical rehabilitation. The studies found in this database search vary in subjects and in quality; because of this there is no conclusion over the overall quality of the PNF concept. But for specific objectives within the patient management the PNF concept can be beneficial within the physical therapy provided for a wide range of indications.

### **Background and purpose**

The PNF – concept is an exercise therapy, which has its roots in the 40ties of the last century. Dr. Kabath and Mrs. Knott developed an exercise therapy concept for polio patients. The exercise therapy, which they proposed, was revolutionary for that time. This exercise therapy concept developed through the years and decades up to a fully recognized therapy strategy for many physiotherapeutic indication<sup>1</sup>.

Evidence based physiotherapy treatment is based upon external support of the therapeutic care/intervention combined with the expertise and experience of the therapist and adapted to the needs and objectives of the patient<sup>2 3</sup>.

In respect on the nowadays view of evidence based treatment, scientific support of our actions as a physiotherapist is necessary. In case that in our patient manage-

ment the PNF approach gets a place (maybe based upon expertise and experience of the therapist), a search for external support is justified<sup>3</sup>.

This literature search shows you in which way the PNF - concept is described and researched on its effectiveness and working principles.

### **Objectives:**

The purpose of this study is clarified with the following four objectives:

- To find out to which extend there is publication available on the PNF concept
- To find out in which way effectiveness is described, and on what kind of PNF components.
- To find external support for EBP approach with the PNF concept
- To set up new goals for research on PNF topics

**Method:**

Via the databases of Medline (Pubmed), Academic search elite and Pedro, a search was established to find publications in which the PNF – concept or components of it where subject of the study. This study was limited in time to respect as much as possible the nowadays study designs. The time limitation was from January 1990 till August 2006. The collection took place between February and August 2006. The search terms were: **PNF, Proprioceptive neuromuscular facilitation, facilitation techniques, treatment techniques, exercise methods, exercise concepts, treatment methods, and treatment concepts.** Since the PNF concept covers several different techniques and is applicable in several different indications<sup>1</sup> the results of the search had to be categorized in groups. During the study it became clear that the following 5 groups would appear; Vital functions, Stroke related, Gait related, PNF relaxation techniques and ADL/sport performance related.

Inclusion criteria: One or more of the listed criteria should be met within the publication:

- ✓ PNF as a concept must be a part of the publication.
- ✓ Techniques from the PNF concept must be a part of the publication.
- ✓ PNF concept or techniques must be a part of the treatments for a specific indication, discussed in the publication.
- ✓ The publication must be published after January 1990.
- ✓ Publication must be listed in one of the electronically databases used in this search.
- ✓ Publication must be either a review, a RCT, a clinical trial, a fundamental research, or describing text.

We sub-categorized the publication groups in Reviews, RCT's, CT's, fundamental research and describing texts<sup>3</sup>.

**Results.**

We found 42 publications, they could be categorized in 5 groups. These groups are listed below.

**A:** Vital functions (2): Two publications were found one RCT concerning the oxygen saturation in patients with myotonic dystrophy and one clinical trial studying the effect of HR and CR on acute blood pressure.

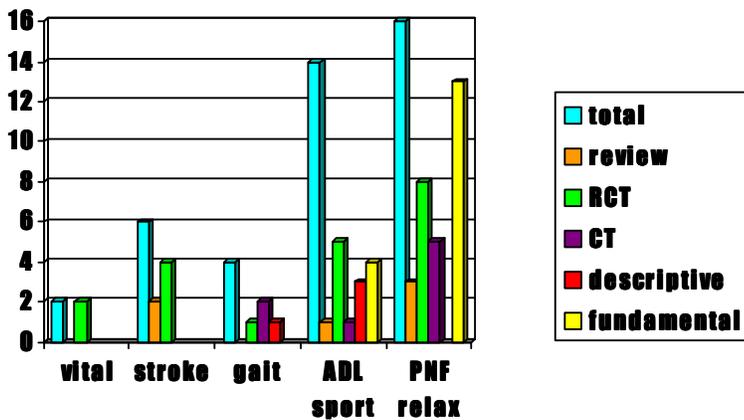
**B:** Gait related (4): four publications on gait therapy using the PNF approach, one describing the PNF procedures, one RCT on amputee patients, one clinical trial on stroke patients and one on Parkinson patients.

**C:** Stroke related (6): We found six publications concerning stroke rehabilitation in which the PNF concept was a part of the studied therapy strategies. There were two review articles, one concerning therapy concepts and one concerning therapy towards the arm function. Four RCT studies were found, studying the effectiveness of home exercise programs, of gait training, of arm rehabilitation training and the follow up of acute physical therapy care.

**D:** ADL/Sport performance related (14): Fourteen publications in a variation from fundamental research to descriptive text. There are four fundamental papers dealing with voluntary movement, muscle hypertrophy, overflow and muscle output. We found one review dealing with shoulder instability in which PNF functional exercise was recommended. Six RCT studies were found ranging from patella femoral pain syndrome (PFPS) over reaching, low back pain into general activity and flexibility in elderly and muscle output in sports. Also three descriptive texts were included describing the PNF approach in lumbar instability, shoulder instability and muscle chains.

**E:** PNF relaxation techniques (16): The articles found vary in intention of research. Two reviews about the effect of stretching on ROM and relaxation. Eight RCT's studied the procedure of the HR and/or CR technique in terms of contraction intensity,

contraction time and prepared situation. Five clinical trials could be considered like fundamental research dealing with the effect and/or explanation for the increased ROM. Generally relaxation effect is doubted in these publications. One text dealt with the frequency of use of PNF relaxation techniques by therapists.



**Discussion:**

According to the International PNF Association, the PNF approach is considered to be a conceptual approach<sup>4</sup>. Some authors regard it as a method. The differences in considering the terms concept and method become clear by the description of using components of the PNF approach and the clinical reasoning in making up a treatment strategy.

Methods are clear described treatment performances. In that way there are no variations possible. A concept is based on ideas, philosophy and logical clinical reasoning. The PNF approach proposed by the IPNFA is based upon a philosophy and a set of basic procedures. The choice of treatment strategy is made up by using these basic procedures for specific objectives for the patient, which are set based upon clinical reasoning with the use of the described philosophy. Then the choice of PNF technique is made, this component can be considered as a method. Still executed using the philosophy and basic procedures<sup>4</sup>.

In considering the studies found in this literature search we found several studies concerning the method of a specific technique without using the concept. Therefore the results of these studies have to be considered only for these specific components of the PNF concept. To study the whole concept is very difficult because of the wide field of indications that can be treated with PNF.

*Vital functions:*

Cornelius<sup>6</sup> ea.(1995) Studied the effect of Hold Relax and Contract Relax techniques on acute blood pressure. The outcome states that it is save up to a maximum of 3 repetitions with a 40-60% of MVIC. Burke and Nitz<sup>7</sup> (2002) studied the effect of specific PNF treatment of breathing compared to staged basal expansion techniques and concluded that PNF approach was the main contributor in increasing O2 saturation and Thoracal Abdominal Motion (TAM).

In the first study it is not clear whether the PNF was applied in diagonals or it was just used to describe isometric contraction followed by passive stretch to the antagonists. The second study was very clear about the approach, manual contact and diagonal movements in the way it is advocated by the IPNFA. The number of patients involved in the study was small (7) and the study was specific to patients with myotone dystrophy. Therefore it is hard to draw conclusions beyond this specific indication.

Author	Design	Topic	outcome
Cornelius ea. 1995	RCT	blood pressure	3 x of 60%
Burke Nitz 2002	RCT	O2 saturation	PNF mean contributor

Table 1: vital function publications.

*Gait related:*

The RCT from Yigiter<sup>8</sup> ea.(2002) concerned 50 patients with a trans femoral amputation.

In the publication is a description of the use of basic PNF procedures and less clear of the PNF techniques. Patients benefit from the PNF approach compared to classic training in terms of significant improvement of gait parameters.

The two clinical trials we found concerned Parkinson (Mirek<sup>9</sup> ea. 2003) and stroke patients (Wang<sup>10</sup> ea. 1994). In both studies patients improved in gait speed, cadence, and rhythm. Conclusion for Parkinson patients are hard to make because of the limited amount of patients, just three patients were included in this study. The study of Wang ea. contained a clear described treatment with specified PNF patterns, techniques, treatment positions and frequency of repetitions and therapy sessions. The results were categorized for patients with a hemiplegic condition of short and long duration. In the treatment was no gait training only pattern training of pelvis pattern. The above mentioned studies do not allow to make statements concerning the effectiveness of PNF gait training, although there is clear indication that PNF gait training is more helpful than classic gait training. According to the discussions in the publications, authors do believe that the proprioceptive stimulation is the main contribution to the beneficial situation for patients.

The descriptive publication of Reichel<sup>11</sup> (1996) about functional gait training using the PNF concept is not very specific. The text should be considered is a general guideline in performing PNF gait training.

Author	Design	Topic	Outcome
Yigiter ea. 2002	RCT	Amputees	Speed, cadence <sup>^</sup>
Mirek ea. 2003	CT	Parkinson	Speed, cadence <sup>^</sup>
Wang ea. 1994	CT	Stroke	Speed, cadence <sup>^</sup>
Reichel 1996	instruction	Teaching	non

Table 2: Gait related publications.

<sup>^</sup> means improvement.

#### *Stroke related:*

The review of Luke<sup>12</sup> ea. (2004) dealt with treatment concepts to improve arm function in hemiplegic patients. They concluded that there was no superiority in any studied concept. This is consistent with other reviews concerning stroke rehabilitation approaches.

Ernst<sup>13</sup> ea. (1990) recommended in their review to use the most cost – effective form of treatment in stroke patients. He was not specific in which treatment concept that would be, but lined out that it is depending on the setting of the patient care.

Duncan<sup>14,15</sup> ea. (1998; 2003) studied in RCT's treatment programs for stroke patients in 1998 a home-based program including PNF diagonal exercises with resistive elastic bands was advocated. In 2003 a structured program including PNF training with manual resistance was proven for sub acute stroke patients to gain in endurance, balance and mobility beyond that of natural recovery. Pohl<sup>16</sup> ea.(2002) Studied the benefit of treadmill training versus conventional training which was defined by techniques from the Bobath and PNF approach. The conventional group was treated by therapist with additional qualification in Bobath and PNF concepts. Their conclusion was that treadmill training was more beneficial for stroke patients. Kraft<sup>17</sup> ea.(1992) studied the recovery of hand function by comparing electrical stimulation with PNF resistive treatment and no treatment. The PNF group improved by 18% while the electrical stimulated group improved up to 42%.

The PNF described in the above mentioned publications seems to be according to the guidelines from the IPNFA.

Author	Design	Topic	Outcome
Luke ea. 2004	Review	Arm function	No superior concept
Ernst ea. 1990	Review	Cost / effective	Use most cost effective

Duncan ea. 1998	RCT	Home program	Inclusive PNF
Duncan ea. 2003	RCT	Structured program	Inclusive PNF
Pohl ea. 2002	RCT	Gait	Treadmill is best
Kraft ea. 1992	RCT	Hand function	Electrical stimulation over PNF

Table 3: Stroke related publications.

*ADL/sport performance:*

This category deals with a wide range of functional activities. Since researchers choose their specific functional problems and the specific therapy strategy, there is just a small amount of studies concerning the same functional problem with the same treatment approach. This explains why there is a wide range of functional topics and just a small amount of publications on the same topic with a treatment management including (a component of) the PNF concept.

Still there is a substantial support for the PNF approach in its fundamentals. Shimura<sup>18</sup> ea (2002) showed with measuring EMG reaction time and motor evoked potentials in the brain that PNF positions, patterns and procedures are beneficial in initiating voluntary movement. Kofotolis<sup>19</sup> ea. (2005) proved that PNF treatment increases the cross sectional area of muscles and also influences the muscle fiber type. Arai<sup>20</sup> ea. (2001) showed that with PNF pattern treatments there is a clear cross education to the contra lateral side of the body, thus supporting the idea of overflow and irradiation. Marek<sup>21</sup> ea. (2005) studied the effect of PNF stretching on mean power output (MP) and ROM, they concluded that it reduces MP and increases ROM as well active and passive.

In the review of Meyers<sup>22</sup> ea. (2000) about shoulder instability in athletes it is recommended to build in PNF in functional exercise.

Epifanov<sup>23</sup> ea. (2000) stated that PNF treatment should have a place in the management of patients with cervical degeneration problems. Schneider<sup>24</sup> ea. (2001) showed in a RCT that in case of PFPS (patella femoral pain syndrome) treatment with a splint is more effective than PNF treatment. However in that study only PNF in an open chain was performed. Klein<sup>25</sup> ea. (2002) concluded that PNF treatment in elderly brings significant improvement of general flexibility, ROM, strength and ADL function. Godges<sup>26</sup> ea. (2003) studied in a RCT the effect of PNF stretching techniques on external rotation and reaching over head, and concluded that PNF is effective in increasing ROM. Kofotolis<sup>27</sup> ea. (2006) studied in a RCT the effectiveness of two PNF techniques on women with CLBP (chronic low back pain). The rhythmic stabilization (RSt) and combination of isotonic (CoI) techniques both produced a significant improvement of muscle endurance, flexibility, and ADL function. In spite of the correct names of the techniques, the description of how to perform these techniques was not according to those of the IPNFA.

Church<sup>28</sup> ea (2001) performed a clinical trial on the effect of warming up inclusive and exclusive PNF stretching techniques. They measured the vertical jump after the warming up procedures. With the PNF stretching the performance was decreased. This is corresponding with the results of Marek<sup>21</sup> ea. (2005).

Mc Mullen<sup>29</sup> ea. (2000) described the benefits of using muscle chains like in PNF patterns in treating shoulder problems. Johnson and Johnson<sup>30</sup> (2002) described clearly how the PNF concept combined with manual therapy could be implemented in the management of patients with lumbar instability. Margery and Jones<sup>31</sup> (2003) advocated in their master class publication in clinical reasoning to use PNF setting exercises in patients with shoulder instability. Indirectly they point out the benefits of the replication technique.

In general the publications are positive about the PNF (components) approach. Although stretching techniques do not

benefit in stronger muscle output, but help in increasing ROM.

Author	Design	Topic	Outcome
Shimura ea. 2002	Fundamental	Voluntary movement	PNF is beneficial
Kofotolis ea. 2005	Fundamental	Muscle effect	Hypertrophy, fiber type alteration
Arai ea. 2001	Fundamental	Cross education	PNF has a clear effect
Marek ea. 2005	Fundamental	Stretch effect	Reduced MP ROM increased
Meyers ea. 2000	Review	Shoulder instability	Functional exercise
Epifanov ea. 2000	RCT	Cervical artrosis	PNF part of management
Schneider ea. 2001	RCT	PFPS	Splint is better than PNF
Klein ea. 2002	RCT	PNF in elderly	PNF increases ADL function
Godges ea. 2003	RCT	Reaching over head	PNF increases ROM
Kofotolis ea. 2006	RCT	CLBP	ADL function improved
Church ea. 2001	CT	Vertical jump	PNF decreases jump height
Mc Mullen ea. 2000	Descriptive	Muscle chain	Non
Johnson 2002	Descriptive	Lumbar instability	PNF combined with manual therapy
Margery, Jones 2003	Descriptive	Clinical reasoning, shoulder	PNF setting exercise

Table 4 : ADL/sport performance publications.

#### *PNF relaxation techniques.*

Sarburg<sup>32</sup> (1997) assessed the use of PNF stretching techniques in 1981 and 1993 and concluded that therapist use those techniques equally frequent then and now.

Only a slight increase for ankle rehabilitation was found. Further PNF stretching was mainly used for the rehabilitation of knee, shoulder and hip injuries.

The review of Weerapong<sup>33</sup> ea. (2004) states that the effect of stretching, inclusive PNF stretching is inconclusive on its effect of increasing performance, but an improvement of ROM is evident. Chalmers<sup>34</sup> ea. (2004) wrote in their review that ROM is clearly positively influenced by PNF stretching techniques, however there is no prove for relaxation. The H-reflex and EMG activities are just minimally decreased. Other reasons for increasing of ROM must be studied to explain this feature.

The RCT of Funk<sup>35</sup> ea. (2003) showed that PNF is more effective than static stretching (SS) after activity. Wenos<sup>36</sup> ea. (2004) also showed that HR stretching is more effec-

tive after an active warm up program, it needs 70% increment of heart rate reserve to make muscle more prepared for the treatment technique. Contrary to these findings Davis<sup>37</sup> ea. (2005) concluded in his RCT that PNF is not as effective as static stretching. Feland<sup>38</sup> ea. (2004) studied the effect of the contraction intensity, and concluded that sub-maximum and maximum voluntary contraction have equally good results in increasing ROM. Schuback<sup>39</sup> ea. (2004) compared self applied and therapist applied HR techniques. Both are significant in increasing ROM. Rowlands<sup>40</sup> ea. (2003) studied the contraction time in the relaxation techniques. Their conclusion was that a longer contraction time results in more increment of ROM. In contrary Bonnar<sup>41</sup> ea. (2004) came with the result that contraction time of 3 or 6 or 10 sec is equally effective in increasing ROM. Deccicco<sup>42</sup> ea. (2005) studied the effect of HR and CR in shoulder ROM in over head athletes, and concluded that they are equally effective. The clinical trial of Moore<sup>43</sup> ea. (1991) showed

that HR results in a short phase of relaxation, the H-reflex in calf muscle was reduced up to maximally 1 second after HR. Ferber<sup>44</sup> ea. (2002) concluded in a controlled trial that agonist CR is more effective than CR in older adults. In an other publication of Ferber<sup>45</sup> ea. (2002) they concluded in the same target group (elderly) that CR influences ROM positively but that the EMG activity did not decrease, thus the ROM increment was not because of relaxation. Olivo<sup>46</sup> ea. (2006) also stated

that CR agonistic and antagonistic did not decrease EMG activity. They studied masticatory muscles. Carter<sup>47</sup> ea. (2000) studied the muscle activity in terms of mean output after PNF stretching techniques and concluded that the muscle activity decreased.

The findings of Moore<sup>43</sup> ea. (1991), Ferber<sup>45</sup> ea. (2002) and Olivo<sup>46</sup> ea. (2006) are consistent with the findings in the review of Chalmers<sup>34</sup> ea. (2004).

Author	Design	Topic	Outcome
Sarburg 1997	Review	Frequency of PNF	Equally in 1981 and 1993
Weerapong ea. 2004	Review	PNF stretching	ROM ^, performance?
Chalmers ea. 2004	Review	PNF stretching	ROM ^, relaxation?
Funk ea. 2003	RCT	stretching	PNF > SS
Wenos ea 2004	RCT	Warming up (WU)	HR more effective after WU
Davis ea. 2005	RCT	Stretching	SS>PNF
Feland ea. 2004	RCT	Contraction intensity	Equal
Schuback ea. 2004	RCT	Application	Self = therapist
Rowlands ea. 2003	RCT	Contraction time	Longer results in more ROM
Bonnar ea. 2004	RCT	Contraction time	All times equally effect
Deccicco ea. 2005	RCT	HR versus CR	Both are equal
Moore ea. 1991	CT	H-reflex	Short time of reduction
Ferber ea. 2002	CT	ROM in elderly	Agonist CR > CR
Ferber ea. 2002	CT	EMG	No EMG decrement
Olivo 2006	CT	Masticatory muscles	No EMG decrement
Carter ea. 2000	CT	Mean output after stretching	Reduced activity in the muscles

Table 5: PNF relaxation publications. ^ means improved, > means bigger than, ? means discussible

From 7 of the RCT's the studied muscle group concerned the hamstrings, only one concerned the shoulder. In the clinical trials also masticator and calf muscle was studied. The out comes are conclusive with the reviews concerning the effect on ROM and on relaxation. The relaxation techniques indeed help in increasing ROM but this is not based upon relaxation of those muscles. There is a contradiction in the outcomes from Bonnar<sup>41</sup> and Rowlands<sup>40</sup> concerning the contraction time.

In general one has to argue that the PNF techniques mentioned in the studies are not all clear described, at least not according to

the IPNFA recommendations. Besides that in the studies it is not clear whether the exercises were performed in diagonals with appropriate manual contact and other basic procedures. It seems that the studies only concerned the type of sequences performed during the HR or CR technique without dealing with the muscle chains within the pattern.

On the other hand in this way all the RCT and clinical trials could be considered like fundamental research. In this way the outcomes can support the PNF concept and therapists when a treatment objective is dealing with increasing ROM.

About the chosen method of categorization in the five groups one may find some arbitrary decisions. Especially the study of Wang<sup>10</sup> ea. (1994) could be considered as stroke related and the study of Pohl<sup>16</sup> ea. (2002) could be considered as gait related. In the first case the categorization was made upon the outcome measures the second one was categorized based upon the treatment group (stroke patients) and the fact that different approaches were compared to each other.

Also the publications of Godges<sup>26</sup> ea. (2003) and Marek<sup>21</sup> ea (2005) could be considered as publications dealing with PNF relaxation techniques. Because these studies emphasis on the effect in performing in function and less on the effect of change in ROM and/or relaxation we categorized them as ADL/sports related.

The internal validity of the publications varies. In some the inclusion criteria are clear described, in others they are vague. The number of participating patients vary, for example in the study of Mirek<sup>9</sup> only three patients participated. Not in all the RCT's are control groups, they lack also in the clinical trials.

For the external validity one has to ask himself if the situation of the study is similar to the practise situation of the treatment for which one is looking for external support<sup>5</sup>.

### **Conclusion**

There is a small amount of support for the PNF concept as an approach for physical rehabilitation.

The majority of publications for PNF deal with PNF stretching techniques, but this term is not specific and not according to the IPNFA descriptions of the HR and CR techniques.

The studies found in this database search vary in subjects and in quality, because of this there is no conclusion over the overall quality of the PNF concept. But for specific objectives within the patient man-

agement such as increasing range of motion, improving voluntary movement, improving gait speed, improving reaching etc. the studies found indicate that the PNF concept can be beneficial within the physical therapy provided for a wide range of indications. The effectiveness is depending on the specific situation. The publications on gait, stroke and vital function are overall fitting in the PNF concept. The articles about ADL/sport performance deal with indications which are suitable for the PNF treatment.

Indications for the PNF concept range from central neurological disorders, over orthopedic and traumatic problems up to sport injuries. Patients treated with the PNF concept may differ from young adults up to elderly people according to the publications found in this search.

Several articles can be used for supporting the choice of PNF treatment when the proper patient and treatment situation is present.

Based upon the outcomes of this search we recommend that further research in PNF should deal with more patient oriented objectives. The PNF philosophy and basic procedures should be secured in the studied treatments. The PNF techniques have to be described and executed in the appropriate way, according to the teaching units of the IPNFA. Only this way we can find out if the techniques are sufficient or that we should consider changes in the concept.

### *Acknowledgement.*

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Literature list:

1. Buck M, Beckers D, Adler S: PNF in Practice. *Springer Verlag / publishers* 2000
2. Maher CG, Sherrington C, Elkins M, Herbert RD, Moseley AM: Challenges for EBP: Accessing and interpreting High-Quality evidence on therapy. *Physical therapy* 2004 (7) 644-654
3. Straus SE, Sacket DL: Getting research findings into practice. *BMJ* 1998 (8) 339-342
4. IPNFA, educational committee: Course curriculum content, teaching units. [www.ipnfa.org](http://www.ipnfa.org) .
5. Herbert R, Jamtvedt G, Mead J, Hagen KB: Outcome measures measure outcomes, not effects of intervention. *Australian journal of physiotherapy* 2005 3-4 (editorial)
6. Cornelius WL, Jensen RL, Odell ME: Effects of PNF stretching phases on acute arterial blood pressure. *Can. Jo. Appl Physiology* 1995 (2)222-229
7. Nitz J, Burke B. A study of the facilitation of respiration in myotonic dystrophy. *Physiotherapy research international* 2002 (4) 228-238
8. Yigiter K, Sener G, Erbahceci F, BayarK, Ülger ÖG, Akodogan S: A comparison of traditional prosthetic training versus PNF resistive gait training with trans-femoral amputees. *Prosthetics and orthotics international* 2002 (26) 213-217
9. Mirek e, ea. Przydatnosc trójwymiarowej analizy lokomocji dla usprawniania ruchowego metoda PNF chorych na chorobe Parkinsona. *Neurol. Neurochir. Poland* 2003 (5) 89-102
10. Wang RY. The effect of proprioceptive neuromuscular facilitation in case of patients with hemiplegia of long and short duration. *Physical Therapy* 1994 (12) 25-32
11. Reichel HS PNF: Gangschulung. *Sportverletzung, sportschaden* 1996 (10) A11-A20
12. Luke C, Dodd KJ, Brock K: Outcomes of the Bobath concept on upper limb recovery follwing stroke. *Clinical Rehabilitation* 2004 (18) 888-898
13. Ernst E: A review of stroke rehabilitation and physiotherapy. *Stroke* 1990 (21) 1081-1085
14. Duncan P ea.: A Randomized, controlled pilot study of a home – based exercise program for individuals with mild and moderate stroke. *Stroke* 1998 (29) 2055-2060
15. Duncan P ea. RCT of therapeutic exercise in subacute stroke. *Stroke* 2003 (34) 2173-2180
16. Pohl M, Mehrholz J, Ritschel C, Rückriem S: Speed dependent treadmill training in ambulatory hemiparetic stroke patients : A RCT. *Stroke* 2002 (33) 553-558
17. Kraft GH, Fitts SS, Hammond MC: Techniques to improve function of the arm and hand in chronic hemiplegia. *Arch. Phys. Med. Rehabilitation* 1992(3) 220-227
18. Shimura K, Kasai T: Effects of proprioceptive neuromuscular facilitation on the initiation of voluntary movement and motor evoked potentials in upper limb muscles. *Human movement science* 2002 (1) 101-113
19. KofotolisN, Vrabas IS, Vamvakoudis E, Papanikolaou A, Mandroukas K: Proprioceptive neuromuscular facilitation training induced alterations in muscle fiber type and cross sectional area. *British Journal of Sports Medicine* 2005 (3):e11.
20. Arai M, ea : Effects of the use of cross-education to the affected side through various resistive exercises of the sound side and settings of the length of the affected muscles. *Hiroshima journal of medical science* 2001 (3):65-73
21. Marek SM ea. : Acute effects of static and PNF stretching on muscle strength and power output. *Journal of athletic training* 2005 (2) 94-103
22. Myers JB, Lephart SM: The role of the sensorimotor system in the athletic shoulder *Journal of athletic training* 2000 (3) 351-363

23. Epifanov VA, Shuliakovskii V V: The rehabilitative therapy of patients with osteochondrosis of the cervical spine and manifestations of hyper mobility by means of therapeutic physical exercise. *Vopr Kurortol Fizioter Lech Fiz Kult* 2000 (1):8-11.(Russian)
24. Schneider F, Laps K, Wagner S: Chronic patello femoral pain syndrome: alternatives for cases of therapy resistance. *Knee surgery sports traumatology arthroscopy* 2001 Sep;9(5):290-295
25. Klein DA, Stone WJ, ea. PNF training and physical function in assisted living older adults. *Journal of aging and physical activity* 2002 (10) 476-488
26. Godges JJ, Matsen-Bell M, Thorpe D, Shah D: The immediate effects of soft tissue mobilization with proprioceptive neuromuscular facilitation on glenohumeral external rotation and overhead reach. *Journal of orthopedics sports and Physical Therapy* 2003 (12) 713-718
27. Kofotolis N, Eleftherios K: Effects of two 4-week PNF programs on muscle endurance, flexibility, and functional performance in women with CLBP. *Physical Therapy* 2006 (7) 1001-1012
28. Church JB, Wiggins MS, Moode FM, Crist R: Effect of warm-up and flexibility treatments on vertical jump performance *Jo. Strenght cond. Research* 2001 (3):332-336
29. Mc Mullen J, Uhl TL: A kinetic chain approach for shoulder rehabilitation. *Journal of athletic training* 2000 (3) 329-337
30. Johnson GS, Johnson VS. The application of the principles and procedures of PNF for the care of lumbar spinal instabilities. *The Journal of manual and Manipulative therapy* 2002 (2) 83-105
31. Magarey ME, Jones MA. Dynamic evaluation and early management of altered motor control around the shoulder complex. *Manual Therapy* 2003 (4) 195-206
32. Sarburg PR, Schrader JW: Proprioceptive Neuromuscular Facilitation Techniques in Sports Medicine: A Reassessment. *Journal of athletic training* 1997 (1):34-39.
33. Weerapong P, Hume PA, Kolt GS: Stretching: mechanisms and benefits for sport performance and injury prevention. *Physical Therapy Reviews* 2004 (9) 189-206
34. Chalmers G: Re-examination of the possible role of Golgi tendon organ and muscle spindle reflexes in proprioceptive neuromuscular facilitation muscle stretching. *Sports biomechanics* 2004 (1) 159-183
35. Funk DC, Swank AM, Mikla BM, Fagan TA, Farr BK: Impact of prior exercise on hamstring flexibility: a comparison of proprioceptive neuromuscular facilitation and static stretching. *Journal of strength and conditioning research* 2003 (3):489-492
36. Wenos DL, Konin JG: Controlled warm-up intensity enhances hip range of motion. *Journal of strength and conditioning research* 2004 (3):529-533
37. Davis DS, Ashby PE, Mc Cale KL, Mc Quain JA, Wine JM: The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. *Journal of strength and conditioning research* 2005 (1):27-32.
38. Feland JB, Marin HN: Effect of sub maximal contraction intensity in contract-relax proprioceptive neuromuscular facilitation stretching. *British journal of sports medicine* 2004
39. Schuback B, Hooper J, Salisburg L: A comparison of a self stretch incorporating PNF components and a therapist applied PNF technique on hamstring flexibility. *Physiotherapy* 2004 (3) 151-157
40. Rowlands AV, Marginson VF, Lee J: Chronic flexibility gains: effect of isometric contraction duration during proprioceptive neuromuscular facilitation stretching techniques. *Research Quarterly Exercise and sports* 2003 (1):47-51.

41. Bonnar BP, Deivert RG, Gould TE: The relationship between isometric contraction durations during hold-relax stretching and improvement of hamstring flexibility. *Journal sports medicine and physical fitness* 2004 (3) 258-261
42. Deccicco PV, Fisher FM: The effects of proprioceptive neuromuscular facilitation stretching on shoulder range of motion in overhand athletes. *Journal of sports medicine and physical fitness* 2005 (2):183-187.
43. Moore MA, Kulkulka CG: Depression of Hoffmann reflexes following voluntary contraction and implications for proprioceptive neuromuscular facilitation therapy. *Physical Therapy* 1991 (4):321-329; discussion 329-33.
44. Ferber R, Gravelle DC, Osternig LR. Effect of PNF stretch techniques on trained and untrained older adults. *Journal of aging and physical activity* 2002 (10) 132-142
45. Ferber R, Osternig LR, Gravelle DC: Effect of PNF stretch techniques on knee flexor muscle EMG activity in older adults. *Journal of electromyography and kinesiology* 2002 (12) 391-397
46. Olivo SA, Magee DJ: Electromyographic assessment of the activity of the masticatory using the agonist contract – antagonist relax technique (AC) and contract – relax technique (CR). *Manual therapy* 2006 (2) 136-145
47. Carter AM, Kinzey SJ, Chitwood LF, Cole JL: PNF decreases muscle activity during the stretch reflex in selected posterior thigh muscles. *Journal of sport rehabilitation* 2000 (9) 269-278