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A LITERATURE REVIEW ON THE USE OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION IN NEUROMUSCULAR REHABILITAION

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The purpose of this thesis was to review and critically analyze the literatures from 1990 to 2013 in order to investigate the methodological quality of the studies, indications and goals of PNF treatment, and to explore the components of PNF that are being used in treatment of neurological disorders. And to overview on the effectiveness and use of PNF approach in neuromuscular rehabilitation through the findings of this study.

The research method used for this thesis was systematic literature review. The manual search for relevant scientific researches on the topic of study was conducted through Academic Search Elite (EBSCO), PubMed, Science Direct, and Physiotherapy Evidence Database (PEDro).

13 literatures were gathered after screening of the studies found from all the databases used. The methodological quality of the studies was assessed using Physiotherapy Evidence Database (PEDro) scale system. And the findings were summarized according to PICO model.

This study found stroke as the biggest indication of PNF in neuromuscular rehabilitation. The goals and components of PNF were discussed. The assessment of methodological quality of individual studies showed remarkable variations in scores that prevented from articulating any concrete opinion on overall quality of PNF approach in neuromuscular rehabilitation. The effectiveness of PNF however cannot be determined from this study consequently need of further review was suggested.

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1 INTRODUCTION

Proprioceptive Neuromuscular Facilitation is a philosophy and a concept of treatment that has been one of the most recognized treatment concepts in physiotherapy since the 1940s and being practiced widely by physiotherapists all over the world (Adler et al. 2008, & Smedes 2006). PNF is defined as method of promoting or hastening the response of the neuromuscular mechanism through stimulation of the proprioceptors. It is based on theoretical principle that the body's neuromuscular components are adaptable or plastic hence, stronger body movement patterns of spiral and diagonal in nature are used to facilitate weaker ones, and to increase motor and sensory awareness (Westwater-Wood et al. 2010). Although PNF was introduced as a treatment approach for neurological rehabilitation, today it is used in various other sectors such as orthopedic, sports, traumatic training and rehabilitation. This thesis particularly focuses on use and effectiveness of PNF in neuromuscular rehabilitation.

Westwater-Wood et al. (2010) suggests that physiotherapy profession views the concept of PNF is often based on treatment techniques that have limited scientific support and are based upon inadequate and unreliable evidence, and the science behind therapeutic techniques is not as strong as the beliefs of the therapists in their effectiveness. The amount of scientific researches regarding its use in neuromuscular rehabilitation is limited and there is lack of evidence-based data to support its usefulness and effectiveness.

Neurology and neuromuscular rehabilitation has been a greatest subject of interest for me since the very beginning of the physiotherapy studies. Particularly PNF has been a subject of a great fascination, for in my opinion it has unique techniques and treatment approach that requires manual skills in therapist, and equal participation from the patients. During physiotherapy practice in Nepal, I got great opportunity to work in the field of neuromuscular rehabilitation and practice PNF techniques in patients with various neurological disorders, particularly one case of 23-year-old patient with Guillain Barre Syndrome (GBS). Physiotherapy treatment was started from the very first day of onset and all the progressions were recorded. As soon as the patient achieved grade 3/5 in manual muscle testing PNF treatment was employed. A dramatic response was noticed after three months train-

ing; remarkable improvement in functional capacity and the overall muscles strength increase to grade 4-5/5. However, there was no motive of evaluating the effectiveness of PNF through the rehabilitation process. Nevertheless, the experience I gained from that case played a big role to develop interest towards PNF approach.

Apparently, PNF concept is considered to be outdated in Finland and it is neither a part of curriculum in Physiotherapy Bachelor's degree program, which made the possibility to engage in an original research on this chosen topic quite narrow. Consequently, conducting a systematic literature review appeared to be one of most favorable ways where it is possible to combine the results of available primary literatures to meet the aims and purpose of my research. This thesis aims to find the extent to which the publications are available on use of PNF in treating neurological disorders and make an overview on its effectiveness.

2 BACKGROUND

PNF is a manual treatment method first described in the late 1940s and early 1950s by Dr. Herman Kabat and Margaret Knott as a means of rehabilitation for neurological disorders such as multiple sclerosis, cerebral palsy and poliomyelitis. It is a concept of treatment based on a philosophy that every human being including people with disabilities possesses an unexploited existing potential (Adler et al. 2008, 2).

PNF philosophy supports positive and active approach to treatment where the body movements of both the therapist and patient are incorporated into patterns that have a specific, and purposeful goal for achieving highest level of function (Hesbach 2013). In this approach, principle of motor control and motor learning is integrated focusing on exceeding the patient's limits by manipulating his unexploited existing potential. Treatment is intended at a total human being, rather than only at a particular problem or body segment that involves treatment on the level of body structures, on the activity level as well as on the participation level, which makes it an integrated approach. All PNF treatments aims to increase strength, coordination and control of motion, develop proper balance between motion and stability, and to increase endurance (Adler et al. 2008, 2).

PNF is a multifaceted and time efficient treatment approach; it can be used to treat any diagnosis or condition depending on patient's condition (Adler et al. 2008, 2). The practice of PNF had evolved through years and flourished in last decades and its indications has widened beyond its origin. Today PNF is practiced in various fields like neuromuscular-rehabilitation, orthopedic and musculoskeletal disorders and rehabilitation, sports medicine and sports rehabilitation, activities of daily living, pediatric problems, cardiorespiratory problems, and geriatrics (Smedes 2006). According to Scifers (2012) PNF is widely known as a stretching technique and technique to increase range of motion (ROM) in sports and musculoskeletal physiotherapy nowadays. The stretching effect of PNF is even believed to be superior to other stretching techniques. The neuromuscular inhibition induced using stretching components helps relaxing the contractile component of shortened muscles to promote muscle length and increase joint range of motion.

2.1 Basic procedures of facilitation

PNF is based on the principles of functional anatomy and neurophysiology in which proprioceptive, cutaneous, and auditory input is used for facilitation. Through the basic procedures the therapist helps the patient gain efficient motor function by increasing ability to move or remain stable, helps increasing stamina and avoid fatigue. Therapist helps to guide the motion with the use of proper grips and appropriate resistance and help the patient achieve coordinated motion through timing. For facilitation, movement, rhythm and auditory cues are used for it diminishes cortical initiation and abnormal EMG activity. Rhythm enables the client to move continuously with alternating flexion and extension without becoming fixated and clapping or music enhances this effect.

Before starting the basic procedure, the sequential movements from starting position to terminal position are explained and demonstrated to the patients and when the subject is able to perform the movement pattern, the facilitation process is started. There is always active participation of the patient in the therapy. The basic procedures for facilitation explained by Adler et al. (2008, 6-13) includes:

"Resistance" assists the ability of muscles to contract, induces motor control and motor learning, and gives the patient an awareness of motion and its direction. It induces reciprocal inhibition and promotes relaxation and helps increasing strength. "Irradiation and reinforcement" can be defined as stimulation produced through use of the spread of the response. In this procedure the therapist directs the reinforcement of the weaker muscle by the amount of resistance given to the strong muscles to stimulate contraction or relaxation in the synergistic muscles and pattern of movement. "Manual contact" promotes tactile-kinesthetic perception, provides security and confidence to the patient, facilitates muscles to contract, and stimulates synergistic limb muscles to reinforce the movement and assists movement. "Body position and body mechanics" is important for ergonomics, efficiency, stability, guidance and effective control of patient movement. "Verbal commands" are used to guide movements, encouragement, and for corrections and feedback. The therapist should appropriate words and vocal volume. "Vision" patient observing his own movements leads to better movement guidance and increase in force, correction and control of position and motion. It influences both the head and body motion, provides opportunity to observe progress or areas to improve, gives encouragement, and helps in cooperative in-

teraction between therapist and the patient. “Traction and approximation” promotes stabilization, facilitates weight bearing and the contraction of antigravity muscles and upright reactions, and resist compensatory movements. “Stretch” passively stretching muscle induces stretch reflex that stimulates muscle contraction, and decrease muscle fatigue. “Timing” encourages normal timing and promotes muscle contraction through “timing for emphasis”.

“Patterns” of facilitation are considered one of the basic procedures of PNF, which consists of movements combined with spiral and diagonal motion. According to Adler et al. (2008, 48-49) Normal functional motion is composed of mass movement patterns of the limb and the synergistic trunk muscles, and PNF patterns are the result of combinations of those synergistic muscles. The PNF patterns combine motion in all three planes creating the spiral and diagonal motion – the sagittal plane (flexion and extension), the coronal plane (abduction and adduction, lateral flexion and trunk), and the transverse place (rotation). The figure 1 below presents the spiral and diagonal pattern of PNF (Adler et al. 2008, 49).

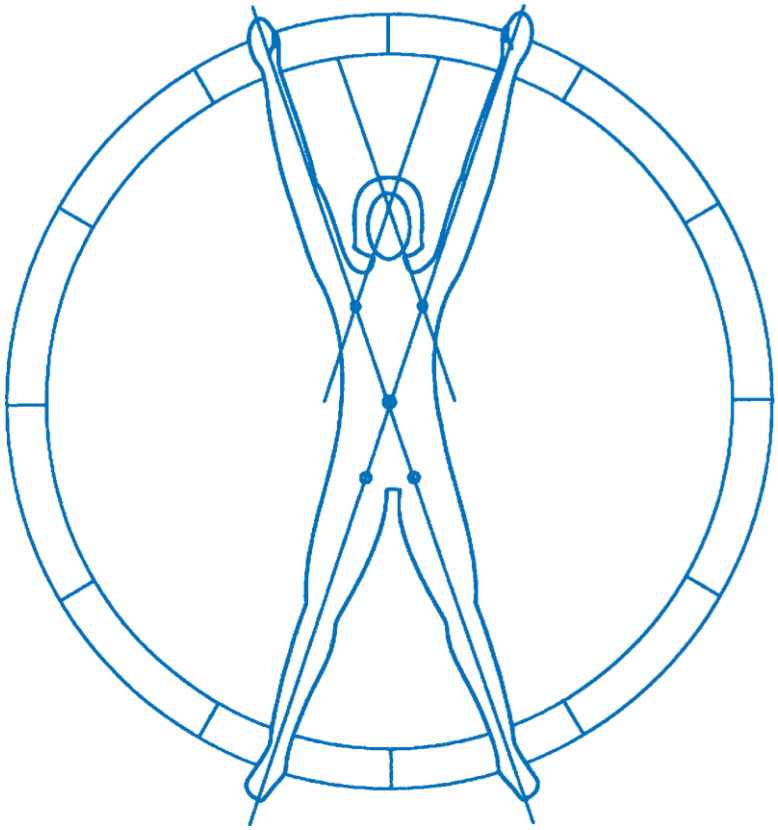

Fig. 1. Spiral and Diagonal Pattern of PNF (Adler et al. 2008, 49)

2.2 Significance of PNF in neuromuscular rehabilitation

PNF consist of therapeutic exercises that use a series of facilitation and synergy patterns in an effort to get muscle strengthening, neuromuscular reeducation, and "overflow" from the stronger muscle groups to the weaker muscle groups as this system provides opportunity for the weaker muscles work with the stronger muscles and not in isolation (Stoker 1995, 368).

PNF is a positive functional approach that can become an important source of external information to stimulate patients during the first stages of motor learning in a rehabilitation process. In cases of movement disorders, where clients loses the ability to exchange sensory and cognitive information that determines motor outputs to interact with the surrounding or environment, causing them unable to no longer trust their internal information and limiting patients to learn a new task (Adler et al. 2008, 2).

2.3 Techniques of facilitation useful in neuromuscular rehabilitation

PNF purposes various techniques that are essential to induce facilitation, inhibition, strengthening, and relaxation of muscle groups in order to promote functional movements. The techniques are employed according to the needs of each patient with the use of concentric, eccentric and static muscle contractions applying proper facilitation procedures and suitable amount of resistance (Adler et al. 2008, 19-10). Various techniques described by Adler et al. (2008, 20-35) that are used in PNF are:

“Rhythmic Initiation” technique helps in initiation of motion, improves coordination and normalizes the rate of motion. There is rhythmic motion of the limb or body through desired range, starting with passive motion and progressing to active resisted movements. “Combination of isotonic contractions” technique requires patient to have most strength or best coordinating to begin. It uses combined concentric, eccentric, and stabilizing contractions of one group of muscles (agonists) without relaxation. Its goals include active control and increase the active range of motion, coordination and strengthening of muscles, and functional training in eccentric control of movement.

“Reversal of Antagonists” – There are three reversals of antagonists:

"Dynamic reversals (slow reversal)" – technique uses continuous agonist and antagonist contractions that help increasing active range of motion, strength, coordination, increase endurance and decrease muscle tone. "Rhythmic Stabilization" technique utilizes alternating isometric contractions against resistance. Patient does not intent any movement and maintains his position against manual resistance. This technique is useful to increase active and passive range of motion, strength, stability, and balance, as well as to control pain. "Stabilizing Reversals" technique operates alternating isotonic (concentric and eccentric) contractions against resistance. The patient tries to move against the resistance applied by the therapist. The goal of this technique includes increasing stability, balance, strength, and coordination between agonist and antagonist. "Replication" aids in motor learning of functional activities by teaching the patient the outcome of a movement or activity. It helps assessing the patient's ability to sustain a contraction when the agonist muscles are shortened.

According to Hesbach (2013) Rhythmic Stabilization and Stabilizing Reversals techniques can be combined and used in a variety of patient positions, static or dynamic, depending on the level of independence with functional mobility and on the goal of treatment. The treatment with this technique can be modified and made more challenging by changing the surface of support, differing distractions etc. according to the progression of patient.

3 AIMS AND PURPOSE, AND RESEARCH QUESTIONS

3.1 Aims and purpose

The aim of this literature review is to investigate the extent to which scientific researches are available and through them, obtain an overview on effectiveness of PNF concept in neuromuscular rehabilitation.

3.2 Research questions

To meet the aims and purposes of this study following questions were formed:

1. What is the methodological quality in published PNF studies from1990 - 2013?
2. What patient groups are being included in PNF studies?
3. What kinds of PNF components were being used in selected studies and what are their goals?

4 METHODOLOGY

In this thesis, Systematic Review of Literature was used as the method of study. In a literature review, an important published literature that supports a study is organized, critically collected and evaluated in order to form an extensive, systematic, and critical review of the most important published scholarly literature on a particular topic (LoBiondo- Wood et al. 2006). Unlike traditional literature review method, systematic review is more transparent as all the decisions used to evaluate information are pre-defined and clear, which allows readers to evaluate themselves the quality of the review process and the potential for any bias (Garg et al. 2008). The review protocol is pre-defined specifying the research question and the methods that will be used to perform the review. Its defined search strategy aims to detect only the most relevant literatures whilst explicit inclusion and exclusion criteria are used to assess each potential primary study. The collection, abstraction and compilation of the data go through a more rigorous and prospectively defined objective process. The definition, structure, and methodologies of the underlying studies are critically appraised, evaluated and systematically recorded (Bartolucci et al. 2010).

4.1 Database search

An electronic search was established on 15th of December 2012 to find publications using the databases of Medline (PubMed), Academic search elite (EBSCO), Science Direct and Physiotherapy Evidence Database (PEDro), in which the PNF – concept or its components were subject of the study in a neurological rehabilitation program. A manual search of the reference sections of relevant articles was also conducted. The time frame for this study was determined from 1990 till 2013 in order to maximize the availability and inclusion of publications. In the meantime, it provides an opportunity to note the vari-

ation in availability of researches and changes that occurred in PNF practice between last two decades. The following search strategy were used for all the above databases:

#1 neuro-rehabilitation
#2 neuromuscular rehabilitation
#3 PNF
#4 Proprioceptive neuromuscular rehabilitation
#5 rehabilitative techniques
#6 Proprioceptive neuromuscular rehabilitation or PNF
#7 #1or #2 or #3 #4 or #5 or #6

The titles and abstracts from searches on electronic databases were screened to identify those articles relevant to this systematic review. Full articles were retrieved through a second search for further assessment. The Google search engine was also used to find the full articles where the preferred search engine could not provide. All full text articles were read to make a decision on inclusion. International Proprioceptive Neuromuscular Facilitation Association (IPNFA) website provided a PNF program bibliography, which was published in 2012, where references of literatures from past five years were listed. Manual search of the provided references was conducted to gather more relevant literatures.

4.2 Inclusion criteria

The following criteria should be met within the publication. PNF concept or techniques from PNF must be a part of the treatments for a neurological disorder, or a specific indication related to neurology discussed in the publication. The publication must be written in English and published within 1990 – 2013. Publication should be either a randomized controlled trail or a clinical trial and full text of the publication must be available.

5 LITERATURE REVIEW

The articles included for review were summarized and categorized according to the study design. 22 publications, related to the topic of this study were found however, after further screening only 13 articles appeared to fulfill the inclusion criteria of this research. Where, two articles were not included for the full texts of the studies were not available and there were two reviews, one pilot surveys, and four case studies, which were also discarded. The methodological quality of the publications was assessed and rated using the PEDro scale according to which, studies scoring 7/10 or more points are classified to be moderate to high quality. There are following 10 aspects of methodological rigor as being either absent or present: specification of eligibility criteria; randomization; concealment of treatment allocation; differences between groups at baseline; blinding of therapists; blinding of patients; blinding of assessors; greater than 85% follow-up for at least one key outcome; and point estimates of variability provided for at least one key outcome (Website of PEDro. 2012). There were 6 studies for which scores were confirmed in PEDro database and the rest were scaled following the criteria on administration provided in the web page of PEDro.

The scientific research articles were then independently studied, summarized and analyzed using the PICO model. Fetters et al. (2012) explain, PICO as an abbreviation that comprises the key components of a searchable clinical question about interventions. ‘P’ stands for population and clinical characteristics, ‘I’ is intervention under investigation, ‘C’ is the comparison (refereeing to an alternative intervention) and ‘O’ stands for outcomes. Table 1 show the study design, database, PEDro scale, and information on confirmation of scale by PEDro, of the selected publications. And on table 2, individual summery of articles using PICO model can be seen.

Table 1. PEDro Scale of the Articles.

Author/Publication year	Study Design	Databases	PEDro Scale (/10)	Scale confirmed by PEDro
Khanal et al. 2013	RCT	IPNFA	8/10	No

Mohamed et al. 2012	RCT	PEDro	6/10	Yes
Britto et al. 2012	RCT	PubMed	8/10	No
Eunjung et al. 2011	RCT	PEDro	4/10	Yes
Gnat et al. 2010	RCT	EBSCO	5/10	Yes
Duncan et al. 2003	RCT	PubMed	8/10	No
Mehrholz et al. 2002	RCT	PubMed	6/10	Yes
Duncan et al. 1998	RCT	PubMed	7/10	Yes
Akosile et al. 2011	CT	EBSCO	3/10	No
Kumar 2005	CT		3/10	No
Kawahira et al. 2004	CT	EBSCO	3/10	No
Nitz Burke B., 2002	CT	EBSCO	3/10	Yes
Wang 1994	CT	PubMed	3/10	No

Notes: RCT = Randomized Controlled Trail, CT = Clinical Trail, N/A = Not Assessed

Table 2. PICO Summery of the Articles.

Author/Publication year	Patients	Intervention	Control	Outcome Measures
Khanal et al. 2013	30 hemiparetic stroke pt., randomly divided into experimental & control groups	Pelvic PNF	Conventional PT (task-specific exercises of the upper & lower trunk.	Trunk Impairment Scale (TIS), Trunk Lateral Flexion Range of Motion (TLF ROM), & Tinetti Test
Britto et al. 2012	23 subjects with a mean age of 56.7±8.0 years and mean time since the onset of stroke of 27.7±20.3 months	Gait training based on PNF method (N=11),	Treadmill training with partial body-weight support for 12 sessions.	Stroke rehabilitation assessment of movements (STREAM) score & Motor functional independence measure (FIM) score
Eunjung et al. 2011	40 pt. with hemiplegia due to stroke (20 experimental & 20 control)	Trunk stability exercise using PNF	General Exercises	Electromyography (EMG) in the Functional Reach Test.
Akosile et al. 2011	17 male & female post-stroke subjects mean age (56.73+8.79 years)	PNF protocol (UL & LL) twice weekly for 8 weeks.		The Emory functional ambulation profile: 5-metre walk on hard surface, 5-metre walk on the carpeted floor, performance of 'up and go' task , Negotiation of an obstacle course , ascent & descent of 4 stairs
Gnat et al. 2010	96 late-stage stroke subjects randomly as-	Experimental 1 – PNF, 2 - traditional therapy +	Traditional post stroke methods, 18	Two-point discriminatory sense, stereognosia & therm-

	signed to 3 groups (control, experimental 1, experimental 2)	PNF & neuro-mobilization.18 training sessions, 45 min each.	training sessions, 45 min each.	aesthesia
Kawahira et al. 2004	22 subjects with stroke & 2 brain tumor-operated subjects	Two 2-week PNF sessions (more than 100 repetitions a day for each of 5 kinds of movement) applied at 2-week intervals in Pt. with hemiplegia		Brunnstrom Recovery Stage of hemiplegia, the foot-tap test and the strength of knee extension/flexion) & walking velocity
Duncan et al. 1998	20 minimally and moderately impaired stroke pt. with completed inpatient rehab, 30 to 90 days after stroke onset.	8-week, 3-times-per-week, home-based exercise program, assistive and resistive exercises using PNF or Theraband exercise to the major muscle groups of the UL & LL.	Usual care as prescribed by the physicians	Fugl-Meyer Motor Assessment, Barthel Index of ADL, Lawton Scale of Instrumental ADL, and Medical Outcomes Study–36 Health Status Measurements. Functional assessments of balance & gait (10-m walk, 6-Minute Walk), the Berg Balance Scale & Jebsen Test of Hand Function.
Duncan et al. 2003	100 pt. (mean age, 70 years; mean Orpington score, 3.4) consented & randomized	In-home, therapist- supervised program emphasizing strength (PNF), balance, endurance (cycle)	Usual care prescribed by their physicians.	Post-intervention strength (ankle and knee isometric peak torque, grip strength), Fugl Meyer, Berg and functional reach, endurance (peak aerobic capacity & exercise duration), Wolf Motor Func-

				tion Test, and 10-m walk and 6-minute walk distance
Mehrholz et al. 2002	60 ambulatory post stroke pt. randomized. STT-20, LTT-20, CGT-20	Structured Speed-Dependent Treadmill Training, Limited Progressive Treadmill Training	Conventional Gait Therapy, PT gait therapy (PNF and Bobath concepts)	Walking speed, cadence, stride length on treadmill, & Functional Ambulation Category scores.
Mohamed et al. 2012	30 Levodopa dependent PD Pt. (9 female, 21 male), age ranging from 49-70, randomized into 2 equal groups (G1 & G2).	PNF techniques and vibratory stimuli during walking on the treadmill	Individually designed PT program of mild intensity exercises conducted by a neuro-physiotherapist	Qualysis Pro-Reflex motion analysis system to measure cadence, stride length, hip, knee, & ankle joints' angular excursion.
Wang R.Y, 1994	20 individuals with hemiplegia (12 male and 8 female), short duration (X=4.4 months, SD=0.8,range=2.8-5.6;n=10) and long duration (X=15.4 months, SD=1.7, range=127-18.5; n =10)	Side lying, 10 minutes each of rhythmic initiation, slow reversal, and agonistic reversals in pelvic region, 30 minutes sessions three times a week for 4 weeks.		Measurement of gait speed and cadence and Newman-Keuls test.
Kumar P.B.N., 2005	30 pt. in range of 50-70 years with Diabetic Sensorimotor Poly-	3 sets of PNF exercise per day with 10 min of rest between each set, 5		MMT, Manual Proprioception test, Wilcoxon signed rank test (Sensorimotor neuropathy

	neuropathy (DSP)	repetitions each set of exercise	test)
Burke B et al. 2002	7 non-congenital myotonic dystrophy pt.	6 Rx. levels: resting in high support sitting; resting in left side-lying; PNF of deep breathing in high support sitting; PNF of deep breathing in left side-lying; Staged Basal Expansion (SBE) in high support sitting and SBE in left side-lying.	Oximetry and thoraco-abdominal motion (TAM) (arterial oxygen saturation (SpO_2) and heart rate), & Pneumograph (respiratory rate).

Notes: PT = Physiotherapy, UL = upper limb, LL = Lower limb, Pt. = Patient, rehab = rehabilitation, Rx. = Treatment, ROM = Range of Motion, MMT = Manual Muscles Test, ADL = Activities of daily living,

6 OUTCOMES OF INTERVENTIONS IN PRIMARY STUDIES

Khanal et al. (2013) ruled out both Pelvic PNF and the conventional exercises groups improved on trunk performance, lateral range of motion, balance and gait however, experimental group showed more improvement than control group, concluding PNF is effective in improvement of trunk movement in patients with hemiparetic stroke.

A study by Britto et al. (2012) compared the effects of the treadmill training with partial body weight support and PNF method on gait of people with chronic stroke; they discovered increase in the STREAM scores and motor FIM scores along with improvement in symmetry ratio-swing time in affected leg in both groups. Whereas PNF group showed increase in maximum ankle dorsiflexion over the swing phase. The conclusion was made that the two approaches has equivalent effect hence, cost-effectiveness of each treatment may have important role in choosing the favorable approach.

Eunjung et al., (2011) stated the experimental group performing trunk stability exercises using PNF showed significant improvement in functional reach test (FRT), activities of quadriceps, hamstring, and soleus muscles on the affected side, and activities of the quadriceps, and soleus muscles on the non-affected side, where the control group showed significant improvements only in activities of the quadriceps, and soleus muscles on the non-affected side. That indicated that trunk stability exercises using PNF approach are successful at improving functional reaching and lower limb muscles activities.

Akosile et al. (2011) in Nigeria attempted to investigate the effect of an 8-week PNF treatment program on the functional ambulation of post stroke individuals, through a clinical trial. The PNF protocol used in this study led to improvements in all the Emory Functional Ambulation Profile (EFAP) subtasks and consequently overall functional ambulation.

In a trial of Gnat et al. (2010), PNF was combined with Butler's Neuromobilization in attempt to reduce sensory deficits of upper limb in late stage stroke. The results reveals remarkable improvements in Two-point discriminatory sense and Thermaesthesia in experiment group 1 that received traditional therapeutic program with individual PNF along with neuromobilization of the affected upper extremity, comparing two other groups. This

study concludes that PNF combined with Butler's neuromobilization has greater effectiveness in reduction of sensory deficits than PNF or traditional therapy alone.

Kawahira et al. (2004) evaluated the effects of the intensive repetition of PNF movements on improvement of voluntary movement of a hemiplegic lower limb in patients with brain damage. 22 subjects with stroke and two brain tumor operated subjects participated. The outcomes of the study demonstrated significant improvements in Brunnstrom recovery stage of hemiplegia, foot tapping and the strength of knee extension/flexion of the affected lower limb.

According to Duncan et al. (1998 & 2003), structured, progressive, physiologically based exercise program and home-based exercise program with resistive therapy band using PNF concept is fruitful for improving strength, balance, upper and lower extremity motor control function, and gait velocity in patients with mild and moderate stroke.

Mehrholz (2002) made effort to compare the effects of structured speed – dependent treadmill training (STT) with limited progressive treadmill training (LTT) and conventional gait training (CGT) (in form of physiotherapeutic gait training using PNF and Bobath concepts), on clinical outcome measures for patients with hemiparesis. The finding reveals STT group scored significantly higher than other two groups in over-ground walking speed, cadence, stride length and functional ambulation, proving STT as a better option than PNF and other approach for patients with stroke as the approach is dynamic and integrative.

Wang (1994) clearly described treatment with specific PNF patterns, techniques, treatment positions and frequency of repetitions and therapy session. The treatment however was not a specific gait training it rather focused on facilitation of pelvic movement. The results showed the cumulative effects of PNF are more beneficial than the immediate effects and patients with short duration hemiplegia respond to training sooner than long duration. The study concluded that there are very few researches available on pelvic facilitation for gait improvement and that the effectiveness of PNF- based treatment has been both supportive and conflicting.

Mohamed et al. (2012) aimed to determine the influence of paired Proprioceptive cues on gait parameters of individuals with Parkinson's disease. In this trail one group received PNF techniques and vibratory stimuli during walking on the treadmill in addition to the

individually designed physiotherapy, and another got only an individually designed physiotherapy prescribed by a neuro-physiotherapist. Both treatment groups improved in cadence stride length and lower limb joint's angular excursion. However improvements in spatio-temporal parameters and angular excursion were higher in the study group than in the control group.

According to the clinical trial carried out in India by Kumar (2005), PNF is useful in improving motor component but not sensory component of Diabetic Neuropathy. D1 and D2 patterns of PNF were used in lower limb as treatment.

Burke et al. (2002) studied the effect of specific PNF treatment of breathing compared to stage basal expansion techniques. The study concludes that PNF approach was the main contributor in increasing Oxygen saturation, decrease in Thoracic Abdominal Respiratory rate and immediate drop of heart rate after treatment. The study was conducted with a small number of patients (n=7) with only myotonic dystrophy, which limits the possibility draw any conclusion beyond this specific indication.

7 DISCUSSION AND FINDINGS OF LITERATURE REVIEW

The biggest challenge of this study was insufficient knowledge, theoretical background, and experience in the field of research more specifically systematic literature review that led to unsystematic starts of the research process. A through self-study (using books, and electronic journals and articles) on theoretical background of literature review process along with sufficient guidance from tutor made it easier to proceed, eventually. Following that a study plan was made for initiation of writing process, and a table of content was formulated to determine a clear organizational structure of the study. Determination of a concrete topic took a while although the area of study was clear from the very beginning. Finally research questions were formed, which provided proper directions to proceed further.

The electronic search was not the most time consuming part although, screening of the publication to identify articles relevant to this systematic review took considerable amount of time. The most time consuming phase however was summarizing and analysis of data in literature review process that would form the body of this thesis. Proper use of excel program for data extraction and summarization was found very challenging and time consuming. The time frame under inclusion criteria was extended to 1990 – 2013, which was 2000 – 2013 initially, as the availability of publications was limited. However, after further screening only two articles were found relevant from 90's and most of the included studies were from last decade, which suggests the use of PNF approach in neuromuscular rehabilitation sector is more prominent in recent years.

This study found that the availability of publication on use of PNF concept in neuromuscular rehabilitation is limited. It was discovered that the amount of publications dealing with PNF stretching techniques and ROM was significantly higher than ones that matched the criteria of this study. 13 studies were found relevant to this literature review, eight of them are randomized control trials and five articles are clinical trials. This review discovered results of all the included studies except one, advocates PNF as an effective approach in neuromuscular rehabilitation. The included controlled trails suggest PNF treatment is superior to traditional and usual rehabilitation methods. The clinical trials lacked controlled groups within the studies, even though the outcomes show encouraging results.

However, it is very important to emphasize the fact that this systematic literature review is not rigorous enough to entirely prove the effectiveness or superiority of the PNF approach in neuromuscular rehabilitation. Hence, there is a need for more advanced literature review such as meta-analysis that uses statistical method to summarize outcomes and investigate the validity of the results of primary studies. These sorts of studies are conducted usually as a part of a systematic review.

The overall outcomes of included researches purpose PNF treatment is effective in improvement of trunk movement and stability; increasing upper and lower limb strength; reduction of sensors deficit in upper limb; overall strength; voluntary movements; improvement in balance, motor control, and gait in patients with stroke. It also helps improve motor component in lower limb in diabetic neuropathy; improve gait in clients with Parkinson's disease, and improve respiratory function in myotonic dysfunction. On the other hand Mehrholz J. (2002) found speed – dependent treadmill training is a better option than PNF training in gait training for post stroke patients.

The methodological quality assessment of the included studies displays huge variations in the scores, which makes it difficult to draw conclusion over the overall quality of use of PNF concept in neuromuscular rehabilitation. There were only for studies, which can be considered as high quality researches, out of which three studies scored 8/10, and one with 7/10. Although these studies provides strong evidence to support the efficacy of PNF approach, the majority of studies are below moderate to low quality with the score below 7/10 failing to provide reliable and valid evidence base. There is one publication with score of 6/10, two with 5/10, one with 4/10, and five studies with score 3/10. This result denotes the need of further research into clinical application of PNF in Neuromuscular Rehabilitation with higher methodological quality to provide stronger evidence base for future practice.

This review found that the indication of PNF approach within the neuromuscular rehabilitation is rather narrow; only five indications within neurological disorder were discovered. The patient groups that were included in PNF studies are: stroke, Parkinson's disease, brain tumor-operated subjects, myotonic dystrophy and diabetic sensorimotor polyneuropathy. Whereas more of other indications have also been noted from the studies that

were not included in this research that includes: post-polio syndrome, spinal accessory nerve injury

Out of 13 studies, there were nine studies on stroke (or clients with stroke) concerning stroke rehabilitation, ambulatory and gait training, functionality improvement, restoration of voluntary movements, and stability improvement training. This proves stroke is the biggest indication of PNF approach and patients with stroke are the favorite client group within neuromuscular rehabilitation. There is one study on Parkinson's disease that concerns with PNF in gait training. And other literatures studied issues includes; efficacy of PNF in improving sensory motor function in patients with Diabetic Neuropathy affecting lower limb, facilitation of respiration in myotonic dystrophy.

The studies found in this database search concerns with the use of physical and function rehabilitative components, and strengthening components rather than stretching components of PNF in the field of neuromuscular rehabilitation. The basic procedure of facilitation must be followed in any PNF intervention, which includes; manual contact, stretch, resistance, verbal command, approximation, timing, vision, patient positioning and pattern. There were eight studies that did not declare any specific PNF techniques and two studies, which neither presented any PNF techniques nor any patterns exploited in the treatment procedure.

Khanal et al. (2013) and Wang (1994) operated with rhythmic initiation, slow reversal, and agonistic reversals techniques of PNF to facilitate anterior elevation and posterior depression pattern of pelvis. Gnat et al. (2010) treatment with PNF approach included; combination of isotonic contraction, stabilizing reversal and replication techniques, where scapula and the pelvis motion patterns (separately and in combination), ipsilateral upper extremity patterns and trunk patterns incorporating extension were applied. Eunjung et al. (2011) studied the effects of trunk stability exercise using PNF approach where intervention with stabilizing reversal and rhythmic stabilization on the hemiperetic side was the treatment protocol. Diagonal motion pattern of trunk was applied in both sitting any lying position.

Duncan et al. (2003, 1998) in a home based exercise program for stroke patients used PNF as one of the treatment methods that consisted active motion in PNF unilateral pat-

terns with manual resistance using theraband in anatomical planes. The diagonal patterns of movements on upper and lower extremities in PNF treatment were employed in following studies Akosile et al. (2011), Kumar (2005), and Kawahira et al. (2004). Britto et al. (2012) States the application of scapular and pelvic region facilitation pattern that included anterior elevation/posterior depression and anterior depression/ posterior elevation diagonals. In a study of Nitz et al. (2002), assistive and resistive breathing technique was used to facilitate of respiration in myotonic dystrophy. But none of these studies mentioned the PNF techniques administered in their interventions.

Mohamed et al. (2012) mentioned the use of PNF approach along with vibratory stimuli during treadmill training, and Mehrholz et al. (2002), reveals PNF as one of the treatment methods for control group against treadmill training groups. However, both studies did not describe any techniques and procedure of PNF used in the treatment procedure.
The cervical PNF with movement in diagonal pattern and ipsilateral rotation has also been reported to be used in neuromuscular rehabilitation in a study of Hannig et al. (2001) although this study is not included in this review.

To sum up, the PNF techniques used in these studies were; rhythmic initiation, slow reversal, agonistic reversals, stabilizing reversal, rhythmic stabilization, combination of isotonic contractions, and feedback initiation. The PNF patterns used in these studies were:

Scapular and Pelvic pattern - anterior elevation, posterior depression, posterior elevation and anterior depression movements. On figure 7.1 diagonal scapular and pelvis movement patterns are shown (Buck, Beckers & Adler 2008, 55).

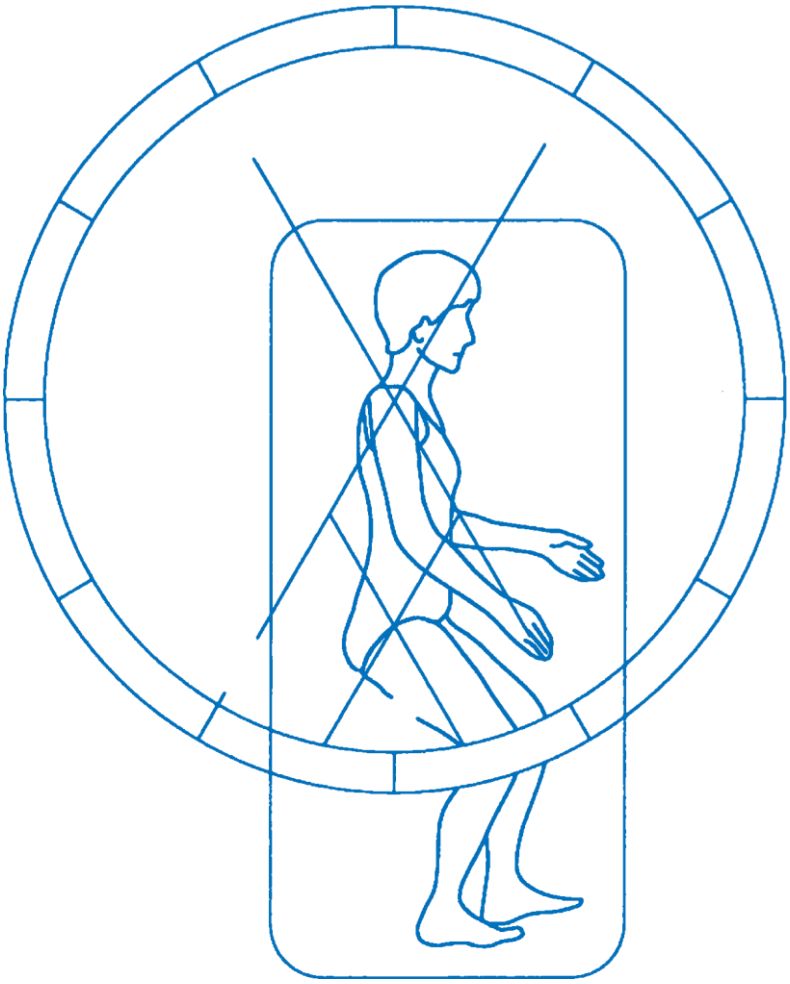

Fig: 7.1. Diagonal Scapular and Pelvis Patterns (Buck, Beckers & Adler 2008, 55)

a) Upper extremity patterns – There are two diagonal motions in upper extremities:
   D1F and D1E: initiating position is flexion – adduction – external rotation of shoulder, supination, radial abduction, palmar flexion, finger flexion, finger adduction and terminal position is extension abduction and internal rotation of shoulder with pronation, ulnar abduction, dorsal extension, finger abduction and finger extension
   D2F and D2E: initial position is flexion – abduction – external rotation of shoulder, supination, redial abduction, dorsal extension, finger extension and abduction and terminal position is extension – abduction – internal rotation of shoulder, pronation, ulnar abduction, palmar flexion, and finger flexion and adduction.

b) Lower extremity patterns – There are two diagonal motions in upper extremities:

D1F and D1E: initiating position is flexion – adduction – external rotation of hip, dorsiflexion, supination, inversion, and toe extension final position is extension – abduction – internal rotation of hip, plantar flexion, pronation, eversion, and toe flexion.

D2F and D2E: initial position is flexion – abduction – external rotation of hip, dorsiflexion, pronation, eversion and toe extension and the final position is extension – abduction – internal rotation of hip, plantar flexion, supination, inversion and toe flexion. On the figure 7.2 upper and lower extremities diagonal pattern is presented.

c) Cervical pattern – diagonal motion (neck flexion – lateral flexion – rotation and neck extension – lateral flexion – rotation)

d) Trunk pattern – diagonal motion (trunk flexion to the left – left lateral flexion – left rotation, trunk extension to the right – right lateral flexion – right rotation, trunk lateral flexion to right).

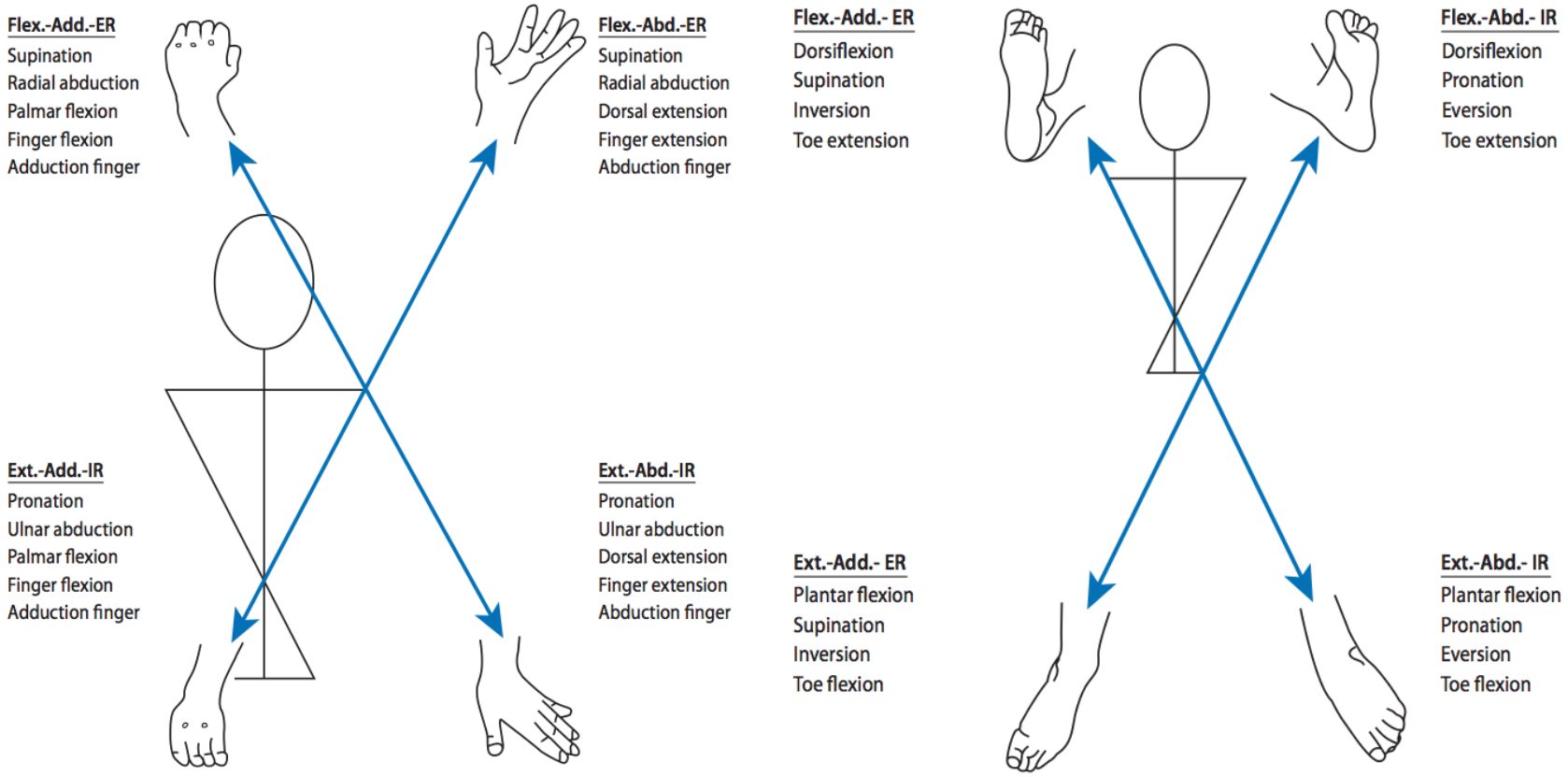

Fig.7.2. Upper and Lower Extremities Diagonal Pattern (Buck, Beckers & Adler 2008, 78 & 11)

The final finding of this study shows, the goals of treatment basically directs towards physical and functional rehabilitation through various effects such as neuromuscular re-education, facilitation, reduction of impairments, induction, re-enforcement, and relaxation. The specific objectives within the patient management included in the PNF studies are: to facilitate movement, increase stability, to increase coordination, functional ambulation, to reduce sensory deficits, home exercise as a rehabilitative program, gait training, restoration and improvement of voluntary movements, to facilitate physical activity, to increase muscle strength, to increase motor control, and muscle relaxation.

8 CONCLUSIONS

The findings of this review suggests there is a need of further or advanced review in order to provide a strong evidence base to support efficacy of PNF approach in neuromuscular rehabilitation. Similarly, the assessment of methodological quality of the included studies revealed a remarkable variation in scores between the studies that prevents from articulating any concrete opinion over the overall quality of PNF concept in neuromuscular rehabilitation.

It was learned that stroke and Parkinson disease are most common indication of PNF in neuromuscular rehabilitation whilst the biggest patient group is people with stroke. In rehabilitation process various PNF techniques are employed focusing its effect on strengthening and stabilizing with the general goal of increasing functionality, physical strength, and stability of patients. Diagonal and spiral movement patterns are the core aspects of PNF concept.

The availability of publication on use of PNF approach in neuromuscular rehabilitation was found to be limited whilst, majority of researches were based in PNF focusing its effect on stretching and range of motion. However, the fact that the research on PNF in Neuromuscular rehabilitation is increasing in recent years cannot be denied.

This study discovered that there is necessity of further research into clinical application of PNF particularly in Neuromuscular Rehabilitation with wider variety of patient groups and higher methodological quality to provide stronger evidence base for future practice. Survey on the attitude of the physiotherapy practitioners would also be helpful to investigate the current status of PNF practice in neuromuscular rehabilitation.

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APPENDIX 1

PEDro scale

1.	eligibility criteria were specified	no ❑ yes ❑ where:
2.	subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ❑ yes ❑ where:
3.	allocation was concealed	no ❑ yes ❑ where:
4.	the groups were similar at baseline regarding the most important prognostic indicators	no ❑ yes ❑ where:
5.	there was blinding of all subjects	no ❑ yes ❑ where:
6.	there was blinding of all therapists who administered the therapy	no ❑ yes ❑ where:
7.	there was blinding of all assessors who measured at least one key outcome	no ❑ yes ❑ where:
8.	measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ❑ yes ❑ where:
9.	all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no ❑ yes ❑ where:
10.	the results of between-group statistical comparisons are reported for at least one key outcome	no ❑ yes ❑ where:
11.	the study provides both point measures and measures of variability for at least one key outcome	no ❑ yes ❑ where:

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Last amended June 21st, 1999

Notes on administration of the PEDro scale:

All criteria	**Points are only awarded when a criterion is clearly satisfied**. If on a literal reading of the trial report it is possible that a criterion was not satisfied, a point should not be awarded for that criterion.
Criterion 1	This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study.
Criterion 2	A study is considered to have used random allocation if the report states that allocation was random. The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion.
Criterion 3	*Concealed allocation* means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for this criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was "off-site".
Criterion 4	At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups' outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables alone, by a clinically significant amount. This criterion is satisfied even if only baseline data of study completers are presented.
Criteria 4, 7-11	*Key outcomes* are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure.
Criterion 5-7	*Blinding* means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be "blind" if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind.
Criterion 8	This criterion is only satisfied if the report explicitly states *both* the number of subjects initially allocated to groups *and* the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time.
Criterion 9	An *intention to treat* analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated.
Criterion 10	A *between-group* statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group × time interaction). The comparison may be in the form hypothesis testing (which provides a "p" value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval.
Criterion 11	A *point measure* is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. *Measures of variability* include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group.